**Capstone Projects and their transition into the Software Development Industry: a 10 year systematic review of literature**

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**I. Introduction**

There is an apparent gap between academia and the industry, exhibited by a mismatch between what is taught at higher institutions of learning and what is required from fresh-graduates in the industry. This mismatch is also highlighted by the failure of graduates from higher institutions of learning to demonstrate the required level of skill and competences when they join the workplace. Students usually lack the requisite skills to easily transition into being successful professionals or entrepreneurs, and employers are often compelled to spend thousands of dollars in training fresh recruits. Educators at higher institutions of learning have also been accused of failing to grasp the needs of industries for which they are training graduates, often producing graduates that can neither meet the expectations of employers nor easily create successful start-ups within their professions and career paths. One of the most effective approaches of bridging the gap between academia and the industry is the introduction of appropriate capstone courses for students in their final years of study.

Capstone projects and courses are final year academic subjects undertaken by students to demonstrate their level of learning and the practical skills they have accumulated over the duration of their academic programme. Capstone courses or final year projects are very popular courses in most STEM subjects like civil and electrical engineering, information technology, software engineering, agriculture and other natural sciences, and computer science- but can also be found in the humanities like music and drama, art and design, and social work among other fields. The capstone course is one of the most effective pedagogical methods Mused by instructors to enable students demonstrate their level of application of theoretical knowledge and practical skills. Beyond the use of these programmes for assessing and evaluating students’ academic performance, capstones are also effective in preparing graduating students for professional work life, building their entrepreneurial mindsets and enabling them to create professional networks within their chosen career paths. These terminal courses enable educators instil industry-required competences in leaners, enabling the latter easily transition into their respective sectors. More often than not, the capstone is a combination of some form of research-based learning outcome and a physical or virtual deliverable or artefact that solves a real-life problem or satisfies an existent need in the community. Depending on the profession and academic programme of study, the deliverable from a capstone course may be a physical product, an innovative service, a new technique or way of doing things, a scientific solution, a software artefact, an information system, or simply a proof of concept prototype that attempts to solve an existing organisational or societal problem.

This paper makes a systematic review of 95 research papers about capstone courses downloaded from a range of online scientific databases including ACM Library, IEEE Xplore, Science Direct, Taylor and Francis Online, Emerald Insight, and Google Scholar. The rest of the review is structured as follows. Section one shows the introduction of the study. Section two of paper starts by highlighting how the review was planned, the rationale for the review, and the objectives of the study, and related literature about capstone courses. Section three shows the methodology used in this review, sources of data used to analyse the different articles and documents collected, and the criteria used in selecting the articles reviewed. Section four includes the findings of this review, based on the research objectives, while Section five includes a discussion of the findings, conclusions, recommendations and areas of further study.

**II. Planning the review**

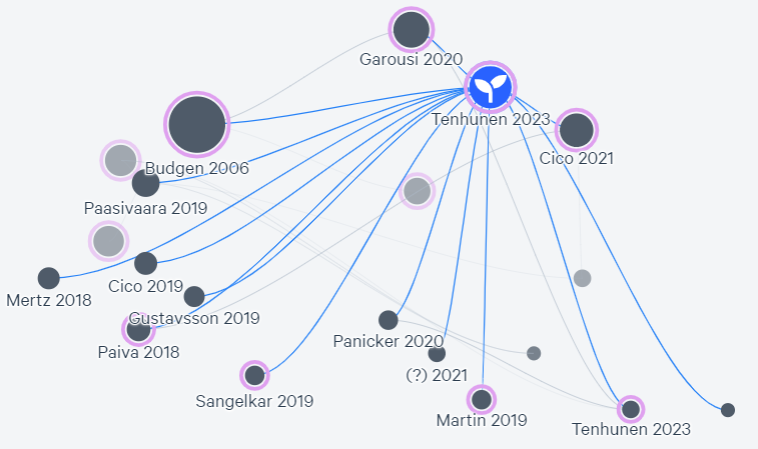
There are a number of systematic literature studies about capstone projects that have been undertaken by researchers like Chanin, et al., (2018), Cico, et al., (2021), Kokkoniemi & Isomöttönen, (2023), Marques, Quispe, and Ochoa, (2014), Pizard et al., (2021), and Tenhunen, et al., (2022). However, there seems to be a number of gaps that need to be filled. The studies in this area seem to be remarkably few, and even then most of them are not comprehensive enough. Pizard et al., (2021) for example mention in their limitations that the papers sampled did not comply with basic quality requirements, and some other papers were eliminated due to their complexity. The most recent and comprehensive study was by Tenhunen, et al., (2023), who undertook a systematic literature review of capstone courses in software engineering. The study however only synthesised capstone projects into a taxonomy comprising of duration of projects, team sizes, client for these projects, project sources, project implementation, and student assessment. This study and many others did not review any capstone project from an African University, did not include projects from other areas of Information Technology (apart from of Software Engineering), and did not review individual contributions of team members to capstone success. The following is an analysis of selected earlier systematic literature reviews, their main findings and limitations that provide a rationale for the current study:

**Summary of earlier reviews and the rationale for the current study**:

|  |  |  |
| --- | --- | --- |
| *Author(s), (Year), Title, Source/Journal, Database* | *Main Contribution* | *Limitation of the review and pathways for future research* |
| 1) Chanin, et al., (2018).  *A Systematic Mapping Study On Software Start-ups Education.*  Source:  EASE’18: 22nd International Conference on Evaluation and Assessment in Software Engineering.  ACM Digital Library | The researchers find that successful SE capstones must ensure integration of three major components; real world projects, the right environment and a multidisciplinary context. | The study only reviewed 31 publications which were remarkably few compared to other reviews in the same area. There is need for a wider coverage of primary studies in the area of software engineering capstone courses. |
|  |  |  |
| 2) Cico, Jaccheri, Nguyen-Duc, & Zhang (2021)  Exploring the intersection between software industry and Software Engineering education - A systematic mapping of Software Engineering Trends  Source/Journal:  Elsevier’s Science Direct/ The Journal of Systems & Software/ | The study highlights that there are possible gaps between the Software Industry and Software Engineering Education. The authors recommend actionable insights that should be undertaken by researchers, educators, and practitioners to bridge these gaps. The study specifically finds that agile methodologies and scrum practices were found to be a major trend that is shaping SE education. | The study used only two databases, that is, IEEE Explore and ACM Library to locate studies. There were other limitations in the article selection process, for example, the use of incomprehensive of search terms. These may have impended the comprehensive collection of relevant primary studies. There were insufficient relevant further investigations available from other digital resources, and certain authors’ bias in applying exclusion/inclusion criteria. These may have limited the collection or led to erroneous exclusion of some relevant studies. There is need for a more comprehensive search in more than 2 databases and inclusion of more relevant studies relating to capstones in SE. |
| 3) Garousi, et al., (2020)  Closing the gap between software engineering education and industrial needs.  Source/Journal:  IEEE Xplore / IEEE Software | The article illuminated on the important knowledge gaps that various software engineering topics help students to understand. It summarises the knowledge about capstone projects in the engineering community, and provides future software engineers with an overall state of the art knowledge about the industrial needs of their profession. | Only 33 papers were included in this review. Secondly, the authors did not explicitly explain their inclusion and exclusion criteria, and the databases or online libraries from where they got the studies that they reviewed. |
| 4) Kokkoniemi & Isomöttönen, (2023)  A systematic mapping study on group work research in computing education projects.  Source/Journal:  Elsevier’s Science Direct/ The Journal of Systems & Software | The study recommends more focused group work research in CS/SE student projects, in which education. This can be achieved by implementing novel theoretical and practical group management approaches to socially-shared regulated learning.  The authors also include a lessons-learned summary for instructors and teachers, which can be used to improve on SE education. | The study’s article selection quality criteria excluded a part of what was subjectively seen as “lighter” research from the mapping. More objective and comprehensive search and inclusion methods are required in a new review. |
|  |  |  |
| 5) Marques, Quispe, & Ochoa, (2014)  A Systematic Mapping Study on Practical Approaches to Teaching Software Engineering  Source/Journal:  IEEE Xplore/ IEEE Frontiers in Education  Conference (FIE) Proceedings | The authors observe that universities have realized the importance of providing practical experiences to leaners as a way of teaching software engineering. The report provides different proposals and approaches that can be undertaken by universities to achieve this. | While this was an extensive study of over 173 primary studies, only those that were published by and whose data available before October 30, 2013 were considered the analysis. This study is now 10 years old and new insights and practices have certainly emerged. There is need to do a more recent review of capstone courses and projects in software engineering.  The exclusion criteria used by the authors was not straight forward and was actually based on their subjective judgment. Most of the classifications used in reviewing the literature were based on only reading the titles, abstracts and in a few cases, the whole article. This kind of review was not in-depth enough to capture all detail relating to capstone courses. A more detailed full-paper review of research relating to the topic is required. |
| 6) Martin (2019)  Designing the IT Capstone Course: A Systematic Literature Review  Journal/Source:  ACM Digital Library/ SIGITE '19: Proceedings of the 20th Annual SIG Conference on Information Technology Education, September 2019. | The authors designed and a newly required capstone course as part of a larger curriculum update in an IT degree program at a large Midwestern university. The systematic literature review was part of best practices identified to ensure quality learning experiences for students. | At the time of publication, this review was considered by the author as an early stage attempt to create the envisaged capstone course. The study was a progress report on in establishing recommended methods. This study was Work-In-Progress, and therefore not conclusive enough to form a basis for a concrete analysis of capstone courses in software engineering and Information Technology. |
| 7) Pizard et al., (2021).  Training students in evidence-based software engineering  and systematic reviews: a systematic review and empirical  study  Source/Journal:  Elsevier’s Science Direct/  Empirical Software Engineering Journal | The authors identified 54 learning outcomes encompassing several aspects of evidence based software engineering and systematic reviews. The study and course conducted during the project was found to be appropriate for students to understand the EBSE paradigm and apply it to practical assignment. | The authors note that some of the papers sampled in this study did not comply with basic quality requirements, and that some other papers were eliminated due to their complexity. Secondly, although the study was based on a variety of evaluation methods, it was devoid of any formal education methodologies. There is need to undertake a more comprehensive review, considering formal SE curricular from recognised institutions like IEEE or ACM, and following internationally recommended literature quality requirements of systematic reviews. |
|  |  |  |
| 8) Tenhunen, et al., (2023)  A systematic literature review of capstone courses in software engineering.  Source/Journal:  Elsevier’s Science Direct/Journal of Information and Software Technology | The paper presents taxonomy for major characteristics of software engineering capstone courses, synthesised into elements including duration, team sizes, client and project sources, project implementation, and student assessment. | i) The researchers indicate that at least one of the co- authors of this study was somehow involved in organising some of the capstone courses that were reviewed and analysed. This breeds bias and conflict of interest on the part of the authors. Additionally, many of the reports reviewed did not have an honest evaluation of author biases. There is need to undertake a new objective review with little or no author biases.  iii) The authors of this review did not review any study from Universities or Higher Education Institutions in Africa. There is need to locate peer-reviewed literature about capstone projects in SE in Africa and document trends in these projects. |

***Table 1: analysis of earlier reviews as a rationale for the current study***

In order to find more systematic reviews and original studies related to capstone projects in software engineering, the author identified one paper by Tenhunen (2023), which was the most recent, most cited, and most comprehensive review of all SLRs about capstone courses. Using this paper, researcher generated a literature map using Seed Maps (<https://app.litmaps.com/seed>) to find other most cited papers that were linked to this paper. The literature map is highlighted in Figure 1 below:



***Figure 1: Literature Map for Tenhunen, et al., (2023) generated from*** [***https://app.litmaps.com/seed/252511371***](https://app.litmaps.com/seed/252511371)***.***

From the literature map, the researcher identified only 15 most cited papers published between 2013 and 2023- the scope of the review being planned. Five (5) of these fourteen (15), (Cico & Jaccheri, 2019; Cico et al., 2021; Garousi et al., 2020; Martin, 2019; and Tenhunen, et al., 2023) were systematic literature reviews that could not be reviewed again in the main study, since the current study intended to review only original research. The most recent SLRs of 5 earlier reviews on the literature maps were papers by Cico et al., (2021), Garousi et al., (2020), Martin (2019), and Tenhunen, et al., (2023). These four were re-reviewed as earlier studies (in addition to other systematic reviews downloaded from other online databases) to ascertain gaps in previous reviews and the rationale for the current review. The remaining papers from this literature map that met our inclusion and exclusion criteria, like Bütt, Person, and Bohn, (2022), Gustavsson and Brohede (2019), Mertz and Quesenberry, (2018), Paiva and Carvalho (2018), and Panicker, et al., (2020) were incorporated in the current study to ascertain if they were in-line with the aims of the current review, and if there were aspects about them that the earlier reviewers did not identify- especially relating to whether products of the capstone courses studied by students were commercialised or up-scaled after project completion. Some papers highlighted from the literature map like Ståhl, Sandahl, and Buffoni (2022), as part of the preliminary analysis of earlier systematic literature reviews were found to be have been written based on postgraduate capstone courses after abstract reviews. These were not in the scope of the current study and were therefore excluded from our preliminary analysis. The review by Tenhunen, et al., (2023) only included papers from IEEE, ACM Library, Scopus, and Science Direct. Other multidisciplinary scientific databases like EBSCOHOST, Emerald Insight, Taylor & Francis, Google Scholar, Semantic Scholar, Springer, and OmniScience were not considered in previous studies. This review intends to undertake a more in-depth systematic literature review, including more online databases covering software engineering, computer science, and information technology capstone projects.

**Research Questions**

This study therefore sought to find answers to the following questions.

* RQ 1. What is the structure of capstone projects in Computer Science, Software Engineering and Information Technology?
* RQ 2. What methodologies are used in implementing capstone projects in different Universities around the World?
* RQ 3. What is the contribution of Capstone Projects on the development of Software Engineering careers among participants?
* RQ 4. To what extent are capstone projects in Software engineering extended and turned into real products on the software market?
* RQ 5. What are the likely research gaps that need to be addressed in the future?

**Literature Review**

**III: Methodology**

**a) Research Design**

**b) Sources of Data**

The researcher reviewed and analysed research papers from ACM Library, IEEE, and Science Direct, which are scientific databases that publish research in STEM subjects and specifically computer science, software engineering and IT. Other papers were downloaded from multidisciplinary databases including EBSCOHost, Emerald, Google Scholar, and Taylor & Francis. Only relevant documents, including research articles, conference proceedings, dissertations and theses were considered in the review.

|  |  |
| --- | --- |
| **Search Boundaries: Databases included** | **Search Terms** |
| ***The major sources for this review included:***  ***a) Scientific Databases that focus on Software Engineering, Computer Science, Information Technology and other STEM fields:***   * *ACM Library* * *IEEE* * *Science Direct*   ***b) Multi-Disciplinary Scientific Databases:***   * *EBSCOHOST* * *Emerald Insight* * *Google Scholar* * *Taylor & Francis* | ***Search Strings and Boolean Expressions used:***   * Capstone Projects in computer science, software engineering and Information Technology and the IT industry * Capstone Projects in Engineering departments in Universities (2013-2023) * Final Year projects in Software Engineering and the industry (2013-2023) * Undergraduate Capstone Projects in Software Engineering: In Computer Science, Decision Science, & Engineering (2013-2023) * Commercialisation of Capstone Projects in Software Engineering, Computer Science, and Information Technology * Students’ final year projects in SE and their transition into the SE industry * Students’ capstone projects in SE, CS, and IT, and the SE industry * Software developed by students in capstone projects and its implementation in the SE industry * Undergraduate Capstone Projects in Software Engineering in Computer Science, Decision Science, & Engineering in African Universities (2013-2023) |

**c) Inclusion and Exclusion Criteria**

|  |  |
| --- | --- |
| **Inclusion** | **Exclusion** |
| * Peer reviewed journal articles and relevant conference proceedings written in English * Original research articles and documents * Only Articles and papers published between 2013 and 2023 * Research articles aimed at assessing capstone projects in Software Engineering, Computer Science, and Information Technology * Research articles and papers in other fields which incorporate a strong element of information technology, computer science and software engineering, for example manufacturing research with Computer Aided Design tools. * Some research articles and papers about capstone projects in related fields that used similar methods like those in CS, SE, and IT. * Conference Papers that are specifically about capstone projects in Computer Science, Information Technology and Software Engineering * Only research papers about undergraduate capstone projects were considered. * Some few relevant dissertations and theses covering the study topic | * Non-peer reviewed journal articles * Papers written in languages other than English * Systematic Literature Review articles about the same subject that are not original research were not considered. * ACM’s reusable and functional artefacts, reproduced and replicated artefacts, and reproduced research results available on <https://dl.acm.org/> were not considered * Papers published before the year 2013. * Book chapters, magazines, and policy briefs were not considered * Non-computing related papers about students’ capstone projects in other engineering fields like architecture, electrical engineering, manufacturing, civil and mechanical engineering, among others. * Non-computing related papers about students’ capstone projects in other fields like humanities, medical sciences, mathematics, and physics, among others. * Projects done by students as internship or continual assessments which are not terminal/ graduation projects. * Where the term capstone only appears in references and the paper is not about capstone projects. * Projects conducted at software companies without involving Universities were also eliminated * Research undertaken at postgraduate level, including Masters and PhD projects |

**d) Journal selection and categorisation**

|  |  |
| --- | --- |
| **Inclusion** | **Exclusion** |
| Only articles from Journals that are relevant to the study topic and are classed as A, B, and C in Australia Business Dean's Council (ABDC) Journal Quality List. | Articles beyond class B in ABCD classifications. |
| Only active journals that have a classification basing on ABCD, and a cite score were included | Discontinued journals that are no longer publishing, and thus do not have an active classification were also excluded |
| Only articles from Journals that are relevant to the study topic and whose latest Quartile Category is either Q1 and Q2 in Clarivate, and Academic Accelerator (academicaccelerator.com) | Articles whose latest quartile category is beyond Q2 on Clarivate and academic accelerator were not considered |
| Articles included in the review must not be from predatory journals and publishers listed on Bell’s List (<https://beallslist.net/>) | Articles and papers from journals and publishers that are listed as potentially predatory on Bell’s List (<https://beallslist.net/>) were not included in this study. |

**e) Justification inclusion of grey literature in the review**

Grey literature is research that is not easily accessible due to intellectual property rights, and is considered of sufficient quality to be collected and preserved by specific library holdings or institutional repositories (Adams et al., 2016 Schopfel, 2010). Most researchers tactfully exclude grey literature from systematic reviews because this kind of research is usually difficult to trace. Such literature can be found non-commercial publishing organisations, conference papers, on-going research, datasets, bibliographies, technical notes, webinars, government white papers, user-generated data (for instance on social media), and informally published or unpublished documents like students dissertations and theses, among others (Adams, Smart, & Huff, 2017; Paez, 2018). However, inclusion of grey literature can sometimes be helpful in many ways. Adams et al., (2016) supports the inclusion of grey literature in systematic reviews as a way of reducing the impact of publication bias that is inherent in most international peer-reviewed journals. This is especially important especially for researchers from the developing world, whose research output faces a lot of alleged bias and discrimination from international journals. Africa for instance accounts for only about 2% of total world publication output due to these alleged publication biases (Avery et al., 2022; Rubagumya, et al., 2022; Tarkang & Bain, 2019). The other reason for including grey literature in a review is to acquire useful contextual information about complex research phenomena- some of which cannot be easily located in peer reviewed journal articles. Grey literature also provides an opportunity for researchers and practitioners to synthesise existent solutions for a particular research problem, in order to identify areas of further intervention development and evaluation (Adams, et al, 2016). Inclusion of grey literature increases the comprehensiveness and timeliness of the systematic review, and enables researchers to paint a more balanced picture of existent research evidence (Paez, 2018).

Owing to these reasons, this systematic review includes some grey literature that is relevant to the topic of analysis. These include conference proceedings from mostly ACM, IEEE, and a few from other selected databases, plus a few relevant dissertations generated from capstone courses. The reasons for inclusion of this grey literature were because the author found a number of useful case studies extracted from capstone projects published as conference proceedings, and these included information that was relevant to the topic. Most of the research papers from Africa were not in peer-reviewed journals, and could only be found in conference proceedings, dissertations and papers from a few African universities’ research centers; yet the author intended to get a perspective of capstone projects in software engineering from an African context. Majority of papers downloaded from ACM, Google Scholar and IEEE were actually conference proceedings, yet the author could not eliminate these two databases as it is one of the leading sources of literature relating to software engineering projects. A total of 33 documents classified as grey literature were included in the final analysis.

**e) Article Selection Process Flow Chart**

Full text review

**57 articles excluded**

Articles excluded after abstract and title reviews, and removal of duplicates

**N=170 articles excluded**

Articles Related to Capstone Projects in Computer Science, Software Engineering and Information Technology

**N=  *313* articles excluded**

**N = *456* articles downloaded**

Final articles & documents included in this review: **N = 86**

**143 documents after further review**

**N = *6,996* documents identified** about SE, CS, & IT capstones

**Scientific Literature Search**

Original number of hits on capstone courses/ projects in general: ***142,469***

**Engineering Electronic Databases Used:**

* *ACM Library 1024*
* *IEEE =* 834
* *Science Direct =* 2530

***Total N= 4,388***

**Multidisciplinary Online Databases Used**

* *EBSCOHost =834*
* *Emerald Insight = 1000*
* *Google Scholar= 759*
* *Taylor & Francis = 15*

***Total N = 2608***

***Figure 2:*** Flowchart for the selection of studies adopted and slightly modified from systematic literature reviews studies Walugembe, *et al.,* (2022), and Elasu, *et al.,* (2023).

**Details of research papers per database and elimination stages:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| No. | Database | Hits on Initial Search about Computing Capstone Projects/ final year projects in general | Number of Hits related to Capstone projects in CS, SE & IT/ ICTs since 2013 | Documents Downloaded after initial review of titles, & journal quality | Eliminated after further review | Retained for full paper review | Documents finally used |
| 1 | ACM Digital Library | *31,811* | *1,024* | *55* | *45* | *10* | ***11*** |
| 2 | IEEE Xplore | *3,509* | *834* | *46* | *14* | *32* | ***30*** |
| 3 | Science Direct | *3,158* | *2,530* | *174* | *133* | *41* | ***25*** |
| 4 | EBSCOHost | *1,586* | *834* | *91* | *54* | *37* | ***6*** |
| 6 | Emerald Insight | *1,648* | *1,000* | *57* | *47* | *10* | ***2*** |
| 6 | Google Scholar (Search specific to SE)\*\* | *49,300* | *759* | *27* | *16* | *11* | ***9*** |
| 7 | Taylor & Francis (Search specific to Education) | *49,301* | *15* | *6* | *4* | *2* | ***3*** |
|  | **Total** | **140,313** | **6,996** | **456** | **313** | **143** | ***86*** |

On initial use of the search term “capstone projects”, the hits on some databases were too many (211,000 for Google Scholar to be precise). The researcher had to narrow the search down to “Capstone Projects in Software Engineering” to get more targeted results. The online databases were accessed using the Nelson Mandela University Library (<https://library.mandela.ac.za/Information-resources/Databases>), and Makerere University Business School membership in the Consortium of Uganda University Libraries, Uganda through MyLoft Library System (<https://app.myloft.xyz>).

**f) Data analysis and analytical categories used**

|  |  |
| --- | --- |
| **Category** | **Category description** |
| ***Year*** | Year in which the document was published. |
| ***Publication and Database*** | Name of the journal or organization where the document was published, and database from where document was downloaded |
| ***Region*** | Continent and country where the study was undertaken. |
| ***University*** | College/University/ Academic Institution where research was undertaken |
| ***Methodologies*** |  |
| 1. Research Problem | The research gap that was being investigated |
| 1. Research Objective(s) | The specific study objectives that the researcher set out |
| 1. Conceptualization/ Conceptual Framework/ Theoretical Models | Articles were grouped based on conceptualizations generated from the literature |
| 1. Research Design | Cross-section or Longitudinal Designs |
| 1. Research Methods | Quantitative, Qualitative, Design Science, or Mixed Methods |
| 1. Population and Sample | Population and sample size in the study being analysed |
| 1. Study Type | Surveys, Case Studies, Experiments, Randomised Control Trials, etc. |
| 1. Data collection | Data collection techniques used (Questionnaires, interviews, system user workshops, system modelling) |
| 1. System Development Methods Used | Traditional approaches (SDLC, Waterfall), or Agile Methods (Extreme Programming, Scrum, e.t.c.); Design Approaches like System Modelling, Prototyping, Problem Based Learning and Project Based Learning |
| **Results** |  |
| 1. Curriculum structure of courses studied | The specific academic programmes done by students, curriculum structure of programmes studied by participant students and the particular courses studied in preparation for the capstone projects |
| 1. Capstone Structure | The structure, type of capstone project, course, length, team composition, objectives of projects, development approaches used in the projects, software, hardware and other tools used by students. |
| 1. Findings and Contribution | The major findings from the research paper and the major contribution of the study |
| 1. Research Limitations and future areas of study | Limitations of the study and areas of future study interests |
| 1. Commercialisation of the artefacts or products from the capstone projects | The possibility that the software artefact or solution that was developed by the studied students was commercialised and taken onto the software market. |

**g) Summary of Research Methodology**

**IV: Findings**

**a) Papers reviewed per Journal**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Journal Name** | **Publishing House** | **Database** | **Frequency/ Number of papers** |
| 1 | IEEE Transactions on Education | IEEE | IEEE Xplore | 12 |
| 2 | Journal of Systems & Software | Elsevier | Science Direct | 8 |
| 3 | Procedia Computer Science | Elsevier | Science Direct | 8 |
| 4 | European Journal of Engineering Education | Taylor & Francis | Taylor & Francis Online | 4 |
| 5 | IEEE Access | IEEE | IEEE Xplore | 2 |
| 6 | Computers in Human Behavior | Elsevier | Science Direct | 2 |
| 7 | Education & Training | Emerald Group Publishing | Emerald Insight | 1 |
| 8 | Mechatronics | Elsevier | Science Direct | 1 |
| 9 | Computer Standards and Interfaces | Elsevier | Science Direct | 1 |
| 10 | Electronics | MDPI | Science Direct | 1 |
| 11 | Journal of Technology and Science Education | Omnia Science | Google Scholar | 1 |
| 12 | Journal of the Acoustical Society of America | Acoustical Society of America | Google Scholar | 1 |
| 13 | Mobile Information Systems | Hindawi | EBSCOHost | 1 |
| 14 | Communications of the Association for Information Systems | Association for Information Systems (AIS) | EBSCOHost | 1 |
| 15 | Journal of Engineering Education Transformations | Rajarambapu Institute of Technology | EBSCOHost | 1 |
| 16 | International Journal of Advanced Engineering and Management Research |  | EBSCOHost | 1 |
| 17 | American Journal of Engineering Education |  | EBSCOHost | 1 |
| 18 | Rapid Prototyping Journal | Emerald Group Publishing | Emerald Insight | 1 |
| 19 | Journal of Engineering Education | Elsevier | Science Direct | 1 |
| 20 | Science of Computer Programming | Elsevier | Science Direct | 1 |
| 21 | Journal of Parallel and Distributed Computing | Elsevier | Science Direct | 1 |
| 22 | IEEE Education Society Section (IEEE Access) | IEEE | IEEE Xplore | 1 |
| 23 | Information and Software Technology | Elsevier | Science Direct | 1 |
|  | **Sub-total** |  |  | **53** |
| ii) **Grey Literature Reviewed:** | | | | |
| **No.** | **Type** | **Sources/ Databases** | | **Freq.** |
| **1** | Conference Proceedings | ACM Digital Library IEEE, Emerald, Google Scholar, & Science Direct | | ***31*** |
| **2** | Dissertations | Google Scholar (College Portals). | | ***2*** |
|  | **Sub-total** |  | | ***86*** |
| **Total Number of papers studied.** | |  | |  |

**c) Sum of studies analysed:**

|  |  |  |
| --- | --- | --- |
| ***Document Type*** | ***Frequency*** | ***%*** |
| Primary Research Papers | 56 | ***62*** |
| Conference Proceedings | 31 | ***36*** |
| Dissertations | 2 | ***2*** |
| **Total** | **86** | ***100*** |

**d) Journal Quality**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No.** | **Journal Name** | **Classification (ABCD) or Latest Quartile Category** | **2022-2023 Cite Score** | **Impact Factor** |
| 1 | IEEE Transactions on Education | Q1 | 5.9 | 2.74 |
| 2 | Journal of Systems & Software | B | 8.9 | 3.514 |
| 3 | Procedia Computer Science | Q2 | 3.6 | 0.883 |
| 4 | European Journal of Engineering Education | Q1 | 5.3 | 0.687 |
| 5 | IEEE Access | Q1 | 4.8 | 3.476 |
| 6 | Computers in Human Behavior | A | 14.9 | 8.957 |
| 7 | Education & Training | Q1 | 4.8 | 3.058 |
| 8 | Mechatronics | A | 8.3 | 3.379 |
| 9 | Computer Standards and Interfaces | A | 8.8 | 3.721 |
| 10 | Electronics | Q2 | 3.7 | 2.69 |
| 11 | Journal of Technology and Science Education | Q2 | 4.0 | 6.781 |
| 12 | Journal of the Acoustical Society of America | Q2 | 3.3 | 3.425 |
| 13 | Mobile Information Systems | Q2 | 2.3 | 1.863 |
| 14 | Communications of the Association for Information Systems | A | 0.693 | 2.384 |
| 15 | Journal of Engineering Education Transformations | Q1 | 0.4 | 3.288 |
| 16 | International Journal of Advanced Engineering and Management Research | Q1 |  | 6.12 |
| 17 | American Journal of Engineering Education | Q1 |  | 6.029 |
| 18 | Rapid Prototyping Journal | Q1 | 7.3 | 4.043 |
| 19 | Journal of Engineering Education | Q2 |  |  |
| 20 | Science of Computer Programming | Q2 | 3.2 | 1.3 |
| 21 | Journal of Parallel and Distributed Computing |  |  |  |
| 22 | IEEE Education Society Section (IEEE Access) |  |  |  |
| 23 | Information and Software Technology | A |  |  |

CiteScore measures the average citations received per peer-reviewed document published in this title. CiteScore values are based on citation counts in a range of four years (e.g. 2019-2022) to peer-reviewed documents (articles, reviews, conference papers, data papers and book chapters) published in the same four calendar years, divided by the number of these documents in these same four years (e.g. 2019 – 22). (Scopus, 2023

The Impact Factor measures the average number of citations received in a particular year by papers published in the journal during the two preceding years. 2022 Journal Citation Reports (Clarivate Analytics, 2023)

**e) Specific papers Analysed:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Paper Code** | **Author** | **Year** | **Summary of problem studied** |
| P1 | Bakrania & Jha | 2020 | Traditional capstone projects in do not empower students to apply and reinforce practical skills in the boarder field of engineering. |
| P2 | Bali, Giriyapur, & Nandi | 2020 | Developing research skills among budding engineers at undergraduate level is difficult. |
| P3 | Al-Yahya, Alkadhi & Alrasheed | 2021 | Although the traditional Waterfall has been used by project software development, is very established in the SE industry, it is not the ideal approach for capstone projects |
| P4 | Venson, et al. | 2016 | Studies in suggest that Software Engineering programmes do not prepare students for successful entry into the software market. |
| P5 | Neyem, Diaz-Mosquera, & Benedetto | 2018 | There is a gap in soft and hard skills expected by employers, and skills acquired by software engineers from education institutions. |
| P6 | Babu, Arulanand, & Chandran | 2020 | Traditional design approaches in capstone projects are weak, constrained by time, inadequate in guiding learners, misdirected, lead to poor technical knowledge of learners, plagiarism & illegal outsourcing of projects by students; and low-quality IT projects. |
| P7 | Buhari, Valloo, & Hashim | 2017 | The development of final year projects (FYPs) using traditional approach is inefficient in developing skills and knowledge for many students. |
| P8 | Vanhanen, Lehtinen, & Lassenius | 2018 | Capstone projects undertaken by students with industrial customers face negative effects that can impact on customer satisfaction. |
| P9 | Ogenrwot et al. | 2022 | Most of the capstone projects in Uganda only end in research dissertations and lack entrepreneurship value. |
| P10 | Deepamala & Shobha | 2018 | Capstone project delivery faces a number of hurdles, like in exhaustive assessment rubrics used, students rarely considering industry needs, and weak collaborations between academic institutions and the industry. |
| P11 | Smajic & Johansson | 2022 | Divergence between SE education institutions and industry affects students and software engineers during their transition to the industry. Students lack technical skills in programming, and soft skills required to work in the industry. |
| P12 | Sinha, et al. | 2022 | Structuring capstone projects in resource- constrained institutions is a challenge. Yet the learning environment keeps on evolving. |
| P13 | Fernandes, et al. | 2017 |  |
| P14 | Ward | 2013 | There is no evidence of common models used by Universities around the world to deliver and implement capstone courses. |
| P15 | Raibulet & Fontana | 2018 | There is usually a gap between industry expectations and the preparation of undergraduate students concerning their first software engineering job. |
| P16 | Włodarski, et al., (2022) | 2022 | While a large variety of software development life-cycle models exists, like SDLC and Agile methods, there is little guidance pertaining which one is most appropriate in the context of working with students. |
| P17 | Guanes, et al., (2022) | 2022 | Most engineering students do not know how to use empathic approaches when design making decision. |
| P18 | Avila, Petegemb & Libotton, | 2021 | Industry reports indicate that less than 30% of software projects are totally successful, and that many software projects fail due to teamwork problems than technical issues. |
| P19 | Tenhunen, et al. | 2023 | The gaps between what students learn in the University and what they are expected to in the industry after graduation. |
| P20 | Weissbach | 2017 | Most research effort in capstone projects concentrated on student learning and the overall design process. There is little research on the perspective of industrial sponsors for capstone projects. |
| P21 | Yeaton | 2021 |  |
| P22 | Panicker, et al. | 2020 | Visually impaired students have challenges in indoor navigation, because GPS signals cannot go through wall barriers. Capstone projects can solve this problem. |
| P23 | Mandale, Patil, & Adamuthe | 2021 |  |
| P24 | Shiller | 2013 | Traditional capstone projects are introduced late in the courses, and are not integrative enough to prepare students for multidisciplinary career. |
| P25 | Sabnis, Kulkarni, & Gurav, | 2020 | Students do not demonstrate ability to work multidisciplinary domains, are unable to understand customer needs, and develop proof of concept prototypes to address these problems. |
| P26 | Wang (2020) | 2020 | It is it increasingly challenging problem for senior engineering students on telecom programs to catch up with the latest technologies. |
| P27 | Zhang (2019) | 2019 | While most universities in Western countries use the CDIO framework in capstone projects, Universities in China are yet to adopt. |
| P28 | Chen, Hong, & Chen, (2014) | 2014 | SE students are usually ‘blind explorers’ in capstone projects, trying to find the proper direction in the course, but lacking team experience, which impedes learning. Secondly, there is no sufficient empirical knowledge about the effects of Meeting Flow (MF) on Team Work Quality in capstone project programs. |
| P29 | Riek, (2013) | 2013 | Students usually spend a lot of time building and maintaining hardware from scratch. Using prebuilt robotic systems would simplify instruction and active learning among students. |
| P30 | Millán-Castillo, (2022) | 2022 | There is excessive delay in the completion of capstone projects among undergraduate students in Spain. Delays are also caused by heavy workload, and lack of sufficient supervision. This in turn delays in their full entry into the labour market; and also affects Universities rankings. |
| P31 | Duarte, et al., (2020). | 2020 | Very few engineering capstone design programs emphasize focus on sustainability aspects of engineering design. |
| P32 | Marques, et al., (2018) | 2018 | The development of transversal capabilities (soft skills), like leadership, teamwork, decision-making, negotiation, and self-reflection, is usually less supported in computer science capstone projects. |
| P33 | Scott, et al., (2014) | 2014 | The large amount of information generated during capstone projects hinders professors to meet each student’s learning profile; and to ascertain the exact skills and preferences of in these projects. |
| P34 | Fagerholm, et al., (2018) | 2018 | SE courses at universities do not offer students a chance to link their skills to real-life business outcomes; yet students are taught traditional development skills. This causes failure of their SE start-ups. |
| P35 | Younis, et al., (2021) | 2021 | Parallel programming concepts have not incorporated in the CS curriculum of Georgia State University. Yet they are needed in today’s ever evolving SE industry |
| P36 | Gan, et al. | 2015 | Lecturers and educational institutions face challenges of equipping students with skills that enable them cooperate in digital context and meaningfully participate in the learning process. |
| P37 | Castillo-Salinasa. | 2020 | Very Small Entities (VSEs) that develop software face problems to relate SE standards such as the ISO/IEC 29110 series. This limits their potentials. |
| P38 | Lehtinen, et al. | 2015 | Software project retrospectives like Root-Cause Analyses are usually neglected by development teams. |
| P39 | Pereira | 2021 | There is limited research evidence of students’ contribution to Open Source Software (OSS) tools and coding repositories like Git Hub in capstone projects. |
| P40 | Licorish, et al. | 2022 | Previous research in capstone projects has not sufficiently explored students’ perceptions about their commitment and adequacy of effort spent on SE projects, their project performance and skills that are developed during course of these projects. |
| P41 | Scott, et al. | 2016 | There is little evidence from SE education literature suggesting the use of the meshing hypothesis or effective approaches that can be used to validate use of teaching methods that fit students’ learning style in SE. |
| P42 | Kudikyala & Dulhare | 2015 | Computer Science and Engineering (CSE) and Information Technology (IT) students are not exposed to soft skills required in the industry. Methods like scrum are not prescribed in their existent curriculum. |
| P43 | Rodríguez | 2016 | Agile approaches to software development do not usually provide sufficient assistance to students as they perform their required tasks. Students tend to write lengthy requirement documents, engage in waterfall like issues, and focus on delivery dates instead of product quality. |
| P44 | Zagar, et al. | 2019 | Special diagnostic equipment that needs to be used for a certain procedure is not available at every location. The existing system of data storage and transfer is complex and has limited sharing capabilities. |
| P45 | Olarte et al. | 2016 | There are divergences between students’ and lecturers perceptions of learners’ efforts and their performance in capstone projects. |
| P46 | Bastarrica, et al. | 2023 | Peer assessments by students on capstone projects leads to little incentive for improvement, which potentially jeopardizes the overall quality of the project outcome. |
| P47 | Jaime, et al. | 2020 |  |
| P48 | Knudson, et al. | 2018 |  |
| P49 | Kim & Strimel | 2020 |  |
| P50 | Friess and Goupee | 2020 |  |
| P51 | Guardiola, & Dagli, & Corns | 2013 |  |
| P52 | Lobo | 2021 |  |
| P53 | Schneider, et al. | 2020 |  |
| P54 | Iacob & Faily | 2019 |  |
| P55 | Do | 2013 |  |
| P56 | Jia, et a. | 2019 |  |
| P57 | Baldassarre, et al. | 2021 |  |
| P58 | Sasipraba, et al. | 2020 |  |
| P59 | Fauzi & Andreswari | 2022 |  |
| P60 | Ardis, Hole, & Manfredonia | 2013 |  |
| P61 | Lin, et al. | 2015 |  |
| P62 | Shaikh | 2021 |  |
| P63 | Khakurel & Porras | 2020 |  |
| P64 | Chang, Shih, & Liao | 2022 |  |
| P65 | Meisel & Williams | 2015 |  |
| P66 | Posthuma, Pieterse, & Baror, | 2019 |  |
| P67 | Zizyte & Tabor | 2022 |  |
| P68 | Zheng, Zhang, & Li | 2015 |  |
| P69 | Porras et al. | 2018 |  |
| P70 | Hundhausen, et al. | 2021 |  |
| P71 | Genevera | 2021 |  |
| P72 | Braught & Siddiqui | 2022 |  |
| P73 | Bütt, Person, & Bohn | 2022 |  |
| P74 | Pembridge & Paretti | 2019 |  |
| P75 | Stahr & Davis | 2021 |  |
| P76 | Mertz & Quesenberry | 2018 |  |
| P77 | Gustavsson & Brohede | 2018 |  |
| P78 | Paasivaara, Vanhanen, & Lassenius | 2019 |  |
| P79 | Paiva & Carvalho | 2018 |  |
| P80 | Heymann & Greef | 2018 |  |
| P81 | Swart | 2016 |  |
| P82 | Greeff, et al. | 2018 |  |
| P83 | Buchele & Dafla | 2015 |  |
| P84 | Omeleze, Pieterse, & Solms | 2015 |  |
| P85 | Pieterse, &Van-Eekelen, | 2018 |  |
| P86 | Boucher, & Piderit | 2017 |  |
| P87 | Greenhalgh et al., | 2022 | Traditional opera theatre experience is too conventional: it uses traditional “end-on” staging, yet this is now increasingly disrupted by smart phones and social media. |
| P88 | Harburg, et al., | 2018 |  |
|  |  |  |  |
|  |  |  |  |

**Table: Problems studied by different researchers**

**Papers analysed per year**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Years | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
| Number of papers | 6 | 2 | 8 | 5 | 4 | 14 | 7 | 14 | 12 | 12 | 2 |

The highest number of papers analysed were from 2018 and 2021 (14 papers from each of these years), representing 32% of the entire sample of papers analysed. These were followed by studies from the years 2021 and 2022 (14 studies in total), representing 28% of the entire number of research papers analysed. The least number of papers came from the years 2013 and 2023 (only 2 papers per year), both years representing a total 4% of the total number of papers analysed. Results from the analysis indicate that majority of the papers studied (69%) were between the year 2018 and 2023 (the last five years). These results indicate that the review was dominated by the most recent events and research trends in the area of capstone projects in SE, CS, and IT; and the conclusions recommendations here from are in tandem with the most recent development in the field of capstone projects.

**ii) Analysis of Problems and Areas of Concern over the last 10 years**

|  |  |  |
| --- | --- | --- |
| Problem/theme | Studies | Number of Studies & Percentage |
| 1. Inability of capstone projects to bridge academia and industry | **P1, P2, P3, P4** |  |
| 1. Lack of soft skills among students |  |  |
| 1. Inappropriate pedagogical skills |  |  |
| 1. Difficulty in creating collaborations with industry players |  |  |
| 1. Difficulty in balancing academic and professional goals of capstone projects |  |  |
| 1. Other cross-cutting issues in capstone courses/projects |  |  |
|  |  |  |

**Journal Quality:**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No.** | **Journal Name** | **Publshing House** | **Classification (ABCD) or Latest Quartile Category** | **2022-2023 Cite Score** | **Impact Factor** |
| 1 | IEEE Transactions on Education | IEEE | Q1 | 5.9 | 2.74 |
| 2 | The Journal of Systems & Software | Elsevier | B | 8.9 | 3.514 |
| 3 | Procedia Computer Science | Elsevier | Q2 | 3.6 | 0.883 |
| 4 | European Journal of Engineering Education | Taylor & Francis | Q1 | **5.3** | 0.687 |
| 5 | Computers in Human Behavior | Elsevier | A | 14.9 | 8.957 |
| 6 | Education & Training | Emerald Group Publishing | Q1 | 4.8 | 3.058 |
| 7 | Information Systems Education Journal | ERIC |  |  |  |
| 8 | Rapid Prototyping Journal | Emerald Group Publishing | Q1 | 7.3 | 4.043 |
| 10 | IEEE Access | IEEE | Q1 | 4.8 | 3.476 |
| 11 | Journal of Information Systems Education | Information Systems and Computing Academic Professionals (ISCAP) | B | 1.824 | 0.484 |
| 12 | ACM Transactions in Computing Education |  |  |  |  |
| 13 | Mechatronics | Elsevier | A | 8.3 | 3.379 |
| 14 | Information and Software Technology | Elsevier | A | 9.1 | 3.862 |
| 15 | Journal of Parallel & Distributed Computing | Elsevier | A | 10.2 | 3.8 |
| 16 | Computer Standards and Interfaces | Elsevier | A | 8.8 | 3.721 |
| 17 | Heliyon | Elsevier | B | 2.1 | 3.776 |
| 18 | Electronics | MDPI | Q2 | 3.7 | 2.69 |
| 20 | Journal of Technology and Science Education | Omnia Science | Q2 | 4.0 | 6.781 |
| 21 | Journal of Engineering Education | American Society for Engineering Education | Q1 | 9.2 | 3.288 |
| 22 | Journal of the Acoustical Society of America | Acoustical Society of America | Q2 | 3.3 | 3.425 |
| 23 | Mobile Information Systems | Hindawi | Q2 | 2.3 | 1.863 |
| 24 | Communications of the Association for Information Systems | Association for Information Systems (AIS) | A | 0.693 | 2.384 |
| 25 | Journal of Engineering Education Transformations | Rajarambapu Institute Of Technology | Q1 | 0.4 | 3.288 |
| 26 | Human Factors and Ergonomics in Manufacturing & Service Industries | Wiley Online | Q2 | 1.72 | 1.699 |
| 29 | International Journal of Advanced Engineering and Management Research |  | Q1 |  | 6.12 |
| 31 | American Journal of Engineering Education |  | Q1 |  | 6.029 |
| 32 | The European Educational Researcher |  | Q2 |  | 3.0 |
| 33 | Computers in Human Behavior | Elsevier | A | 17.8 | 9.9 |
| 35 |  |  |  |  |  |

**d) Categorization of Studies by Country Region**

**e) Universities from which studies were conducted**

1. **Common Research Problems Investigated/**
2. **Common Conceptualization/ Conceptual Framework/ Theoretical Models used**
3. **Methodological Review Results:**

* **Research Designs Used**
* **Research Methods Applied in Capstone Projects**
* **Study Types Conducted:**
* **Data collection Methods Used:**
* **System Development Methods Used**

1. **Curriculum structure of courses studies**
2. **Capstone Courses Structure**
3. **Contributions of Different Researchers**
4. **Research Limitations and future areas of study**
5. **Commercialisation of the artefacts or products from the capstone projects**

**XII: Discussions and Conclusions**

**XIII. Limitations of this Study**

**XIV. Areas of Further Investigation**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| The data Set: Annotated Review table | | | | | | | | |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| Not included | | Adkins & Tu, (2019),  ERIC/Information Systems Education Journal (ISEDJ)  School of Computer Science & IS  Northwest Missouri State University, USA | **Problem Statement**:  Information systems graduates face a major challenge  to productively design, implement,  and manage information systems, in a timely fashion. Well-structured capstone courses can help them achieve this.  **Research Objective**:  To outline the content of a Master of Science in Information System degree and the  development and deployment of the first two iterations of the capstone course.  **Conceptual Framework**:  Not included | | **Research Design**: Cross Sectional  **Methods**  -Case study of a Msc. IS course.  - Mixed Methods, Quantitative, Qualitative, and DS.  -Agile Approach (**Scrum collaborative tool**),  -Systems Analysis & Design  - 2 design teams (one with client and another without) | - Agile methods and scrum are very useful in project success  - Teams must follow project plan  - Teams must work well with clients for success  - Use correct communication media for success  -Effectively engage clients  - Capstone projects are a good learning experience  - Use formal PM approaches for success  -There is value in working with a real life client from the industry (team 1)  - Lack of an external client weakens the experience  **Software used:** Moqups, Justinmind,& Wix.  **Design Approaches Used in projects studied**: Agile, Project-based Learning, Scrum, system analysis and design; Projects mgt techniques: Requirements and design documentation, test plans, test reports,  burn-down charts, Gantt charts, and  documented artefacts  **Academic programme studied**: Master of Science in Information System degree. | | - Study based on a small sample of only 32 students and 2 cohorts. A larger sample would be more generalisable.  - The study only focused on creating prototypes which are not easily transferrable to the industry  - The short time available for the projects does not allow for satisfaction of all client needs  - Difficulty to get interested clients and industry partners. Only SMEs and small NGOs were involved.  - Project-based learning places heavy workload on professors (compared to the normal classwork assessments), and thus they may not support the programme.  **Possibility of Commercialising and up-scaling results of Projects**:  The researchers note that it was difficult to find appropriate real-world projects and clients for short-term capstone projects. Furthermore, most clients did not appear to have time for students’ projects, and that the university is in a small town, which limits the potential clients. ***The products/ prototypes were never commercialised.*** |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| 1. | | Shurin, Davidovitch & Shoval, (2021)  The European Educational Researcher  Ariel University & Shamoon College of Engineering, Israel | **Problem Statement**:  **Research Objectives**:  **Conceptual Framework**: | | **Research Design**-Cross-sectional  **Type**  - Case Study  **Methodology**  -Mixed Methods (Quantitative, Qualitative),  **Data Collection**  - Semi-structured interviews, questionnaires, observations, and more | -Majority of students indicated that the capstone projects are important in preparing them for engineering careers  -Students believed that capstone projects contributed to their independent and group learning capabilities  -Participants felt more self-educated after the projects  -Participants felt like the Projects enabled them cope with new industry challenges  -Well-structured supervisory meetings improve learner satisfaction  - A good number of students still feel the project is a waste of time  -Most capstone projects have not changed much for years, not taking into consideration changes introduced by 4IR.  -Projects lack a standard and method of assessment across universities  - No dynamism. The exact same project is usually done by several students over a span of different years.  **Software platforms and methods used in projects**: Project and Problem Based approaches, systems analysis and design, prototyping.  **Academic Programme studied by students:** Bsc. Mechanical Engineering. | | - Disparity between industry and academia expectations and methods used in project management makes it difficult for academic projects to enter the industry  - Project only concentrated on physical engineering products, computer hardware, and not on software.  - A more comprehensive study is required into the use of capstone projects as a pedagogical tool in industry 4.0, as the study found gaps in using these projects as a learning and project management tool.  **Entrepreneurial Value/ Commercialisation of projects:**  Although most participants attested to the fact that the capstone programmes prepared them for the industry, all of the projects studied were never commercialised. The only attempt to up-scale the projects was partnerships with alumni and sponsors during the course. |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P1 | | Bakrania & Jha, (2020)  Procedia Computer Science/ Science Direct  9th World Engineering Forum, WEEF 2019  Henry M. Rowan College of Engineering, New Jersey, USA | **Problem Statement:** The traditional capstone projects in engineering courses do not empower students to apply board concepts of the field, reinforce their skills and apply their skills in their specialised area of interest.  **Research Objective:** To explore the effect of transforming the traditional capstone program into an Engineering Clinical Math Model/ software that allows students to work on multidisciplinary projects.  **Conceptual Framework:**  Modelling the ECM framework in capstone projects. | | **Research Design**: Design Science  **Type:** Case study  **Methods**:  Mixed Methods  - Quantitative methodology  - Narrative Case Study of 4 Semester/ Term Capstone Projects.  -System analysis, validation and evaluation | The study proposes a progressive capstone project as opposed to a single final year project.  It also proposes a model of pairing students of different years (seniors and juniors) to share experiences and skills  Study outlines the need to equip students with wider skillset as opposed to doing a single project at the end of the engineering programme  A better structured capstone project increases enrolment onto engineering programmes  Good capstone projects must seek funding from the industry and gov’t for them to create employment and linkages with the industry.  **Software and platforms used**: The Clinic Math platform using Google Suite  **Academic Programmes undertaken by students**:  Bsc. Mechanical Engineering (ME)  Bsc. Civil and Environmental Engineering (CEE)  Bsc. Electrical and Computer Engineering (ECE)  Bsc. Chemical Engineering (ChE)  Bsc. Biomedical Engineering (BME), and  Bsc. Experiential Engineering (EXE). | | Study does not provide the long-term benefits of working on multiple projects as opposed to the traditional final year project  The study does not highlight how progressive capstone projects can be effectively administered over the different semesters/ terms.  **Commercialisation or up-scaling the project and taking it to the market**:  While the Engineering Clinic Math Program has not been sold on the market, it has been adopted by the University and since its inception in Fall 2014, almost 5000 students had been assigned to 1200 projects. The project was 100% implemented and acquired by an internal client. |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P2 | | Bali, Giriyapur, & Nandi, (2020)  Science Direct/ Procedia Computer Science  KLE Technological University,  Hubballi, Karnataka, India | **Problem Statement:**  Developing research skills in budding engineers at the undergraduate level is a daunting task.  **Research Objectives:**  To analyse a student project involving the development of a robotic system of 3D printing on fabric.  **Conceptual Framework:**  **Proposed a problem identification and solving model involving:**  Idea-generation, Problem-Defn, Procedures-design, Observation Data analysis , Interpretation, & Communication phase. | | **Research Design**-Design Science  **Type**:-Case Study methodology,  **Methods**  **Mixed Methods:**  - Qualitative  - Systematic survey approach  -Brainstorming for data collection  - Systems Analysis & Design (DS),  - Experimentation during prototype development  - Verification and validation of students’ output/  implemented prototype | - Students underwent a unique learning hands-on learning experience.  - Students were able to easily test the results of projects experiments  -Students were exposed to the constraints of real-time system development and the process of identification of system requirements  -Undergrads were able to appreciate the problem-solving approach of research  Capstone projects enables lifelong learning and peer learning among students  **Software Used by students in their project**: Automation and Robotics program, 3D Printing software, Screen printing and Embossing software, Generation of G-code in Solidworks/MasterCAM, Universal G-code Sender(UGS), Arduino, Java Runtime Environment(JRE) for interface design,  **Academic Programme taken by students**: BSc. Chemical Engineering. | | -Study based on one case study. Findings cannot be easily generalised  -Study used only a few CAD software applications for system design and development. The observations and analyses were only based on only the software and technologies used.  Level of commercialisation and transfer of product to market:  The proposed framework and system developed was only evaluated by a panel of experts and not commercialised. |
| No. | | **Author & Year, plus country** | **Problem Investigated; Research Objectives Theoretical/ Conceptual Framework** | | **Methods/ Techniques Used** | **Key findings** | | **Research Gap**  **Read Areas of further study.** |
| Eliminated due to journal quality | | Ahmad, & Alammary, (2022);  Emerald Insight;  Arab Gulf Journal of Scientific Research;  Saudi Arabia | **Problem statement**:  There are no detailed guidelines for mgt and assessment of capstone projects in Saudi Arabia. Thus variations exist in the mgt, assessment & analysis of the students’ performance capabilities in capstone project courses. It is difficult to align these courses with industry demands, and to use them in achieving the Saudi Vision 2030, is challenging  **Research Objectives**:  **Conceptual Framework**: | | **Research Design**: Longitudinal design (first phase)  **Type:**  Comparative study  **Methods**: Quantitative survey design  31 Universities were studied  Semi-structured Online Questionnaire | - Most projects are undertaken in the final year of study (final 2 semesters)  - Given 3-5 credit units  - Projects have a well-documented process  - Supervision is done on a weekly  - Most projects use SDLC/ Waterfall model in contrast to preferred agile modes  - No digital repositories for projects  - No standard assessment method across universities  - Assessment is both for group & individually  - Only a few projects involve external supervisors from the IT industry (12%)  - Typical research thesis writing is rarely emphasised in these projects  - Capstone project structure in most universities is inflexible with a few CUs  - Team size is too small to allow application of project management approaches on the courses.  **Development approaches, software used, technology platforms:**  **-** Waterfall model, Iterative design, Agile Development  **Software:** Not included  **Academic Programmes**: Bsc. CS, BSc. SE, Bsc. IT. | | **Gaps/ future research:**  **-** Projects studied are mostly based on restrictive methods (Waterfall)  - Data was collected from only instructors, supervisors and administrators. No students were consulted in this study, yet they are the principle investigators/ implementers of these projects. There is need to do a follow up study involving students  - There is need to do an end-line study to evaluate the level at which Universities have gone in implementing the authors’ recommendations.  **Level of commercialisation and up-scale**:  -Most of Saudi universities studied were only focused on archiving the graduation thesis and reports.  - 73% of projects ended with successful project report.  ***- No single project had been up-scaled onto the market. 0%.*** |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P3 | | Al-Yahya , Alkadhi & Alrasheed (2021);  IEEE  Conference Paper:, 2021 International Conference on Computational Science and Computational Intelligence (CSCI), King Saud University Riyadh, Saudi Arabia | **Problem Statement**:  Since the inception of the IT program at KSU, the traditional Waterfall had been used by project software development. Although this model approach is very well known and established in the software engineering industry, it is not the ideal approach for capstone projects.  **Research Objectives**:  To present the transformation  strategy, from waterfall to agile methods in the design of a capstone course, and discuss opportunities and challenges.  **Conceptual Framework**:  Not included | | **Research Design**: Cross Sectional  **Type:** Experience report  **Data Collection**  Qualitative  Narrative research,  Agile development,  Scrum | -The success of transforming traditional capstone projects into agile methods like scrum relies on providing support to Faculty and students  -Faculty members need to be very flexible and willing to try out new ways of delivering capstone projects  -Most models for scrum are based on shippable, physical products. Therefore applying them on IT projects in web development, mobile Apps, and IoT becomes hard for students and staff  -Staff and students are usually reluctant to learn new ways of delivering projects, since scrum and other agile methods require more time, effort and work.  **Development Method: Scrum and Agile**  **Software and platforms used:**  **- Jira Software**: Scrum preparation, creating Product Backlogs and filling it with user stories, creating Sprints and Sprint Backlog, & tracking progress through Scrum board and Sprint burn-down chart.  - **Atlassian Confluence**: for documenting their weekly meetings;    **GitHub:** coding and synchronising files.  **Academic Programmes**: Bachelor’s program in Information Technology. | | **Gaps and future research**:  -The study does not comprehensively show experiences of participants (students and staff) in using agile methods (scrum)  -The researchers do not tell us about the perceptions of participants about the new methods of conducting and administering capstone projects.  **Commercialisation/ up-scaling of products**:  The students only end at submitting two software releases that are evaluated by the faculty and awarded. No further development or effort is made to transfer the products onto the software market. |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | | **Methodology** | **Findings/ Results of Project** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P4 | | Venson, Figueiredo, Silva, & Ribeiro, (2016)  IEEE Paper.  ITRAC – Information Technology, Research and Application Center  University of Brasília – UnB, Software Engineering Faculty, **Brazil**  University of Brasília – UnB, Brazil | **Problem Investigated**:  Studies in Brazil suggest that Software Engineering academic programmes do not prepare students for successful entry into the software development market.  **Research Objectives**: To describe a framework for academia industry collaboration on capstone projects that simulate the real world.  **Conceptual Framework**:  IEEE Ideal (Initiating, Diagnosing, Establishing, Acting,  Learning) Model | | **Research Design:** Design Science/ Action Research,  Descriptive Case study  **Type: Case study**  **Methods:**  - Mixed Methods;  Qualitative (Narrative case study,  - System elaboration/ modelling)  - Quantitative | The study proposed and partially implemented new software development model for the industry  Academic papers were published from the capstone project.  IEEE and IDEAL frameworks enable students acquire experience in solving real world problems through capstone projects  Capstone projects should be undertaken through groups for mutual support among students  Capstone projects must be year-long projects for students to acquire sufficient skills and competences  Capstone projects should have an active customer (from the industry) other than the academic supervisor for students to take it more seriously and be able to raise finances to implement these courses.  **Development Approaches:** Scrum, Kanban, IEEE Curriculum model for Capstone courses. No specific mention of software and tools used.  **Academic Programme analysed:** BSc. Degree Program Software Engineering | | **Limitations and further research**:  Need to analyse participants’ perceptions about the IDEAL frameworks  Need to analyse the framework using Bloom’s taxonomy of learning.  Level of commercialisation/ entrepreneurial value created:   * 3 projects (out of 7) produced new processes for a client organisation- specifically an entire IT department of government ministry; * The system is being used for contact outsourcing by the Ministry. * The processes for inventory management within the systems Inventory are already in use. * 5 academic papers were published in 2 international conferences and one paper in a Brazilian conference out of these projects. * ***Only 43% (3 out of 7) of capstone projects undertaken were commercialised and up-scaled.*** |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | | **Methodology** | **Findings/ Results of Project** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P5 | | Neyem , Diaz-Mosquera, & Benedetto (2018).  Mobile Information Systems  EBSCOHost /Hindawi  Pontificia Universidad Cato´lica de Chile, Santiago, Chile | **Problem Statement**: It is usually difficult to coordinate between students, stakeholders and academic teams in capstone projects. This constrains students learning on these courses.  **Research objectives**: - Paper presents  a Cloud-based mobile information system that can support project management under a framework of best practices in software engineering capstone courses.    **Conceptual Framework**: Not mentioned | | -**Research Design:** Design Science;  **Type:** Experience Report  **Methodology:** Mixed methods, qualitative interviews, quantitative using graphs, Group discussions, System modelling and diagramming, and experimentation | -The systems improves planning of capstone projects  - Using the system allows clear division of tasks  -The method allows for organisation of deadlines and prioritise tasks  - Using stories simplifies requirements definition  - Using Kanban brings order and visualisation of what everyone is doing  - Using Kanban is simple and makes management of capstone projects easy  - Agile tools enable immersion into the project, a high level of engagement  - The methods allowed students to develop products with quality comparable to those of professional software development companies.  - Kanban methods allowed students to communicate easily and professionally with their clients in the industry.  - Kanban methods gave students clear timelines and durations spent on each activity of the projects they were undertaking.  **Software**: ROOM, Google’s ORM;  ***Web Applications &***  **Programming:** HTML5, CSS, and JavaScript, with Ruby on Rails; **Work integration** with the GitHub; Firebase Cloud Messaging technology, IaaS components, Amazon EC2, & Project Management Software  **Development Approaches:** Scrum approach, Kanban, Project Management Approaches. | | **- The paper does not** offer a consolidation of knowledge or experiences of other people who performed similar activities in the past.  - The study does not objectively determine, assess, and predict student teamwork outcomes by applying the proposed framework.  - The methodology used in the paper is a multi-method approach that lacks clarity and is bound to lead to ambiguity.  **Level of commercialisation:** The project only remained as a proposed mobile system and was not yet implemented or even taken to the market for commercialisation. ***0% of projects analysed were commercialised.*** |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P6 | | Babu, Arulanand, & Chandran, (2020);  Science Direct/ Procedia Computer Science;  Conference Paper: 2017 7th World Engineering Education Forum (WEEF)  PSG College of Technology, Coimbatore, India | **Problem Statement:**  There is a gap in soft and hard skills expected from the employer and  skills acquired from the educational system.  **Research Objective**: To proposes a streamlined approach to ensure to produce high quality and efficient capstone projects.  **Conceptual frame**: An educational model for experiential learning. | | **Research Design**-Design Science  **Methodology**  -Solution Proposal  **Development Approach**:  Product Development Approach  **Software & platforms Used:**  - No clear software, programming language mentioned**.**  - Use of Outcome Based Education approaches (OBE) in projects studied. | A model for mapping industry expectations in terms of skills (hard and soft) onto what is taught in schools is developed and piloted  The findings relating to the skills gaps in the industry are used to refine courses, course outcomes, cognitive levels and  tighten experiential learning process of students  The model is applicable for both physical products and software products.  Software & Platforms used in Projects studied: Not included. | | **Gap & future research**:  The model is based on a single case study and cannot easily be generalised to all other cases and scenarios.  **Entrepreneurial value created/ Commercialisation of projects**:  - No formal commercialisation or up-scaling of projects was done for the existing capstone projects.  - Even the model that was developed was only proposed system architecture/ web-based system to automate the for student FYP management activities. It wasn’t also implemented or commercialised. |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P7 | | Buhari, Valloo, & Hashim, (2017).  IEEE, Conference Proceedings  Infrastructure University Kuala Lumpur, Malaysia | **Problem Statement**:  The development of capstone projects (FYPs) using traditional approach is inefficient in developing skills and knowledge for many students. Traditional approach is weak in addressing the issues like time constraint, in adequate guidance, high expectation without proper direction and poor technical knowledge. Thus, student’s ends up with low-quality IT projects which is neither benefit to them nor benefit to society.  **Research Objectives**:  To propose a streamlined approach to ensure to produce high quality and efficient project.  **Conceptual Framework**:  Not included | | -Design Science  Type:  Case Study  Methodology  Case Study of Final Year Projects in Malaysia  Systematic review of literature | Capstone:  Study categorizes capstones development as five main modules namely requirement, development, demonstration, documentation & presentation  Paper builds a framework for ensuring better delivery of final year projects  Authors propose active engagement of the industry in the design, execution, and assessment of FYPs  - Paper proposes Valid, reliable and fair methods of assessment of these projects  -motivational methods should be used to encourage learners actively participate during projects  - Authors propose a web-based system architecture to automate the entire process of managing capstone projects at Universities.  **Academic Programme**: BSc. Information Technology | | The authors did not do a validation of the system architecture they developed to see in fact if it can improve FYPs  - Implementing the proposed framework places an extra workload on supervisors, who may not accept this  - Students may be required to incur extra costs because of the additional tasks they are required to engage in in the proposed model. |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P8 | | Vanhanen, et al. (2018)  Science Direct  The Journal of Systems and Software  Aalto University, Department of Computer Science, Finland | **Problem Statement:**  Capstone projects undertaken by students with industrial customers face negative effects that can impact on customer satisfaction.  **Research Objectives**:  To study problems,  learning and customer satisfaction related to eleven software engineering topics  **Conceptual Framework**:  Not included | | **Research Design**:  Cross-sectional quantitative survey; **Type**  **Case Study**  **Methodology**:  Quantitative  **Data Collection**:  Online Self-administered questionnaire  Problem analysis,  **Population:** 127 students  Data analysis with SPSS  **Programme:** BSc. Computer Science | - Students face difficulty in these projects because they require use of programming languages that they may not have learned in previous semesters/ terms  - Often industry customers have an unclear understanding of the features they want students to develop.  - Customers are now clear about the level of quality they want from projects  - Students promise too much to customers and fail to deliver  - Selecting system testing tools was difficult for most students  - Team member conflicts affected how changes in source code were written  - Lack of communication among team members delayed decisions  - Team developers are often unaware of their tasks  - Customers from the industry are slow in responding to team questions  - Paid work from the industry often overrides the academic aims of the course  - Team members lack motivation  - ***Inexperience in implementing topics among students prevented development of real products***  - There were varying degrees of learning between managers from the industry and students, and among students in the same teams.  - Most projects monitored & delivered online  - challenges in working in teams, like lack of coordination, conflict & mistrust  - Online teams face some level of social isolation | | **Research Gaps**- The study did not ascertain why students doing the same project were having varying degrees of learning  **Level of commercialisation** **or transfer to the market**: In spite of the fact that projects had internal and external customers, the products were never taken up by the prospective clients.  ***No single project was transferred to the market.*** |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| P9 | | Ogenrwot et al., (2022),  Gulu University, Uganda,  : Federated Africa and Middle East Conference on Software Engineering (FAMECSE ’22), ACM Library  Conference Paper | **Problem Statement**  Most of the capstone projects in Uganda only end in research dissertations and lack entrepreneurship value.  **Research Objective:**  **Conceptualised factors** that affect the structure of  capstone project and their transformation intro marketable product:  **Factors identified include**: Curriculum Structure, University Environment,  Nature of Students, IT Infrastructure Available, Industry Collabos/ Strategic Partnerships | | **Design**:  Cross sectional; **Type**:  Case Study  **Methods**  Exploratory research design  Case study of Gulu University  Simple Random sampling  **Data collection:**  Document review of reports about capstone project  Random sampling of documents reviewer  Participant workshop | - Majority of projects developed products for either agriculture, education and health sector  - Only 2% of the 86 projects studied had been commercialised as real products  - The curricula for these projects is biased towards academic components and less emphasis is put on industry or community.  - **Only 2 out of 60% of projects studied demonstrated the entrepreneurial value of capstone projects.**  - Participants recommended the balancing of theory and practice to contribute to community and stakeholder needs  - **Challenges** that prevent commercialisation: theoretical curriculum (teacher-centred), students attitudes to PBL and PrBL, students lack technical competences in programming, students lack soft skills like presentation and creativity,  - Infrastructural challenges like poor internet connectivity, limited bandwidth, lack of access to computers and the internet all affect the success of these projects/  -**Opportunities**: employment, innovation, exposure to industry, knowledge diversification,  - **Recommendations**: Leverage internship, create strategic partnerships, encourage business incubation, use pitching and not presentations, encourage PBL, PrBL, provide infrastructure.  **Academic Programme analysed:** Bachelor of Science in Computer Science and Bachelor of Information Technology. | | - Study only done in One university  - Only 4 years of projects studied. A more comprehensive study is needed in this area.  - Paper does not clarify or present a standard metric or rubric for measuring commercialisation of these projects  - The paper does not show the impact of capstone projects on students’ software engineering skills  **Entrepreneurial Value/ level of commercialisation:**  Only 2 out of 86 projects studied (2%) had been commercialised. **98% of capstone projects undertaken by students are never up-scaled and commercialised.** |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| Not included . | | Morgan, et al., (2021),  Science Direct; Conference Proceedings: Proceedings of Student-Faculty Research Day, CSIS, Paniversity, April 30th, 2021  NYC, USA | **Problem statement:** Capstone courses offered across US universities need improvement to solve real-world problems and adapt to changes due to COVID19.  **Objective**: To make an insight on capstone computing  courses offered at a range of universities across the United  States  **Conceptual Framework:**  Not indicated | | **Design:**  Cross-sectional survey method  Part of a longitudinal study that started in 2015  **Type:**  Comparative Study  **Methodology**  Mixed Methods (Quantitative and Qualitative)  **Data Collection**  Document analysis  -Quantitative | - 90% of respondents indicated that capstones are conducted as team oriented projects  - Instructors/ supervisors have a 66% influence on the outcome of the project  - Projects have clients or customers for whom they are developed/  - Customers include external organizations (local NfPs or for profit companies), internal clients (university needs or faculty/ doctoral student research), and cutting-edge technologies research.  - Most clients were external organisations.  - Learning objectives include: Integrating knowledge; balancing technical, business, and interpersonal skills; challenging students out of their comfort zones; simulating real-world learning experience; integrating technical and non-technical competencies.  - Portfolios used to measure progress: weekly status reports, presentations, visual arts, websites, and demos.  - Standard rubric for measuring performance  - Most self-selected teams/ randomly selected student teams did offer enough learning  - Majority of projects had peer evaluation  - **Software Used**: Some geographically dispersed teams were using **zoom, teams and skype**- though affected by time-zones and social isolation | | - Much emphasis was put on the structure and composition of student teams and less on the influence to industry based clients for the projects  - More research is required in the possibility of collaborations between universities and external clients  - The study did not explore the effect of having multidisciplinary teams on a single project, yet it has potential for improving creativity and team productivity  -Little reference was made to the baseline study that was done in 2015, yet this particular a study was a follow up of the original study.  **Level of Commercialisation/ entrepreneurial value created**:   * 42% of projects studied had external clients. * About 58% of projects were not sold or used by external clients. |
| No. | | **Author, Yr, Journal Country** | **Problem studied; objective(s); Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P10. | | Deepamala & Shobha (2018),  Journal of Technology and Science Education;  Google Scholar/ Omnia Science;  R.V. College of Engineering, India | **Problem identified**:  Capstone project delivery faces a number of hurdles. For instance assessment rubrics used for FYPs are not usually exhaustive & students rarely consider industry needs, and there are weak collaborations between academic institutions and the industry.  **Conceptual/ theoretical framework:**  Problem Based Learning and Project Based Learning Model | | **Research design:** Cross sectional  **Type:**  Case Study  **Methods:**  Case study method  Document analysis of projects over 3 academic years | -The students conducted projects in teams  - Rubrics for the projects were given to students  - Rubrics were not exhaustive and required changes  - Clearly defined course and program outcome helped to improve the program.  - Continuous evaluation of project progress on product development cycle (PDC) at each phase  - Students tended not to consider society and the environment  - Interdisciplinary projects were emphasized.  - Workshops to train students about synopsis/ research report writing,& project management skills  - Industry-academia relationship was needed for project improvement  - Effective documentation and storage of project reports was essential for future reference.  - Some projects were continued in subsequent academic years to complete them.  - The main areas of development were: Networking, Wireless Technologies, Data Mining, Business Intelligence, & Computer Vision  -Majority of the projects developed were Business Intelligence Applications and products  - Projects further evaluated by industry experts, exceptional projects recognised, awarded prizes  **Software/ development platforms used**: Programming Languages: C++, Java, Python etc., and theoretical subjects like Data Structures Computer  Networks, Software Engineering.  **Academic programmes analysed:** Bsc. in Computer Science Engineering | | **Gaps and future research:**  - The study was a case study of one University and only 3 academic years. The results may not representatives of all capstone courses in different Universities.  **Level of commercialisation:**  About 67% of the 289 projects studied in the areas of Networking, Wireless Technologies, Data Mining, Business Intelligence and Computer Vision were implemented as Industry-Live projects, while about 33% were in-house projects.  ***Majority of the projects were up-scaled, but not yet commercialised.*** |
| No. | | **Author, Year, Journal, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P11 | | Smajic & Johansson, (2022).  Google Scholar/ Student dissertation  Jönköping University ,Sweden | **Problem Statement**:  Divergence between SE education institutions and industry affects students and software engineers during their transition to the industry. Students lack technical skills in programming, and soft skills required to work in the industry.  **Research Objectives**:  To identify the parts described in the  CDIO framework that can be applied to capstone projects.  **Framework:**  The Conceive, Design, Implement, and Operate (CDIO) Framework to software development. | | **Design:**  Cross sectional quantitative  **Type:**  Solution proposal  **Method:**  Quantitative  **Data Collection**:  survey method,  Questionnaires and meta data about respondents  and projects; | - 97.3% of respondents had performed capstone projects  - Projects ranged from 1-8months. Majority were less than 2 months  - 63% projects used agile development methods  - Most respondents had worked with the industry, though mostly not more than 3 years  - 75% of respondents performed all CDIO criteria in their capstone project  - Projects longer than two months yield better performance in industry in terms of CDIO.  **Approaches and software**:- Agile project methods include: Scrum (majority), Kanban, XP, and ScrumBan  **Academic Programmes:** Information Technology and Computer Science degree programmes. | | - The project was undertaken at the bachelor’s degree level, and the authors conclusions are more bent on achieving their academic programme rather than making a deeper analysis of capstone projects.  - The study was constrained by time and this affected authors attempt to make more in-depth analyses about the relationship between capstone projects and the industry.  **Level of** **commercialisation of projects studied.**  - Paper only analysed recent graduates of engineering courses without specifically showing whether the projects they undertaken were commercialised or taken to the software market.  ***The focus was more on graduates and their transition into the SE industry than transfer and commercialisation of artefacts they developed during capstone courses.*** |
| No. | | **Author, Year, Journal, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P12. | | Sinha, et al., (2022). I  International Journal of Advanced Engineering and Management Research;  EBSCOHost;  National University, San Diego, California,, USA | **Problem Statement:**  Structuring capstone projects in resource- constrained institutions is a challenge. Yet the learning environment keeps on evolving. There are now requirements of undertaking and supervising projects online, and the speed at which technology changes calls for adaptive courses at Universities.  **Objectives of study: to** critically evaluate a community development project in a low budget environment.  **Conceptual Frame:** Not included | | Design Science; Type:  Case Study; Method: Qualitative | - The capstone project is 3 month course on the ***Bachelor of Science in Information Technology Management (BSITM)***  - Uses multidisciplinary theories, application and tools  - Implements a real-world prototype  - Projects developed in line with sponsors  - Sponsored by low-budget SMEs in the locality  - Students work in teams, guided by faculty instructor & sponsor  - Students use Agile Development methods  - Students present proof-of-concept prototype to panel of judges  - Students use software like Amazon Web Services (AWS), Linux, SQL DB, Amazon EC2to develop the App  - Team writes project report, user manual at end  - No time for rework due to tight schedule  - Team undertook a literature review to find similar products on the market  - Assessment was based on clearly laid out project learning outcomes  -The authors recommend that for low budget capstone projects to succeed there must be:  - listening to client needs,  - conformance to project learning objectives (PLOs)  - Community sponsored undertakings; Teamwork  - Feasible evaluation of the projects  - Students’ ownership of project & responsibilities  - Thorough literature review before developing project | | **Research gap/ further study:** Only one academic programme in one University was studied. The findings here may not be representative of all capstone projects in the STEM professions  **Software, hardware, and platforms used:** AWS, Linux based virtual server, SQL database, PHP programming, GitHub version control, MySQL as a database backend, Amazon EC2 Web Services as cloud-based server, Amazon Relational Database, Adobe Dreamweaver as a PHP testing platform, and XAMPP.  **Level of commercialisation of projects studied:**  The project studied resulted in the development and implementation of a collaborative software and database tool called Community of God, which is used by churches in the California community to reach out to those in need and help them. **The tool was 100% up- scaled though it was developed with a non-profit motive.** |
| No. | | **Author, Journal Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P13 | | Fernandes, et al., (2017);  Google Scholar/ European Journal of Engineering Education  University of Minho (Portugal) | **Problem Statement**:  **Research Objectives**:  **Conceptual Framework**:  Not included | | **Research Design**  -Cross-sectional  **Research Type:**  **Case study**  **Methods**:  Mixed Methods  - Qualitative methods  - Case Study methodology  - Descriptive and explanatory, Basic Content Analysis  -**Data Collection**: Semi-structured face to face interviews and document analysis  **Population**: 8 groups of students and 4 former students | - Project/Course follows Perkins’ (2010), Making Learning Whole’ approach: Ideation, Team Composition, Course Phase (Business Idea development & Product Devt), Seminars, Weekly meetings, Technology dev’t method selection (usually scrum), Contact with market/ experts, & Assessment).  **These steps are detailed below:**  - The capstone project in the case study takes 18 weeks or 4 months  - Students develop a software product and analyse the business potential of the software product.  - Students are organised in teams (8-9 students)  - Students freely join the teams they want to work with  - The project evaluated during execution, based on the  deliverables and evidences of teamwork  - Students acquire technical competences of requirements engineering, systems design, and testing  -Students also acquire soft skills of leadership, team organisation, communication and presentation, business modelling, and entrepreneurship  - Lean Start-up- which is a scrum dev’t method is used  - Teachers/ lecturers supervise projects on a weekly basis  - Students make weekly visits experts in software industry to get advice in: developing business plans for software products, project management, and agile software development.  - Students make a final pitching session with a Start-Up Incubation Centre  **Findings Continued:**  - 2 best projects are incubated annually  - Assessment is continuous & based requirements project documentation, & functioning of software;- Teams are sometimes multidisciplinary  - Projects are usually in the areas of tourism, agriculture, commerce, education, insurance, sports, healthcare, services, etc.  - Involving external experts & partners improves quality of software  of products presented, and the students’ dedication to the projects  - Student suggested projects were preferred - Fewer students in teams produced higher quality projects  - A balanced project team is a critical for success of the projects: different profiles, part-time & fulltime students, et.c..  – Team leadership determined project success  - Students said course requires too much time    - Having to impress many stakeholders made the course difficulty sometimes  -The study also got data from former students who indicated that the course was a good initiation into the field of software development & encourages and entrepreneurial attitude. | | - The case study was based on only University and only a few groups of students. The observations made are not entirely generalisable  - The participants were chosen purposively and not scientifically. There is need to conduct a study using scientific sampling to get a representative perspective from all students.  **Level of Commercialisation**: |
| No. | | **Author, Year, Country** | **Research problem, Objectives; Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research Gaps & Future Work, level of commercialisation of projects studied** |
| Not included | | Silva, et al., (2019);  Taylor & Francis  European Journal of Engineering Education  ISCTE-IUL – Instituto Universitário de Lisboa (Business School). Portugal | **Problem Statement**: While capstone courses are taught on many disciplines, there have not been many attempts to create a multi-disciplinary course in most universities.  **Research Objectives**  To describes and present examples of design outcomes from three very distinct cohorts on a Project Design and Development (PDD) course  **Conceptual Framework**:  Not included | | **Research Design:**  Design Science  **Methodology:** Mixed Methods  - Inductive exploratory case study (Narrative) –  -Unstructured Observations,  -Document analysis; &  - Ex-post literature review  -Prototyping, modelling, & Experimentation | - The 3 cases were in the areas of case, engineering, design & business  - Interdisciplinary teams are more creative  - Cost effective designs result from collaboration btn business and engineering teams  - Teamwork leads to better, richer and more complete products  - Hands-on training improves concurrent engineering in New product Development (NPD)  -Interdisciplinary teams come up with heterogeneous products in spite of using similar methods  - Problem Based Learning (PrBL) enhances flexibility, creativity, active learning, and student-centred problem solving, project mgt, presentation and communication.  - Experiential learning and experimentation in NPD enables analytical thinking, reflective observation and knowledge generation.  - Prototyping improves learning through problem analysis  - Classroom designs that balance theory and practice motivate student involvement and learning.  - The study proposes a “*Novel education framework in New Product Development*” emphasising collaborative designs, PrBL, interdisciplinary (as opposed to multidisciplinary) teams, and experimentation in development, assessment of capstone products, and curriculum collaboration with the industry.  **Academic Programmes Covered:**  Master in Mechanical Engineering (IMME)  MSc in Product Design and Development (MPDD | | **Research Gap and future research:**  - The use of inductive reasoning which suggests what the respondents consider the ‘truth’, in spite of the fact that this may not be assuredly true in practice.  **Commercialisation and entrepreneurial value created**:  The author indicates that “to the best of their knowledge, there had not been any industrial application of the ideas generated in the course.”  0% of prototypes created in the projects were commercialised and taken onto the market. |
| No. | | **Author, Journal, Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P14. | | Ward (2013);  Taylor and Francis  European Journal of Engineering Education,  University of Malaya, Kuala Lumpur, Malaysia | **Research Problem**:  There is no evidence of common models used by Universities around the world to deliver and implement capstone courses.  **Research Objectives**:  To study the capstone programmes implemented at the world’s top-ranked engineering universities to discover common elements which characterise them.  **Conceptual Framework**: Not Included | | **Research Design**:  Cross-sectional  **Research type:**  A multi-case study Analysis  **Methodology :**  - Qualitative Design  - Comparative analyses of courses 12 top ranked universities  - Ranking of Top universities in the world  - Document analysis (published papers from the universities)  - | The Universities studied had the following common characteristics of capstone projects:  - Use of problem-based learning in courses  - Group project emphasis (85% of universities studied)  - Design-build-test models  - Active stakeholder involvement: students, faculty, industry, academic administration, & prospective employers  - Sequential assignments.  - Projects took between 1 to 3 semesters. Most projects take 2 semesters.  - Projects done in either 3rd or 4th year or both  - Majority of projects were core courses on the engineering programmes  - Projects resulted in the building or either hardware, software, digital models, or system combinations  - One University (MIT) specifically developed the Conceive- Design-Implement-Operate (CDIO).- slightly different from Design-Build-Test model  - CDIO is now one of the most applied DS model in capstone projects around the world.  - Groups produce a report or thesis at the end of the project  **Academic Programmes**: Bsc. Aeronautics and Astronautics Engineering programme; MSc. Mechanical Engineering; Bsc. Information Technology; Msc. IT | | **Gaps and future research:**  - Only 12 Universities in the Canada, Japan, Singapore, UK, and US were considered in this study. No single University from the Global South was considered in this study. The study is not representative of the population and location of universities around the World.  - The findings may not be generalisable to all settings, since universities in developing and less developed countries were not studied.  **Level of commercialisation of project outcomes**:  Industry involvement in capstone courses is mostly lacking in the programmes that were studied.  - The study makes no mention of efforts to create entrepreneurial value in capstone projects taught at top-ranked universities in the World. |
| No. | | **Author, Journal Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| Not part of final analysis | | Tenhunen et. al., (2023);  Information and Software Technology  The University of Helsinki,  Finland | **Problem Statement**  **Research Objectives**:  **Conceptual framework**:  The researches applied the Systematic Literature Review method  by Kitchenham and Charters (2007) | | -Systematic literature review for 2007–2022,  - 127 articles describing real-world capstone courses;  -Analysis based on presented course characteristics and reported course outcomes. | - Capstone courses generally last one semester  - Most respondents believed that more than one semester was costly to schools, labour-intensive for staff and required a lot of resources  - Students are divided into groups of 4–5  - Ideas were mostly generated by the clients, then course advisers and a few by the students  - Students work on a project for a client- mostly internal  - In some few courses, the clients are external to the course staff  - There were challenges of engaging external clients: commitment to the project, failure to turn up at bi-weekly meetings, desire by university to retain intellectual property, diverging client aims that makes the project more complicated for students, and the time & effort required to coordinate multiple clients for multiple students groups.  - **Development phases used**: Software life-cycle models (requirements gathering or elicitation, planning and designing, developing, testing and  maintaining the product)  - The main deliverable from the project is a proof-of-concept level software product (for 97% of projects)  - A combination of progress assessment and terminal evaluation of projects  - There were students’ self- and peer-reviews, plus clients’ opinions that were incorporated in grading in a minority of courses. | | - While the review involved an analysis of the nature of capstone projects, some of the authors were in fact part of the teams that the researchers studied- as course advisers on capstone projects. This presented some level of bias in the findings.  - The authors indicated that quite a large number of the reports they used lacked an honest evaluation of the author bias, this therefore means that the finding of this study cannot be considered entirely an objective third-party assessment of literature relating to capstone projects in software engineering.  - While capstone projects are undertaken to prepare student for life after University, this study did not capture what participants students faced later on in their careers or whether the project deliverables were taken up especially by external clients. |
| No. | | **Author, Journal Yr, Country** | **Problem studied; objective(s); Theoretical/ Conceptual** | | **Methodology** | **Findings** | | **Findings, Research gaps, further study, level of commercialisation of projects studied.** |
| P15 | | Raibulet,& Fontana (2018).  Elsevier/Science Direct  Journal of Systems and Software,  University of Milano-Bicocca, Italy | **Problem Statement:**  There is usually a gap between the expectations of the industry and the preparation of undergraduate students concerning their first software engineering job.  **Objectives**: To describe a case study performed in order to collect student feedback on their perception of using mechanisms and tools which support their collaboration and communication in SE projects.  **Conceptual Frame**: The influence of collaboration, communication and knowledge sharing in building a SE career among students. | | **Research Design:**  Cross Sectional  **Research Type:**  Case Study  **Methodology:**  Quantitative methods  **Population**:  **Data Collection**:  Questionnaires | **Curriculum:**  Covered project mgt, communication, team building, programming with GitHub  **Capstone Project:**  - Students learnt how to use the tools during the lab sessions  - Students used the tools for the lab exercises and for the final exam project  - Tutors helped students identify the main difficulties in using these tools.  - Students were teamed in groups of 3-5  - They came up with Web Apps using GitHub  - Students used agile tools to manage teams and implement project.  - MS Project was used to plan time, resources, and budget, and to communicate among teams.  - SonarQube was used in monitoring quality of projects.  **-**Students had no prior knowledge of the Apps before the projects  -They attained several skills after the course  **Applications/ Platforms Used:**  **-** Agile Methods; **-** Project Management Approaches  **Software**  - GIT Hub for task distribution and communication  - SonarQube for teaching software quality assessment  - Microsoft Project for teaching collaborative software development and teamwork | | **Findings:**  The overall feedback about using GitHub, SonarQube and MS Project in their capstone projects was positive;  -Students were responsive to all the applications of the collaborative and teamwork mechanisms and to the use of the new tools  - More than 75% of the students consider that GitHub helped them in the management of tasks distribution for their projects.  **Research Gap and Future research:**  The questionnaire used may have been a little biased given the fact that it was developed basing on only 3 platforms of agile development. It wasn’t comprehensive enough.  **Commercialisation of projects:** projects not commercialised. |
| No. | | **Author, Journal Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P16. | | Włodarski, et al. (2022).  Science Direct/ Information and Software Technology,  Lodz University of Technology, Łódź, Poland  LaBRI, UMR CNRS University of Bordeaux –; l’Institut Universitaire de France, France | **Problem Statement:**  While a large variety of software development life-cycle models exists, like SDLC and Agile methods, there is little guidance pertaining which one is most appropriate in the context of working with students  **Research Objectives:** The paper assesses the impact of iterative, sequential and ‘‘hands-off’’ development approaches on the success of student computing projects.  **Conceptual Framework:** Adopted  Melone’s theoretical assessment of the user-satisfaction construct in  information systems research.  **Independent variable**: Development approaches including iterative design,  agile development, and no formal approach; **Dependent variables**: Project success -  product quality (internal and external quality), team productivity and teamwork quality | | - **Design**: Cross-sectional;  **Type:**  Quasi-Experimental  **Method**  Quantitative  - Population/ Sample: **purposively sampled**; Controlled experiment at  3 engineering schools and 3 groups chosen among; - > 100 Bsc. & 46 at MSc.  **Students;**  **Data collection:** Online Questionnaire- Google Form;  The Group without a specified development method was a control group. | - The control group performed best in terms of the quality of the source code  - The teams that did not follow any development process produced HTML code of generally higher quality.  -Undergraduates found scrum approaches more challenging than postgrads  - The sequential approach with its upfront design practice had a positive impact on the external quality of the software produced. As compared to Agile/ Scrum  - Iterative designs lead to better designs and artefacts  - Iterative design teams showed the highest levels of team cohesion throughout the semester  -Students preferred the iterative approach to scrum, because of its feedback loops, and follow up  - Masters students who are already working preferred the agile way of working and perceived it as advantageous in a commercial setting.  -The control group appreciated that giving students freedom to choose methodologies increases their productivity  - Respondents emphasized the need for system testing which had not been included in the development stages.  - Project quality might have been affected by the workload from other courses covered in the semester.  **Software/platforms Used by students**: HTML codes, PHP, CSS, Online code validation tools like W3C and BetterCodeHub  **Development Approaches:** Waterfall model being compared with Agile/ Iterative design using Scrum, and one group not following either approaches.  **Academic programmes sampled:**  Bsc. Telecommunications  Msc. Telecommunications program. | | - The study may not be adequately generalizable since all projects studied were limited to Web programming. Findings cannot be generalised to other domains of Information Technology  - The small sample size, purposively chosen limits the generalizability of the findings.  **Level of Commercialisation of Projects**:  The final products of the experiment by the three teams showed lower functional correctness with very many bugs. They could not be implemented. Therefore no commercialisation of these software could happen. ***0% commercialisation of projects.*** |
| No. | | **Author, Journal, Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P17 | | Guanes, et al., (2022); Taylor & Francis;  European Journal of Engineering Education;  Department of Engineering Education,  The Ohio State University, Columbus, OH, USA | **Problem Statement**:  Engineering design decisions have strong implications on a wide variety of stakeholders. However, engineering students do not know how to use empathic approaches when design making decision  **Objectives:**  To explore beliefs of engineering capstone students when they espouse the value of empathic approaches in systems design and development.  **Framework used**:  **The empathic design approaches** **Model** among engineering students. Specific constructs studied include **espouse beliefs** and **enacted beliefs (behaviour)** about empathy in engineering. | | **Research Design:**  Cross-sectional Design  **Type:**  Experience report  **Methodology**: Qualitative  Qualitative data through interviews  **Purposive sample of 10 undergraduate engineering students**  Audio recording, transcription, data cleaning, coding and theme development | - Students/ respondents indicated that using empathic approaches in engineering help avoid probable harmful impacts of engineering products on people  - Participants indicated that empathic approaches help align engineering design to user needs  - Empathic approaches ensure user safety  - Students’ reported behaviour during capstone projects underlined a deep consideration of stakeholders, users and affected persons  - Students reported a behaviour of considering effect of their capstone projects on the environment, Carbone emissions, or whether their product was biodegradable  - Empathic approaches in capstone engineering designs also influence students to think about how product design approaches they choose affect them.  - Design approaches that are preferred by the course advisor were prioritised  - In spite of the fact that empathetic approaches were considered valuable by students in their capstone projects, ultimately they used approaches that facilitated their academic goals, like finishing the project on time.  **Academic programmes studied:**  BSc. Information Science, minor in Engineering (Sci)  BSc. Mechanical Engineering;  BSc. Chemical Engineering;  BSc. Biomedical Engineering;  BSc. Biological Engineering | | **Gaps and future research:**  -The results are not entirely generalisable as they were gathered from only 10 participants. The sample was too small and purposively selected.  - The sample was not scientific and therefore the findings are not very representative of beliefs and behaviours of majority of capstone projects in the USA.  - The exact effect of beliefs on behaviour was not ascertained because the researcher used qualitative measures and data collection methods which are not very reliable and purely scientific.  - Data was only collected from students and not other participants like instructors or the context of projects. The findings are thus limited to only student perspectives.  - The study mostly sampled female participants and this creates a demographic bias on the kind of data collected and the espoused beliefs identified.  - The study only studied explicit or overt, espoused beliefs, and not deeply held, intrinsic beliefs about empathic designs in capstone. Yet implicit beliefs may be more impactful on behaviour.  **Commercialisation/ project up-scaling/ entrepreneurial value created:**  The study makes no mention of whether the 10 projects studied were ever taken to the market. The focus was only on completion of the projects and successful graduation.  ***0% of projects were commercialised and taken onto the market.*** |
| No. | | **Author, Journal, Database Year, Country** | **Problem studied; objective(s); Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Research gaps, further study, level of commercialisation of projects studied.** |
| P18 | | Avila, Petegemb & Libotton (2021);  Taylor and Francis, European Journal of Engineering Education  University of Holguin, Cuba. | **Problem Statement:**  Industry reports indicate that less than 30% of software projects are totally successful, and that  many software projects fail due to teamwork problems than technical issues.  **Research Objectives:** To examine the role of the ASEST framework in improving team cohesion, team performance and team learning among SE students.  **Framework:**  Assessing the ASEST (Agile Software Engineers Stick Together) framework to  Capstone Projects with the aim of improving team rules, team learning, team cohesion, and team performance using a Group Environment Questionnaire (GEQ) | | **Design**:  Cross-sectional research design;  **Type**: Case study  **Methods**:  Mixed Methods: Quantitative (using a GEQ); Qualitative Interviews;  Experimentation (Intervention and Control Group), and  three-stage systematic literature review (SLR);  Quantitative methodology; ;  SPSS for analysis: Descriptive (Mean, Sum,; Correlation);  Shaprio-Wilk and t-tests. | - The paper explores the application of the called Agile Software Engineers Stick Together (ASEST) framework in ensuring team cohesion, performance and team learning;  - Study done on graduate software engineering student teams  - 5 major trends in Software Engineering were identified from literature: collaborative learning, games and gamification, agile methods, global and virtual teams, plus real projects resolution and links with industry.  - A 3 phase ASEST framework for team performance was developed from 4 of the 5 trends in SE.  - The framework had 3 phases: Preparation, Implementation and Adjustment; all decomposed into 8 stages.  - Study found that students’ perceptions of team cohesion, team performance and team learning in the intervention group increased significantly compared with the perceptions of the students in the control group.  - Students’ survey confirmed positive attitudes towards the proposed framework proposal.  **Approaches**: Gamification, agile methods, collaborative learning, PrBL. | | **Limitations**  The study is based on a very small sample that was not scientifically drawn. Students were allowed to determine which group they belonged to- intervention or control group. This might have led to instrumentation bias and unconscious bias that may have compromised the results of the study.  **Commercialisation**: Not included. |
| No. | | **Author, Journal, Year, Country, Database** | **Problem investigated; Objective(s);**  **Theoretical/ Conceptual Frame** | | **Methodology** | **Findings** | | **Other findings: Challenges in SDA &**  **Limitations/ Areas of further study/ Level of commercialisation** |
| P19 | | Tenhunen, et al., (2023), IEEE Xplore  IEEE Xplore; 2023 IEEE/ACM 45th International Conference on Software Engineering: Software Engineering  Education and Training (ICSE-SEET);  The University of Helsinki,  Finland. | **Problem Statement**: The gaps between what students learn in the University and what they are expected to in the industry after graduation.  **Objective:** To examine the development of a university-led  internal software start-up called Software Development Academy  (SDA).  **Conceptual Framework:**  Not included. No theory used. | | **Design Science**  **Design Science**  **Study type:**  **Comparative Case Study**  **Methods**;  **analysis** of Conventional Capstone methods with SDA method;  **Qualitative Methods:** Semi-structured interviews with SDA 15 alumni  **Thematic analysis** of interview results | **Findings from comparative analysis**  - The Software Development Academy (SDA) is an internal, non-profit software start-up in the University  - SDA develops software used by UH  - Students work at SDA for one year  - **Student team are 4-10 of Bsc. Computer Science**  - Students & staff a salary for the work they do  - All years- 1st to 4th year can be employed in SDA  - Competence overrides year of study in enrolment  - External members from other university units act as clients (as opposed to lack of external members in traditional capstones)  - Projects take longer than traditional capstones  - Students work part time as they complete their courses  - Both MSc. and BSc. students are recruited  - SDA is managed by a lecturer who earns a salary  - The Unit has produced academic systems, like a course feedback software used by over 1000 members of UH  - All software developed in SDA is Open source  - Work is flexible with members free to choose what they work on, and flexible working hours  - Use of modern technologies like React, Node.js, virtualised machines for better performance  - If projects are specifically for final year students (capstones), & external clients like local business  **Interviews Feedback:**  -Working with SDA gives a sense of meaning  - Actual users of our software are happy  - Working with SDA helps in entering work life  -Too much freedom in SDA sometimes delays products  - Earning money in SDA motivates us  - Strong community and networking opportunities  - Working with experts offers project mgt skills  - The Unit provides enough time for deep learning  - SDA offers projects that match industry practices  **Software programs, development platforms, and technologies used:** Common stack web development environments, including “React”- used in the frontend and Node.js in the backend.  **Academic Programme Analysed: Bsc. Computer Science** | | - The members mostly lacked industry experience  - Synchronising other work with SDA work become a challenge to most participants  -Working freely on independent projects deprives members of the teamwork skills  - Being managed by one faculty staff meant a lot of workload  **Gaps/ Limitations and future work**  - The study did not study the effect of SDA work on people’s work in their primary units in the university  - The criteria for choosing participants in this study in the study was not clearly shown. The findings are therefore not entirely reliable.  **Entrepreneurial value/ commercialisation of project:**  - SDA developed web applications uniquely customised to the University of Helsinki. The most important being the course feedback system that was acquired internally by the University.  -It was observed and noted that most capstone projects undertaken by SDA are never taken to the external market. |
| No. | | **Author, Journal, Year, Country** | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | **Methodology** | | **Findings** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P20 | | Weissbach, et al., (2017).  American Journal of Engineering Education  EBSCOHost  CC-BY 13 The Clute Institute, United States | **Problem Statement:**  Most research effort in capstone projects concentrated on student learning and the overall design process. There is little research on the perspective of industrial sponsors for such projects.  **Research objective**: to present a perspective from an industrial sponsor who has sponsored several large-scale capstone design projects in Universities.  **Conceptual Framework/ Theoretical frame:**  Not indicated | **Research Design:** Design Science  **Type:**  Experience report  **Method:**  Mixed Methods | | - An external sponsor funds projects in electrical and computer engineering  - Projects also include industrial automation solutions  - Projects are large with many participants  - Projects are designed to provide benefits to both the sponsor and the participants  - The sponsor provided over 100,000USD for funding of projects  - Project only employs already experienced students to reduce the cost of training  - Trainees are provided professional development by the PDA/ sponsor  - Sponsor provides technical support for out of scope requirements  - Members acquire professional and project management competences  - Multiple staff members to optimise competences  **- Academic Programmes analysed:** Master of Science in Mechanical Engineering Technology (MET) students and Bsc. Electrical and Computer Engineering Technology (ECET) | **Gaps/ further study**:- The study does not show how the approach used by Process and Data Automation unit fits into the educational framework of Engineering Collections.  **Commercialisation/ Entrepreneurial value**:  -The project received provided over 100,000USD of funding from sponsor  -The Capstone project in conjunction with PDA has developed a Knowledge Park of 24,000 square feet of open, quasi-manufacturing space, concrete floors with drains, with ample electrical power, overhead crane, recessed truck dock, and other utilities  -The park is located adjacent the University campus. The park allows the university extend internship and capstone projects beyond the classroom expand both our intern and capstone projects.  The facility has assembled more systems that are larger and more complex systems, and permanent equipment with oversight labs for software-specific projects. These projects are used by the College and sold on the market. | |
| No. | | **Author, Year, Journal Country** | **Problem investigated, objectives, Theoretical/ Conceptual Frame** | **Methodology** | | **Findings** | **Gaps/ Limitations/ Areas of further study; Level of commercialisation** | |
| P21 | | Yeaton, (2021)  Google Scholar/ Student Thesis  Portland State University, United States | **Problem Statement**:  **Research Objectives**:  **Conceptual Framework**: | **Research Design**:  Design Science  **Type**: Case Study  **Methods**:  Case Study  Narrative methods Agile Methodology, specifically SCRUM | | - Use of SCRUM sprint methods in developing systems  - Students were divided into teams guided by a Peer advisor and a professor  - The projects took 2 academic terms  - Project was affected by COVID 19  - Development used a trello task board  - Incremental task development reflected on task board  -Slightly edited the original SCRUM Process Model (Project start, Sprint Planning, Sprint, Sprint Review, Sprint Retrospective, Project Completion) to accommodate other courses students are doing  - Weekly meetings with sponsors  - Following original scrum had led to slow project progression. So weekly meetings had to be turned into daily short stand up meetings  - The frequency of meetings is closely related to level of productivity members  - Some of the meetings were virtual due to Covid 19, so synchronising the results with those of physical meetings. | -The scope of the study was quite limited to only one project studied in one University  - The study did not do a thorough comparison of the use of SRCUM and other development methods  - The limited time available to complete the study, due to Covid 19 restrictions affected the comprehensiveness of the study and its findings. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P22. | | Panicker, et al., (2020);  IEEE Frontiers in Education Conference (FIE),**.** IEEE  Department of Electrical and Computer Engineering  National University of Singapore  Singapore | **Problem Statement:**  Visually impaired students in the University have challenges in indoor navigation  is because GPS signals cannot go through wall barriers. There was need to develop a state of the art system for indoor navigation for these visually challenged students.  **Objective:**  Development of an Indoor Navigation System for visually impaired.  **Conceptual Framework:**  Not included. | **Research Design:**  Design Science  **Type:**  Action Research  **Methodology:** Mixed Methods: Quantitative and qualitative, plus experimentation of the developed system.  System Analysis and Design Method  **Data Collection**  Survey | | - The capstone project was a semester-long, 6 Modular  Credits of 2.5 hours per week programme,  - Project taken by third year students of computer engineering  - The course is co-taught by 2-3 lecturers from both computer science and electrical & Computer Engineering  - Diagramming tools are used for system modelling  - Mapping software was used to calculate distance navigated  - Students interviewed visually impaired people to better understand the problems they face  - Students are blindfolded and made to evaluate and validate the system after development  - Continuous evaluation and learning from each other  - The social-responsibility aspect of the project contributed to higher motivation among team members  **Quantitative Results:**  - 33% found the project time consuming yet interesting  - 18% found the project uncertain and challenging  - A few, around 10-15% found the project new and difficult  **Qualitative/ Interview Results**  -The student found the new method more fun, engaging, awesome, and enabled them to think beyond ordinary limitations  -Some of the specifications provided for the project were not very clear, and this affected the design.  **Academic Programme Studied:** BSc. n Electrical and Computer Engineering Technology (ECET).  **Software, hardware, platforms used**: wiring schematics, Human Machine Interface (HMI) designs, and panel wiring. Process and Data Automation, Logix Batch and Sequence Manager (LBSM), Physical construction and/or framing, Physical plumbing, & Electrical control panel wiring. | **Gaps and areas of further study:**  - The project is limited to only form of disability (visual impairment), and the researchers did not explore similar problems involving training students to solve human problems.  - There seemed to be no active visually impaired participant among the project’s core team. That limits the applicability and social feasibility of the developed solution.  **Entrepreneurial Value/ Commercialisation of Project**  **- *The capstone project*** that uses a so-called state-of-the-art problem, indoor navigation, ***was only introduced but not implemented or commercialised***. The students had issues with time management, difficulty in getting the Raspberry Pi WiFi connected to the university’s WPAEnterprise WiFi. ***These technical and curriculum related challenges that needed to first be rectified if the project’s prototype was to be implemented and possibly commercialised.*** | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** |  | |
| P23. | | Mandale, Patil, & Adamuthe, (2021);  Journal of Engineering Education Transformations  Computer Science & Information Technology Department, RIT, Rajaramnagar, India;  EBSCOHost | **Problem Statement:**  **Research Objective**:  **Framework**:  Industry Oriented Software Engineering  Practices (IOSEP) methodology in improving capstone courses at Universities | **Research Design:**  Design Science  **Methodology**:  Experience Report  **Agile Methods:** GitHub, Real-Time Deployment,  LaTex for Documentation; **Data Collection:** Previous years report analysis (doc reviews),  **Questionnaire to collect feedback from industry experts**;  **Problem Analysis** (fishbone to determine limitations to existing development methods;  **Why and Why analysis** identify how to prevent the issue from happening again.  **K-Means statistical method** for students performance Analysis | | **a) Analysis of Previous projects:**  - Students currently use waterfall model, which does not easily incorporate changes  - Students work in teams though they divide the project into modules executed individually- this makes integration difficult, there is convention ambiguity,  package conflict;  - Students use manual testing methods that are not very effective;  - Use Microsoft Word to document project;  - Focus is mostly on technical aspects of projects and not soft skills;  - Only faculty advisors are used. No industry experts;  **b) Alumni and industry expert feedback analysis**  - Industry experts say that students are not using methods used in their industry  - 81% say that students need to change to agile  - Students use manual coding methods, yet industry use GiTHub  **c) Findings from Ishikawa Diagram**  - Use of rigid waterfall model  -Less involvement of clients in project  - Little client satisfaction  - Manual code integration and testing  - Less awareness about agile methods  - Plagiarism in documentation  - Limited time for deployment  - Student focus more on prototype than real system deployment  - No permission from sponsoring agency to allow implementation  - Poor usage of OOD  - Lack of problem-specific knowledge  **d) Findings from WHY-WHY analysis**  **-**The IOSEP methodology was applied to  3rd year and final year projects.  **IOSEP which included the following software and platforms**  **-**Assignment of an industry expert mentor; Agile Project development; Code Integration using GiTHub; Testing using automated tools like selenium; Real-time project development on Google-Pay and an active domain for web apps; Report Writing using LaTex  - **For mobile applications** using Android, encouraged students for Junit framework, Monkey, device testing,    - There were 16 mini projects, 12 final year B. Tech projects. A total of 120 students were involved/  - The study finds that agile methods may lead to improved project quality better staff and students’ performance.  - IOSEP led to better project development-time mgt, improved coding, better use of technology, & improved technical report writing.  - Industry-sponsored project ignited more students’ participation.  - **Academic Programme studied by students**: Bachelor of Technology Degree. | - The sample of 120 students and 26 industry experts was purposively selected, which was not entirely scientific and therefore the results cannot be generalisable;  - The students projects studied for the evaluation of the proposed IOSEP had a very short duration (one semester). That time was too short make reliable conclusions about the veracity of the proposed method.  **Commercialisation/ Entrepreneurial Value:**  - 8 out of 12 projects (67%) were sponsored and commercialised  -All 12 projects have been deployed and are downloadable on Google Play Store/i-Store (for mobile apps), and hosted as websites. Students bought domain names for their projects.  -All 12 projects participated in national competitions and 3 of them won prizes  -3 research papers from at least 3 of the projects have been published in journals approved by the Universities  -The capstone programme course a considerably high entrepreneurial and commercial value. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P24. | | Shiller, Z. (2013). IEEE Transactions on Education,  Ariel University  Center, Ariel, Israel,  IEEE | **Problem Statement:** Traditional capstone projects are introduced late in the courses and are not integrative enough to prepare students for multidisciplinary career.  **Objectives:**  a) To create a multidisciplinary, integrative capstone course that meets specific needs of the robotic industry; b) teach students teamwork &project mgt; c) encourage creativity and entrepreneurship; d) Instil a sense of contribution to society thru projects.  **Conceptual Frame:**  Not included. | **Research Design:** Design Science**;**  **Methods:** NarrativeCase Study  **Methods:**  **Mixed Methods**  Laboratory Experimentation, participatory brainstorming;  problem identification through observation and interviews;  **Spiral Approach divided in 4 tracks:** Computing,  Mechanics, Physics, & Mechatronics**;**  **Development approach:** physical integration of  a mechanical system, electronic circuits, control software, and a microprocessor | | - **Curriculum design**: The capstone course integrates Mechanical Eng as a major, plus 3 minors- a) CS, b) electronics, c) Engineering & Mechatronics.  - Students are taught introductory courses in the initial years, like digital and analog electronics, Programming with C++, microprocessor assembly, modelling and analysis of systems, design and devt of electronic circuits, and robotics engineering as a way of preparing them for the final capstone.  **-Software and Requirements Used**: Industrial Robotics, C++ programming, Open source Arduino boards, data analysis with Excel, analogue controllers, simulated microcontrollers, actuators, sensors, digital microcontrollers.  **Capstone Project structure:**  - Students divided into groups of 2 to 3.  **Problem Identification:**  - students visit hospitals, nursing homes, and rehabilitation centers, observe and interview potential users to better understand their true needs.  - Students identify a real problem that needs a computing solution and is commercially viable.  -Cooperation with the industry is not encouraged in problem identification since the industry may dictate which problem to focus on.  **System Design, Development:**  -Students make engineering designs, manufacture, assemble, test, and present a robotic project to the entire class.  - Classes of about 30 to 40 students are taught how to design and develop the project  -Brainstorming and free flow of ideas, plus peer evaluation of projects  -Students learn from each other and improve their projects, their creativity and critical thinking  - Student team formation and social groupings in these projects enable teamwork, sharing of expertise and ideas across the class.  -Emphasis on supporting the most vulnerable in society (CSR)  **- Final Course deliverable:** - Design and manufacture of 80 original working mechatronic robotic systems.  **Degree Studied by students:** B.Sc. in Mechanical Engineering and Mechatronics. | **Research Gaps:**  -The study only concentrates on one capstone project in a University in Tel Aviv, Israel. It may not be representative of all mechatronic capstone courses in the region.  - It was difficult to ascertain the students individual levels of learning since there was a lot of cooperation in the groups and the projects were undertaken in teams  -The study indicates that the project does not encourage easily collaboration with the industry. This is perhaps why most projects were not commercialised.  **Further research:**  - There is need to undertake similar studies in other universities and make a comparative analysis of such courses in Israel.  -There is need to explore the viability of greater industry collaboration to produce more commercially viable artefacts.  **Commercialisation/Entrepreneurial Value**:  - Of the 80 projects studied, one was upscale, attracting partners and funders from the industry, and implemented as “TaxiBot concept” of an automated tow truck that pulls aircraft to a runway.  - All other 79 projects remained as working projects.  - 99% of the projects were not up-scaled in spite of being very innovative. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| Not Included | | Mancha & Yoder, (2014);  The Council on Undergraduate Research Quarterly  Trinity University, Texas, USA | **Problem Statement**:  The level of achievement among students in the U.S. lags behind that of the top international performers STEM subjects. This has created concerns about the future U.S. workforce, national innovativeness, and economic development  **Objectives**: identify the CSFs that are critical for successful undergraduate research initiatives; study disparities in perceptions between faculty and students.  **Conceptual Framework**:  Application of the Critical Success Factors (CSF Method) for Undergrad Capstone projects. | **Research Design**-Cross-Sectional  **Type:**  **Methodology**: qualitative survey design;  -Case study method  - Purposive sampling of students  & staff engaged in research  - Borda count method was used to rank the CSFs | | **Most students indicated that they undertake projects to**:   * Learn, practice & conduct research skills; * Get experience/ explore a field of study * Prepare for graduate school * Achieve professional growth/ Improve their resume * Get connections in the field.   **Most staff indicated that they supervise students’ projects to**:   * Prepare, direct, & motivated students for grad careers * Meet curricular requirements * Explore new areas of study   Make publications in their field   * Interact with students   **Top 10 CSFs for capstone projects identified included**:   1. Student motivation & commitment to projects 2. Resources and Institutional support 3. Students’ skills, knowledge, and expertise 4. Communication, collaboration & teamwork 5. Scope and feasibility of project 6. Creativity, initiative & curiosity of learners 7. Interpersonal factors 8. Mentorship relationship between students and course advisors 9. Clear deadlines, responsibilities & outcomes 10. Time available for the projects.   **Academic Programmes studied:** Bachelors of Science: Biology & Chemistry (natural sciences); Bsc. Computer science; Bsc. Engineering, BA. Social Sciences, humanities, and BA. Business. | The study only concentrated on one university, Trinity University, Texas, and the findings may not be representative of all capstone project courses that exist in different schools or universities  The respondents did not rank and show the most important CSFs for undergrad capstone projects. A further study is needed in this.  **Commercialisation and entrepreneurial value creation:**  The projects studied only concentrated on academic achievement, personal development and publication with no emphasis on commercialisation of solutions developed by students.  ***There was 0% commercialisation, up-scaling and transfer of products to the market.*** | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P25. | | Sabnis, Kulkarni, & Gurav, (2020).  Science Direct/ Procedia Computer Science  Rajarambapu Institute of Technology (RIT), India | **Problem Statement**:  Students do not demonstrate ability to work multidisciplinary domains, are unable to understand customer needs, and develop proof of concept prototypes to address these problems.  **Research Objectives**: to examine and describe efforts of transforming engineering campuses into innovation centers  **Conceptual Framework/ Theoretical Model used:**  Product Based Learning Framework in Engineering | **Research Design:**  Design Science  **Research Approach**:  Case Study/ Narrative method  **Methodologies**:  Mixed Methods:  Narratives,  Laboratory Demonstration  **Population** of 515 Students in - Mechanical, Electrical, Civil, Automobile, Electronics,  Computer Science and IT develop and  incubate engineering products | | - The project is undertaken in Electronics, CS, IT, Engineering (Mech, Elec, Civil, & Auto).  - Students are prepared for their capstone projects from their 1st year up to the 4th year  - Instructors use Activity Based, Problem Based, and Project Based Learning  - The Institute has a specially designed Learning Studio and ‘Thinkering Lab’ to enhance practical learning  - 1st year: Students are taught entrepreneurship & business incubation skills  - 2nd year: Students continue developing their skills  - 3rd year: students are introduced to the unique concept of “Living Labs”, where they develop proof-of-concepts and proto-type products  - 4th year: Students are guided by Industry experts in interdisciplinary and entrepr.. environments.  - Students use IOT to do projects like SMART campus, prototypes in Agric, Health & Automated Electrical Vehicles/ Cars.  - The developed prototypes are installed in customer environments for field trials for validation and quality improvement.  - After ideas are validated, prototypes are improved, & students with entrepreneurial mind-sets are encouraged form start-up in the campus’ Technology Business Incubator (TBI)  - Incubatees mentored by Industry Experts  - For the particular year studied, researchers report that:   * Over 450 first year students completed the engineering exploration course and * 120 mini products were demonstrated in an exhibition. * In IOT, we have 15 students, demonstrated 5 products in IOT * 1 start-up formed by students and faculty in IOT was incubated. * 50 students in AEV worked on 8 projects and demonstrated working proof of concepts of partial autonomous Electric Vehicles. * In total the project produced 7 start-ups in the Technology Business Incubator * The project received government funding (the Maharashtra State Innovation Society Rs5Cr funding) to encourage innovation   - The researchers indicate that expert-mentored product-based learning coupled with entrepreneurial skills enhance learning and helps students face industry life after university.  **Academic Programmes covered/ analysed:**  Bachelor of Science in Computer Science, Information Technology, and Engineering (Mechanical, Electrical, Civil, & Auto). | **Gaps and further research-**  The findings in the paper are based on a single College and Model. No attempts were made to compare pedagogical methods with other Universities to come up with more representative conclusions.  - The study participants and sampling methods used were not scientifically selected. The authors do not show how the sample of participants was drawn and the findings are not entirely generalisable.  **Level of commercialisation/ entrepreneurial value:**   * In total the project produced 7 start-ups were formed out of 120 projects in the Technology Business Incubator      * This is like only 6% of the projects undertaken in the University and Incubator. 94% of the projects were not incubated and remained on shelf. * The project received government funding (the Maharashtra State Innovation Society Rs5Cr funding) to encourage innovation | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| Not included | | Włodarski & Poniszewska-Marańda (2019);  Conference Paper: 45th Euromicro Conference on Software Engineering  and Advanced Applications (SEAA). IEEE Library  Lodz University of Technology  Lodz, Poland | **Problem Statement**:  The wide and growing prevalence of Agile methods in the SE industry has not been reflected in research studies about their use in academic contexts.  **Research Objectives**: The paper presents an experience report discussing the introduction of a  Waterfall model to support student teams developing Artificial  Conversational Entities for an industrial client.  **Conceptual Framework**:  Application of Royce’s SDLC/ Waterfall model in SE. | **Research Design:**  Design Science  **Type:**  **Experience Report**  **Methods:**  **Mixed Methods.**  - Case study methodology.  -Experimentation  Descriptive and Quantitative. | | **- 46 students who had enrolled in a master’**  program in Computer Science participated  - Practical application of analysis, design and implementation methods and tools of a software engineering  -Involvement of different stakeholders perspectives: business analyst, programmer, tester etc.  - Involvement of an external client  - Students developed an information system as a deliverable  - Prototypes were not developed to be used commercially  -Students study 15 weeks in a semester  -The short semester time does not allow use of all Waterfall stages in projects  - Group formation: students divided into project manager, architect, UX designer,  tester (Q&A), developer, integrator.  -Emphasis on teamwork and project mgt**.**  **-The waterfall model is systematic, though it imposes stringent deadlines to students.**  **Development Approaches Used:** software development methods and the waterfall model.   * Preliminary Analysis: Students did requirements analysis, group formation; Analysis and Design, implementation, Testing, Closure * No time for maintenance and review.   **Academic Programme**: MSc. Computer Science. | **Gaps and future work:** the paper concentrates on only the Waterfall model, yet SE processes are nowadays moving towards scrum. It is necessary to undertake a comparative study of teams using scrum and others using the traditional waterfall model.    **Entrepreneurial value/ commercialisation**: The implemented chat-box solutions were not designed to be used commercially. The company’s main aim was to impart practical skills of using Artificial Intelligence for business solutions in the region. | |
| No. | | **Author, Yr, Journal, Country,DB** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P26. | | Wang, (2020); Conference Paper.  TALE2020 – An International Conference on Engineering, Technology & Education;  IEEE; Huazhong University of Science and Technology; Wuhan,, China; | **Problem Statement**:  With the rapid development of the wireless  communication industry, it has become increasingly challenging problem for senior engineering students on telecom programs to catch up with the latest development of technologies.  **Research Objectives**: To present the results of project to design and implement a lab platform to for capstone projects using a 5G experimental platform.  **Conceptual Framework**:  Not included. | **Research Design:** Design Science Methodology  **Type:**  Action research  **Methods:**   * Mixed Methods * Experimentation in Laboratory * Structural diagramming/ systems modelling | | - The capstone course involves prior predation through class work, field visits, measurement, evaluation and discussion of experimental results.  Project funded by Ericsson and China Mobile  - Students developed a 5G smart campus and meeting the requirements of edge computing for mobile office and scientific research within the campus  -Systems came with Large bandwidth and connections, with an improved campus network capacity.  -Project created a flexible network to enable differentiated network resource for various applications of smart campus.  - Students explored, developed, and test the joint power control schemes of the network to eliminate network-coverage blind areas formed by multiple base stations  -Project equipped students with first-hand information and skills relating to the design of advanced network systems.  -Students completion ratio of the two basic tasks  in the capstone project was nearly 100%.  **Development Method**: Agile Development  **Software, platforms Used by Students:**  - 5G network.  - Enhanced Mobile Broadband (Embb)  - 5G Radio Access Network (RAN)  - Cloud Radio Access Network (C-RAN)  - Frequency-Division Duplex (FDD) devices  - 6 antennas  - Edge computing, the campus network could  IP Queue mechanism/ Android kernel for testing.  - upgrade of campus network to support a variety of new traffic, such as high-definition video access.  **Academic Programmes**: Bsc. Telecommunications | **Limitations and further study areas**:  The case focuses on only one capstone project in a single University. It is necessary to extend this research and the technologies used to other Universities and settings and analyse the students and tutors perception in these projects.  **Commercialisation of Project**: The project was supported by external clients, that is, Ericson and China Mobile who ensured that the product/ 5G network is implemented within the University in Wuhan City. There was 100% up-scaling of the project, in spite of the fact that it was not sold on the open Software market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P27. | | Zhang, W. (2019). Conference Paper  IEEE; 2019 International Conference on  Computational Science and Computational Intelligence (CSCI)  College of Computer Sci. and Eng., Northeastern University, China. | **Problem Statement**:  While most universities in Western countries use the CDIO framework in capstone projects, Universities in China are yet to adopt.  **Research Objectives**:  To describe the implementation of the CDIO model as a way of providing students with a realistic learning experience in an enterprise environment.  **Conceptual Framework**:  The Conceive, Design, Implement and Operate (CDIO) Model | **Research Design:** Design Science  **Research Type:**   * Experience report   **Research Method:**   * Quantitative method * Comparative analysis of 4 universities in Western Europe and North America with Chinese Universities.   **Data Collection:**  - Questionnaires given to Faculty and students  - Pre and Post evaluation of students’ projects. | | - Students developed an automated candy vending machine  - Conducted in collaboration with enterprises from the Industry.  -Students must first understand the culture, strategy, structure, technology and management styles of the client enterprise.  -Project funded by external enterprises  - Students set project objectives at start  - The project coordinators detail the roles of supervisors and students on the project  - They make thorough understanding of the industry they are dealing with  - They then develop the project  - Project implementation is done using a combination of hardware and software  - Students write a project report at the end.  - The projects are then evaluated by Faculty.  -Students in Western Universities demonstrated stronger skills in teamwork, economics, verbal communication, leadership, project mgt, mathematics, systems conception  -Students still needed to strengthen system implementation skills.  **Software, hardware and technologies** **used**:  Arch Linux, Windows 10, Flex 2.6.4  GNU Compiler Collection  Lex programming  Use of data flow charts  Hardware: laptops  **Academic Programme studied by students**: Bsc. CS, Bsc. Engineering Mgt, & Bsc. IT. | **Research Gap**/Limitations:  - The study only compared 4 Western Universities with Chinese Universities without including the criteria of selecting which Universities to analyse.  The study did not include a University from the Global South/ less developed countries.  It would be ideal to conduct a similar comparative study in Africa or global South.  **Entrepreneurial Value/ Commercialisation of the Solution**:  The candy vending machines was only produced for academic purposes and never commercialised. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P28. | | Chen, C., Hong, Y., & Chen, P. (2014).  IEEE Transactions on Education  National Central University, Jhong-Li City,  Taiwan | **Problem Statement**:  CSE are usually like ‘blind explorers’ in capstone projects, trying to find the proper direction in the course, but lacking team experience, which impedes learning. Secondly, there is no sufficient empirical knowledge about the effects of Meeting Flow (MF) on Team Work Quality software capstone project training programs  **Research objective**:  - This study investigated the Team Meeting Flow approach as applied in capstone project.  - To examine the soft skills and team-related educational consequences that MF might bring to student.  **Conceptual Framework**:  Applied the Meeting Flow approach to a science Technology, Engineering and Mathematics (STEM) capstone project. | **Research Design:** Cross-sectional  **Research Type:**  **Experiment (Randomised Control Trial)**  **Research Methods:**  - Mixed Methods  - quantitative and qualitative that consolidated feedback on team experiences  - Hypotheses building  -Use of interviews and a self-reporting survey questionnaire  -Quantitative statistics to analyse findings  - Population: 204  - 44 Students teams enrolled on capstone project  **-** 4-5 members per team for effective learning  - | | **a) Project Setting**  - Study found that MF significantly improves a team’s communication and coordination and balances members’ contributions by allowing them to giving mutually support each other.  - However, MF has less impact on student team cohesion.  **- RCT:** 15 groups (test groups) used MF and the remaining 29 did not use (control group).  Participants surveyed after 4 months development period.  - Students in both groups had the same curriculum  **- 4 stage experimental procedure:** initiation, execution, post-test, and interview  **Results from Control Group:**  - Students in control group (not using MF) followed common Waterfall stages, no specific devt models, worked in teams, consulted each other, collaboration was not formalised.  -Students in control group were not taught how to use MF approach but allowed to use ordinary meeting approaches.  **Experiment Group**:  -Students used MF to coordinate their activities  - Projects based on cycle development model  -Scrum approaches were also incorporated  - Student teams in experimental group concentrated on 2 or 1 functional module during the cycle development loop  -Cycle development loop was 1 or 2 weeks  - Projects were developed by implementing modules, piece by piece (sequentially)  - WBS items/ PM software was used for planning  - Use of collaborative work items like requirements elicitation, task assignment, brainstorming, programming testing, and public reporting on project progress  **b) Results**  - MF significantly improved the frequency, timeliness, formalization, and openness of information exchange within the teams in the experimental/ test group  - More spontaneous communications were reported to be generated if students prepared well and followed up on their meetings  - MF helped formalize information exchange  - Higher levels of coordination and mutual support within the MF teams compared to the control group  - “Free-riders” in capstone teams in the control group present a common problem to capstone projects. They do not actually contribute to the team effort, but nevertheless try to pass the course  - There was no problem of free riders in the MF teams.  - Higher levels of team cohesion in the test/ experimental group  - Lower scores on emotional connection among members in the experimental group.  **Academic Course:** Bsc. Computing Engineering Undergraduate Program**.** | -The authors state that the experiment was not designed to be repeatable in any situation. The findings are therefore not generalisable.  - The hypotheses were tested using a field experiment in a capstone course, rather than in a controlled laboratory or simulated environment. They are therefore somehow deficient on internal validity.  - The study only concentrated on capstone projects in software engineering. Future research may be needed in other STEM subjects.  - Future research may be needed to ascertain the influence of other factors that have a potential effect on team processes other than teamwork quality.  **Level of Commercialisation**:  Like many studies on capstone projects, this study concentrated on the implementation process and the capstone project setting rather than the outcome of the projects undertaken by the students. The authors do not indicate whether solutions developed were indeed up-scaled and commercialised. | |
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| P29. | | Riek, (2013).  IEEE Transactions on Education,  Department of Computer Science and Engineering,  University of Notre Dame, Notre Dame, USA | **Problem Statement**:  Students usually spend a lot of time building and maintaining hardware from scratch. Using prebuilt robotic systems would allow easy instruction and active learning among students.  **Research Objectives**:  To describe a newly designed upper-level  undergraduate and graduate capstone course called Autonomous Mobile Robots.  **Conceptual Framework**:  Not Included. | **Research Design: Design Science**  **Research Type:**  - Case study  **Research Method:**  - Mixed Methods  - Narrative research.  - Quantitative methods of data analysis and presentation  **-** System modelling and diagramming  **Data Collection** | | **Project/ Course Setting:**  - Autonomous Mobile Robots (AMR) is a three-credit Computer Science and Engineering (CSE)  - 16 weeks long semester project  - 20 students enrolled in programme (10 undergrads and 10 postgrads)  - Participants need programming skills to enrol  -Participants may not be required to have skills in robotics before joining teams  - 2 sessions of 75 minutes per week of class  - Use of straight lecturers and cooperative learning  - Homogeneous teams of 3 or 4 that are retained throughout the semester  -Self-directed teams of students.  - Students make weekly presentations in class while their colleagues ask questions.  **Software, hardware, platforms used in projects/ course**:   * The Turtlebot Robotic platform, which includes: * iRobot Create wheeled platform, * Microsoft Kinect sensor * ASUS laptop running Ubuntu Linux * Robot Operating System (ROS) [ * -Mobile desks and computers * Lockers to store the robots * 24/7 card access to allow students to use the robots whenever they chose * Many lecture materials come from the RoboticsCourseWare.org website   **Development Approaches:** Active learning, problem-based learning, cooperative learning, weekly assignments, mobile robotics, outreach.  **Findings in the Paper:**  **Assessment & Evaluation**  - There was self-assessment by students  - Peer assessment during presentations  - Evaluation: 70% on their software implementation and 30% on their written report.  - Students did quite well on the regarded assessments  - Students wrote a final report after the project  -Students participated in a National Robotics Week as part of the assessment  -The robotics exhibition was attended by members of the community like children, adults and students from a nearby college.  - Students collaborated with a nearby University in report writing  - Students from partner University played the role of an external client to guide the project  - The teams finally came up with two robotic systems that they presented at the national robotics faire  - Generally the participants reported to have enjoyed the presentation and the development process.  - Students demonstrated an understanding of what robots are and what they do  **Academic Programme:** Upper-level Undergraduate (Bsc.)/graduate (MSc.) in the Computer Science. | **Research Gaps**:  The study concentrated on one capstone course in a University and students were using only one robotic programming software (Turtlebot Robotic platform) which is reported to have presented a number of development challenges.  Future research should be directed towards cases where more time is allocated for capstone projects, because several students’ teams are reported to have encountered logistical problems in the projects.  **Level of commercialisation**:  The 2 robots that were crated were only used to assess academic performance and the only attempt to upscale them was during the national robotics week presentation. No further attempt was made to turn them into commercial products. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P30. | | Millán-Castillo, (2022);  Google Scholar/ Journal of Acoustical Society of America,  Universidad Politecnica de Madrid, Madrid, Spain. | **Problem Statement**:  There is excessive delay in the completion of capstone projects among undergraduate students in Spain. The delays are also caused by heavy workload, and lack of sufficient supervision. This causes delays in their full entry into the labour market; and also affects Universities rankings.  **Research Objective**:  This article presents an approach that tries to overcome these challenges and avoid delays in project submission called Engagement capstone projects.  **Conceptual Framework**: **The Engagement Capstone Project Framework**.  ***Components include***:  -Collaboration with industry and other students  -Division of tasks into smaller tasks as part of a bigger project  -Weekly meetings  -Clear scope of work  -Use of of cutting edge programming software | **Research Design:** Design Science  **Research type:**  - Case study of 2 Spanish Universities  **Methodology:**  Qualitative design- narrative  **Data Collection:**  Observation of students and document review | | **Original Capstone course structure:**  - Lecturers propose topics  - students have access to the list of topics  - Students are also allowed to propose a topic  - Students choose topics and sign an agreement with lecturer who becomes s supervisor  - 2 supervisors are given to each student  - Students write a short proposal  - Students implement project once proposal is approved  - A final report/ dissertation is written after  - Students defined their final project in a presentation to 3 faculty members  - This is a lengthy process, leads to delays, lacks supervisory capacity, and is characterised by disagreements between students and supervisors.  **Proposed Engagement Framework**:  - Training on the use of GitHub  - Training done by industrial partner  - Regular follow up meetings after 15 days are planned by supervisor and industrial partner  - Students seek support from partners in the industry and online community  - Code is reviewed by supervisors in real time on GitHub  - Students must write a user manual of their project using Jupiter Notebook  - Finally, students present a project thesis to the University  - Engagement CP would reduce the difficulty to implement projects due to resource constraints and tight deadlines.  -  **Project Implementation**:  - The engagement methodology described in this paper still is under development and refinement.  - 4 students have completed their projects using this model  - Value training is gained in the model  - Advanced technical skills are gained  - Critical thinking by students  - Students gain knowledge in product development life cycle for IS  - Improved communication skills  - Independent learning capabilities were developed.  **Software Used by students:**  Python programming  GitHub  **-**  **Academic Programme:**  Bachelor of Science (BSc) in Telecommunication Engineering (Electrical Engineering). | **Research gap**:  Only a few finalist students were tested for the proposed engagement capstone project. The conclusions made are not very representative of the entire 2 Universities studied and cannot be relied upon.  Further experimentation on the application of this framework is required to reach more generalisable and reliable conclusions about the efficacy of this framework in capstone projects.  **Level of commercialisation/ possibility of creating entrepreneurial value out of the project.**  Projects performed were for purely academic purposes and no business intent was created. No project was taken to the market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P31 | | Duarte, et al., (2020).  IEEE Transactions on Education; Instituto Superior de Engenharia do Porto (ISEP),  Polytechnic University of Catalonia (UPC) and Universitat Politècnica de València (UPV). Portugal & Spain (Iberian Penisula) | **Problem Statement**:  While most engineering capstone design programs emphasize solving real world problems, hands-on training, and soft skills, very few focus on sustainability aspects of engineering design.  **Research Objectives:**  To analyse the extent to which sustainability is present in the syllabi, project briefs, report templates, and student final reports of the three Iberian European project semester (EPS) providers, over a five-year period.  **Conceptual framework**:  The UN sustainability framework on Transforming Our  World: the 2030 Agenda for Sustainable Development | **Research Design**:  Design Science  **Types**  **-**Descriptive and exploratory design  **Methods**:  - Qualitative methods  - Comparative analysis of projects in 3 Universities  - Document review  - Project reports review  - Evidence based analysis  -Semi automatic data analysis  - Manual extraction of students data  - Report generation using WordClouds.com  - Python NLTK used for the automatic removal of stop words, lemmatization and term-frequency analysis.  - KH Coder, a free tool  for quantitative content analysis  - 19 reports from a five-year period were analysed. | | **Curriculum Structure:**  **-** Courses taught in capstone projects include: “Ethics & Deontology” and “Energy and Sustainable Development”, “Systematic Innovation” and “Human Centered Design”, and “Systematic Innovation” and “Engineering Product Design.  -Students taught projects mgt, communication, marketing, energy and sustainability, and foreign languages.  - **Project solutions**: Bio-mimetic robots, environmental tech, & sustainable food production, innovation for leisure, energy consumption techs, engineering solutions, nature preservation, etc.  - 48% of the projects were about sustainability  **Software ad platforms used by students**:   * Python programming * KH Coder for content analysis * World Clouds for report generation * Robotics technology * Natural Language Tool Kit (NLTK). | **Research Gaps**:  The study concentrated on the concept of sustainability in engineering design, without necessarily detailing how solutions were developed by students.  Further research may be needed to describe the design and development of projects mentioned in this study.  **Commercialisation**:  No mention of whether project outcomes were upgraded and taken onto the market. In spite of the fact that the study was about sustainability, we do not see how these projects were further enhanced and possibly commercialised. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P32. | | Marques, et al., (2018);  IEEE Transactions on Education;  Department of Computer Science, Universidad de Chile, Santiago, Chile | **Problem Statement**:  While computer science programmes offer capstone projects to enhance technical skills, and keep pace with industry innovations, the development of transversal capabilities (soft skills), like leadership, teamwork, decision-making, negotiation, and self-reflection, is usually less supported in these programs.  **Research Objectives**: To propose a Reflexive Weekly Monitoring (RWM) method in order to enhance students’ learning experience during project-based courses.  **Conceptual Framework**:  This paper proposes a formative monitoring method, reflexive weekly monitoring (RWM), for use in project courses, as a way of enhancing learning and teamwork in capstone projects. | **Research Design:**  Cross Sectional  **Methodology:**  Mixed Methods; Qualitative, Quantitative, &  Experimentation  **Research type**:  Solution Paper  **Data Collection**:  Document review and 5-point Likert scale questionnaire  **Data analysis**:  SPSS and thematic analysis for qualitative | | **Project Setting**  - Course uses project based learning  - 2 lectures per week  - Teams to 5-7 students in each group  - 20-30% of participants were already working in the software industry  - Teams work on their projects for 12 weeks  - All teams were homogenous in background, structure, and size.  - At total of 205 computer science undergrad students participated in the evaluation.  - 18 teams (112 students) were monitored  while the other 14 (93 students) were not monitored.  - 65% male and 35% mixed participants  - Between 22 and 25 years  - Projects studied were comparable in terms of size, complexity, and duration, and all teams followed the same software development process.  -Teams have to deploy their solutions at the end of the project.  - The researchers were monitored by graduate students  - 18 out of 32 capstone software development teams were monitored  - Teams use a web based IS to address at least one problem in the University  - Projects involve real products and clients  - Students sign agreements with clients and users about the scope of work.  **Software, hardware, and development platforms Used**:  PHP Model-View-Controller framework  MySQL or PostgreSQL database engine  - All teams use the SRM (Software Requirement Manager) tool, which is a shared repository of the projects’ work products.  -Teams do team reflection during the course to identify and solve issues that may affect project  - Final course evaluation are managed by an e-portfolio tool (U-Cursors)  -Student must produce a major software product increment at the end.  **System development model**:  - Simple Software Process (SSP) model  - The team is coordinated and supervised by a monitor who acts as a Scrum master  **Results of this study:**  - RWM was applied in a case study over  9 consecutive semesters.  - RWM was found to be effective in enhancing the learning  - RWM improves student team coordination, sense of belonging to a team, and effectiveness, but not necessarily their productivity.  - Little evidence was found of monitored students being more productive than students working in non-monitored teams.  -RWM in capstone projects helps detect free-riders and project risks.  - Non-monitored teams served as the control group    - Non-monitored teams show significantly lower performance than monitored groups  Academic Programme: **Bsc. Computer Science.** | **Limitations**:  While the results of this study are valuable, there were reported issues with the quality of data collected from the peer-assessment. Students are expected to make this assessment fairly, but sometimes they do not evaluate their peers as they should. There is need to explore mechanisms of enhancing fair peer assessments in capstone projects.  The study analysed a single capstone project in a Chilean university. Further research may be required to examine the effect of RWM in other settings and Universities.  **Commercialisation or Up-scaling of Project**:  The solutions developed were taken up by the University/ internal client to solve existing problems in learning. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 33. | | Scott, et al., (2014).  Science Direct/ Computers in Human Behavior,  ISISTAN Research Institute (CONICET-UNICEN), Campus Universitario,  Paraje Arroyo Seco, Tandil, Buenos Aires, Argentina | **Problem Statement**:  There is a large amount of information generated during capstone projects and the entire learning process. This hinders professors to meet each student’s learning profile; and to ascertain the exact skills and preferences of in these projects.  **Research Objectives**:  The aim of the study was to discover the relationships between students’ performance along a Scrum-based capstone project and their learning style.  **Conceptual Framework**:  The Felder–Silverman model, towards a first step to build the profiles.  **Independent variables**:  Perception, processing, understanding and input.  **Dependent Variable**:  Student Performance in Scrum projects | **Research Design:**  Cross Sectional  **Research Type:**  Case study  **Methodology:** Descriptive,Exploratory, &  Qualitative  **Methods:**  - Document review/ mining of students’ online interactions and analysing them  - Analysis of the  behaviour of 33 students from a Software Engineering course  - Experimentation  - Analysis of students’  behaviours while performing different web-based actions such as navigating the web, using email, and taking part in online forums. | | **Course setting/ Curriculum:**  - Study analyses a 1 semester capstone course in SE  - Course uses Scrum Methods  - Course is 16 weeks divided into 4 sprints  - Students attending the course must have been trained in software system design, object-oriented programming, O.S, networks and database management.  - The course aims at introducing learners to Scrum practices in Software Engineering  - Lecturers/ professors and students are assigned roles  - A professor plays the role of the Product Owner, who owns project requirements (i.e. User Stories)  - Prof. leads teams to clarify the requirement specifications,  - Students are divided into Scrum Teams  - One student plays the role of the Scrum Master – Projects involves iterations (Sprints)  - The Scrum Teams develop User Stories assigned by the Product Owner, and the Scrum Master facilitates the process and must ensure the productivity of the team.  -Students work with a virtual Scrum environment to coordinate their projects  - After developing virtual working environments in virtual scrum, students then implement their projects  - Students meet daily for planning purposes  **Results of the experiment**:  Students were able to use the FS learning Styles Model and virtual scrum to create stories. The students did this through sensing/intuition, sequential learning, developing global perspectives, active/reflexive learning, and visual/verbal learning styles.  The study discovered better ways of delivering capstone projects using FSLSM. Specifically, the study found that:   1. Sensing students prefer to learn using concrete material 2. Intuitive students prefer more abstract material. 3. Sequential students learn better in linear and well-defined steps 4. Global students prefer long steps with more freedom. 5. Active students prefer doing tasks or talking about concepts 6. Reflexive students are likely to manipulate and examine the information introspectively. 7. Visual students prefer to learn through images or other visual representations,   **Software Used in Students Projects**: Virtual Scrum  **Academic Programme**: Bsc. Software Engineering. | **Research Gap/ Future Research**:  The study made no clear relationship between the proposed model (FSLSM) and Scrum practices.  - The researchers do not show how the components of the FSLSM model relate to each other and how they can enhance scrum.  - There is need to explore students behaviour in capstone projects using not only the FSLSM model, but also common agile practices and platforms like JIRA2, Teamwork3, and software development methodologies (like Rational Unified Process or Extreme Programming).  **Commercialisation of students’ projects**:  The study concentrated on students’ behaviour and no effort was made to describe the kind of software artefacts developed or whether they could be upgraded and sold onto the SE market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| Not included | | Grimheden (2013);  Science Direct/  Mechatronics  KTH, the Royal Institute of Technology, Sweden | **Problem Statement:**  Capstone courses and projects at KTH are becoming increasingly complex and based on knowledge and competencies in several fields, spread  over all members of the student team (and faculty). For this reason, agile methods have been introduced into the capstone courses.  **Research Objective**:  This paper presents a study of the integration of agile methods into mechatronics design education, as  performed at KTH Royal Institute of Technology. | **Research Design:**  - Cross Sectional  **Type:**  - Experience study  **Research methods:**  **-** Qualitative  - Descriptive  **Data collection:**  **Population and Sample:**  37 students  **Data Analysis:** | | **Curriculum Design:**  - Mechatronics was introduced at KTH Royal Institute of Technology  - 30 – 50 students  - 3 Semester courses that end with a capstone project  **The Capstone Project**:  - Spans over one and half academic semester  - Lasts typically 8 weeks  - Most popular engineering capstone in Sweden  - 37 students of Mechatronics student were engaged in the Case study that was studied.  - 5 companies involved  - Students divided into teams of 3, 6, 9 and 10  - Project focussed on how to develop engineering products  - Students have a scrum team and one of them acts as a scrum master  -Students divide project into modules called sprints  - Use Of project management tools like WBS  - Team planning on sprint tasks  - Students work with a corporate sponsor who provides guidance  - Each spring aims at achieving a certain task  - Students hold daily scrum meetings to measure progress  - Scrum teams determine what to do next based on the previous task  - Consultations are made from project supervisor and sponsor  - Clients can easily change requirements  - Quick feedback is given to clients  - Project worked with 2 small company clients and 3 large complex organisations  **Findings from students**  -Most students rank it as one of the most valuable courses in their degree  - Student teams got experience of completely designing and implementing products  - Scrum requires limited documentation as opposed to Waterfall, is more flexible and more participatory  - Integrating scrum in mechatronics capstone projects enhances student preparation for a future career as mechatronics designers or product developers.  - Scrum prepares students with greater flexibility to handle projects with increased complexity in mechatronics product development.  - Scrum enables project teams to deliver results faster, more reliable and with higher quality.  **-Academic Programmes:**  Masters programs of mechanical engineering.  **Development Method:** Scrum method, prototyping, Incremental development. | **Gaps/ Limitations:**  The study did not measure the level of learning of students or the time invested by tutors. A further study is required to explore this.  The study is based on single case study and is not entirely generalisable.  **Entrepreneurial Value**:  The products delivered by the project remained in the institute and were never transferred onto the software market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 34. | | Fagerholm, et al., (2018);  Elsevier/Science Direct  The Journal of Systems and Software  Department of Computer Science, University of Helsinki, Helsinki, Finland | **Problem Statement**:  - University SE courses do not offer students a chance to link their skills to real-life business outcomes.  - Software development projects require extremely innovative and attractive end products; yet students are taught traditional development skills.  - Start-ups work in a volatile SE industry. This causes failure of SE start-ups, termination of development efforts and bankruptcy of SE start-ups.  **Objectives**:  To analyse experiences gained during 7 years of teaching start-up knowledge and skills  in a higher-education institution.  - Study explores how to how to introduce entrepreneurship in the core expectations of a computer science program  **Theoretical Framework**:  Software Factory Project Blueprint.  1: project selection, 2: student selection,  3: kick-off,  4: project execution, 5: end demo,  6: debriefing | **Research Design**:  Longitudinal design as part of an earlier paper in 2017, and an analysis of 7 years of experience in design  **Type:**  - Experience Report  **Method:** Mixed Methods, including:  - Design Science  - Design Factory Simulation  **Data Collection**:  - Qualitative  - Quantitative  - Document Review  - Experimentation  - Student Interviews  - Ethnography- one of the co-authors participated as an observing researcher | | **Project Set UP/ Curriculum Structure**.  - The University of Helsinki set up a software factory in 2010.  - The professor in charge of the course spent a year-long sabbatical as a student in a typical start up to gain experience and impart these skills in the factory students  - Students/ participants are selected initially through mock job-interviews.  - Admitted students are communicated to  - Students meet each other, their coaches, and the customer for the first time in the kick-off meeting.  - Project Based Learning is used in the factory  - Students experience software dev’t in a typical start up environment.  -Students work in teams to identify tasks that would create customer value  - Students work in pairs to ensure productivity  - Teams of Msc students use contemporary tools and software to come up with working prototypes  - Teams work in collaboration with industry  - Works closely with the CS academic department  - Restructuring of programming courses in academic units to skill learners with relevant coding skills.  -Students’ tasks in teams are rotated to ensure they get out their comfort zones  - Students were empowered to teach their peers.  - Incorporation of the cognitive entrepreneurship cycle in programing classes  - The software start-up requires presence of student as a fulltime start-up employee  - Course is 2 months/ half term  - Simulation of a typical software start-up industry  - State of the art SE dev’t tools  - Use of team rooms equipped with start-up education  - Team rooms resemble real workplace  - Functional aesthetics and interior design to inspire co-creation  - Allow transparent communication between teams  - Well-furnished environments and relaxing enough to facilitate learning and innovation  - Casual communication and taking breaks  -Working hours according to local/country conventions  - Students work at least 6 hours a day  - Between 4-5days a week of work  - Flexible working hours for productivity  - Encourage cooperation and asking for help from each other  - Virtual working alternatives are also provided  - Pragmatic selection of technologies to be used in software development  - Use of collaboration tools for communication  - Self-directed learning. No teaching. Only learning  - Tutors provide guidance to learning  - Establishment of customers for the products  - Weekly customer meetings  - Use of continuous formative assessment  - Peer assessment- everyone assesses everyone  - Students are also given some non-technical skills required in software start- ups:  - Teamwork, leadership, communication, self-awareness, perseverance and showing initiative.  - Constructive feedback from teachers  - Sprint retrospectives  -Learning material is co-created by teachers and students  - Coaches/ mentors/ teachers sometimes intervene in the simulation to ensure learning takes place  - Use of role play in the process: Teachers may act as CEOs of the buying company, mentors or coaches  - 360 degree summative assessments at the end.  Some factors that may lead to project failure/ anti-patterns:  - Teachers concentrating on only knowledgeable students  - Use of old learning material for projects  - Customers being involved in project after completion  - Failure to properly hand-over project deliverables  - Customers being disconnected from project  - lack of clarity in project outcomes  - Teacher taking over the project  - Bureaucratic teacher  Etc.  **Development Methods**:  - Prototyping  - Iterative processes of problem analysis  - Scrum sprint meetings and Kanban tools  - Study offers collection of patterns and anti-patterns of start-ups that can facilitate the design, implementation and operation of physical infrastructure, curricula and instruction methods required for success project-based start-ups in SE.  **Academic Programme**: Bsc. Degree. | **Gaps/ limitations & Areas of Future Study**:  - Some of the authors were active participants in the software start-up. This may have caused bias in the way the data was collected  - The study was based on a single case study of one university in Finland. The findings may not be very representative of the population  - The participants for the start-up factory were not objectively selected. The students were selected via professional-like interviews and a number of them may have missed out on participating. This limited the generalizability of the findings  **Entrepreneurial Value:**  The study mimics a start-up garage of a real software development factory. However the researchers do not indicate the real deliverables and products from the start-up garage.  The clients are mock-customers and not real customers. There were limited efforts to market and promote the said deliverables and products to real clients in the market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P35. | | Younis, et al., (2021);  Science Direct.  Journal of Parallel and Distributed Computing  Georgia State University, USA | **Problem Statement**:  Parallel programming concepts had not incorporated in the CS curriculum of  Georgia State University. Yet they are needed in today’s ever evolving SE industry  **Research Objective**:  To explore the effectiveness of using Project Based Learning (PBL)  to teach these skills when classes are at content capacity  **Conceptual Framework:**  PBL Model | **Research Design:**  Cross Sectional  **Type:**  Narrative Case Study  **Methods: Mixed Methods**  Quantitative methods:   * descriptive statistics, * T-test, * Cohen’s d (Effect Size), * Pearson Correlation, * Ranking of students’ growth (Composite Score)   **Tools used:**  Pre- and post-surveys to measure students learning  **Population:**  **Data Analysis:** | | **Curriculum Design:**  **-** A problem learning based course was developed by the University  - Course acts as a mini capstone to empower students to learn critical programming  - enable students get technical and soft skills of software dev’t  **Capstone Structure/ Project Structure**:  - 247 students were divided into 51 diverse  groups  - 77.73% were male students and  22.26%) were female students  -Groups were assigned five projects  -Each group had two-week to deliver  - Use of project based learning  - OpenMP  - Application Programming Interface (APIs)  - C, C++  - Slack, a messaging application to communicate,  - GitHub, a social networking site for programmers to collaborate, create customized workflows, and share code,  - Google Docs, to collaborate and produce project assignments reports,  - Videos and YouTube, to film, edit, and upload videos to a YouTube channel to present the results.  **Software Systems / Development Platforms Used:**  - Parallel programming  - Multicore computer architectures  - Cloud distributed computing  - General-purpose GPU  - Single board computers (SBCs) including the Raspberry Pi  **Findings**:  -Study found that integrating PBL in capstone projects significantly improves students’ parallel programming and soft skills.  - Students collaboratively learn and apply fundamental parallel programming and soft skills through teamwork, and with indirect guidance.  -Students rated exposure to soft skills highly and beneficial for learning.  - Collaboration using GitHub, Communication using Slack, Writing using Google Doc or MS-Word, Presentation using YouTube were found to be important in project implementation.  **Academic Programme:** BSc. Computer Science | **Gaps**:  - Use of self-reported data and self- assessments by students affected the validity of findings  **Commercialisation/ Entrepreneurial value created**:   * The paper concentrated on the curriculum design and delivery of problem based learning in a capstone course and no effort seems to have been made by the University to further develop prototypes created by students in parallel programming. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P36. | | Gan, et al., (2015).  Science Direct/ Computers in Human Behavior  Singapore Management University, Singapore | **Problem Statement**:  With proliferation of digital collaborative tools, lecturers and educational institutions face challenges of equipping students with skills that enable them cooperate in digital contexts. It is increasingly hard for educators to effectively engage students and ensure meaningful participation in the learning process.  **Objectives**:  To explore mechanisms of integrating digital collaborative learning curriculum and course design, and the entire learning experience.  **Conceptual Framework**:  Collaborative & Problem Based Learning Model | **Research Design:**  Design Science  **Method:**  - Mixed methods  - Explorative–interpretative  case study  - Sporadic observations of students’ learning  - Qualitative: Descriptive reflective accounts of students user experiences on online systems | | **Curriculum Design:**  - Project Based learning  - iPads were introduced in a Knowledge  Management class in an undergraduate course with 45 students  - The aim was to enable them appreciate both the economic importance and management challenges of Singapore’s new economic  cluster ‘WaterHub’.  - Groups of 6–8 students were given one iPad  - Students were required to undertake various learning assignments such as activating the iPad’s map application to get a spatial data  - Students also experimented with the iPad’s multiple platforms such as internet search function, communication and social media  - Students were required to use system to collaborate with 70 local and international organisations  - At the end of the course, most students indicated that iPad were useful in improving ad enriching learning.  **The capstone project:**  **See Next Box**  **Development Platforms/ Approaches:**   * Edmodo- a collaborative social learning platform website * Wikis * web page-creation tools (Google Site) * Animated videos * Ipads * Social media: WhatsApp, YouTube, Facebook | **The capstone project:**  - The project was coordinated on a Google enabled website  - project was undertaken by 6 students  - Over the years, students have created web portals, mobile apps, CMS systems and a variety of other systems for clients, including a scheduling system used to schedule capstone presentations.  **Limitations**:  The study was based on a single project in a Singapore university. It is not clear if the revelations are representative of the entire developing or emerging economies.  **Entrepreneurial Value**:  While the students come up with practical software solutions to real-world problems of the Singapore economy, the study does not provide evidence indicating whether these solutions were deployed in the Singapore IT industry.  **Academic Programme Studied**: Not included. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P37. | | Castillo-Salinasa, et al., (2020).  Science Direct/ Elsevier  Computer Standards & Interfaces  University of Ecuador, Ecuador | **Problem Statement**:  Very Small Entities (VSEs) that develop software face problems to relate  Standards such as the ISO/IEC 29110 series. This limits their potentials.  **Research Objectives**:  To develop a  software product for the scheduling of medical appointments for the Student Wellness Center of a university of  Ecuador.  **Conceptual Framework**: Software Engineering – Lifecycle profiles for Very Small  Entities.  **Components of model**: functionality, performance, compatibility usability, reliability, security, maintainability & portability. | **Research Design:** Design Science  **Research Type-** Experimental Case Study/ -Study group ad experimental group)  - System development  **Methods:**  Qualitative  **Application Development:**  - Empirical software engineering  - SCRUM  - Project management practices  **-** Software  Engineering: Lifecycle profiles for Very Small Entities (VSEs)  - The ISO/IEEE software devt model:  - Software implementation  - Requirements analysis  - Architectural and detailed design  - Software construction  - Software integration & testing  - Product delivery | | **Curriculum Design:**  -Integration of project mgt, ISO/IEC/IEEE models in SE course  - Introduction to scrum practices  **Capstone team development:**  - 4 teams of 6 students were randomly formulated  - Teams were asked to develop the same software product  -Divided into 2 groups of 2 teams  - One group used SCRUM and ISO/IEC methods  - The other used ordinary methods without supervision  - Experimental group received formal training in methods recommended  - Control group got no formal training  - All teams used JAVA programming & NetBeans development environment.  - All teams were required to produce PM documents: product description, scope, objectives of the project, estimated duration of tasks and schedule of tasks.  Results: overall, controlled teams performed better than uncontrolled teams  - Users were more satisfied with the software products from the controlled group  - Both teams were however able to deliver completed products using the different approaches.  **Academic Programme Studied:** Not included. | **Limitations**:  Participants were randomly selected to belong to either the control or experimental group. This may have created a scenario where one team had more experienced or skilled participants than the other.  - There was limited time to implement the website as a delivery of the experiment, yet the scope of work was very wide for the four teams.  - The two groups worked in the same environment and they could have influenced each other’s outcomes.  **Entrepreneurial value**: the 2 groups finally developed a web-based collaborative tool that was implemented by the Student Wellness Center of the university of Ecuador. It is however unclear if an external client would buy the software | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P38. | | Lehtinen, et al., (2015);  Science direct/ Elsevier.  Journal of Systems and Software,  Aalto University School of Science, Finland | **Problem Statement**:  Software project retrospectives like Root-Cause Analyses are usually neglected by development teams. The research question here was to find out if CED is needed in the RCA of software project retrospectives, and if so, why?  **Research Objectives**:  To evaluate the effect of Cause-effect diagramming on the perceived utility of Root-Cause Analysis  **Conceptual Framework**:  Cause-effect diagramming model | **Research Design:**  **Design Science**  **Research Type:**  Experience Report  **Methods:**  - Mixed methods, triangulation, quantitative, qualitative data analysis  - Experimentation method (research type)  - Comparative analysis of CED and RCA  - Visualization methods like:  - Root-Cause Analysis  - Cause-effect diagramming  **Data Collection:** Questionnaires, and Group interviews  **Development platforms, Technologies and software used:**  **Academic programme studied by participants: BSc.** | | **Capstone structure:**  - 11 students teams  - 22 experimental units  - A total of 7-9 students per team  - Teams combine 1 Msc. Student (manager) and the remaining 6 or 8 are BSc. Students.  - Students conducted projects in an industry-like environment.  - Students develop software for an external customer  - Project takes 5 weeks and 150hrs.  - Many of these students already have industry experience  - Teams follow a process framework of iterative steps  - Development process combines practices from both agile and plan-driven models.  - Either adapted to sprints, iteration planning, iteration demos, backlogs, weekly stand-ups, retrospectives, pair-programming, continuous integration, risk management, effort estimation and realization, use-cases, functional testing, and more rigorous quality assurance.  - Students developed software that was truly needed by customers  - Teams had to do a retrospective meeting at the end of the project  - Teams developed either; mobile apps, we apps, play station tools, database systems, and OS tools.  **Findings:**  **-** CED diagramming increased the probability of defect detection in software engineering  -CED improves organizing & outlining detected causes  -Majority of teams (9 out of 11) found more defects and causes of defects using CED.  - CED supported more sense-making and accurate problem analysis in 8 out of 11 teams. | **More Findings/ Implications:**  - CED was preferred by the participants.  - Using CED increase the motivation for RCA in the project retrospectives  - CED provides richer analysis on interrelations of causes  - The differences between RCA & structural lists are not large  - Drawing a CED requires a specific software tool, in practice, whereas a structural list can be used with a standard text editor.  **Limitations and future research**:  The authors presented a number of threats to validity that may have hindered the quality of findings, like the small sample of students, the subjective nature of interviews, the subjective nature of transcriptions form the questionnaires, and the fact that some members dominated others in open ended discussions.  There is need for further research in the same area to explore more representative samples, more objective methods, and more scientific methods of data collection and analysis.  **Entrepreneurial value**: while students came up with real artefacts and products for real industry clients, the products were not up-scaled on the market. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| Not included | | Joshi, et al., (2019);  SAGE/ Science Direct  International Journal of Mechanical Engineering Education  Carnegie Mellon University, Pittsburgh, USA | **Problem Statement**: Literature relating to understanding how the formulation of design problems and establishment of requirements affect the final design solution in undergraduate design education is still lacking.  **Research Objectives**: to measure the relation between problem statement, requirements, and final solutions as compared to other measures such as quality.  **Conceptual Framework**: | **Research Design:** cross sectional  **Method: Mixed methods:** Qualitative data collection, the qualitative and quantitative data analysis.  **Tools:** document analysis of final reports from capstone design class collected  over a period of 10 years is conducted  - One project was randomly selected per year. | | **Findings:**  **-** Problem statements from all 31 reports were thoroughly read and coded using this  Scheme  **- The scheme:** (1) current state, (2) desirable goal state, (3) constraints and criteria, and (4) stakeholders.  - Low content volumes of problem statement and requirements leads to a  medium content volume in the final solution  - High content volume of final solution is more likely to result from either a high or medium content volume of problem statement and requirements.  **Software/ development platforms used by students:**  - Computer Aided Design tools for mechanical engineers.  - Problem Based Learning.  **Academic Programme**: MSc. Mechanical Engineering. | **Limitations**:  Study based on a small number of research reports (only 10 per year). This was not representative enough.  **Entrepreneurial value**: No mention of whether these projects were up-scaled or not. The paper was mostly an analytical paper with no specifics about the kid of projects created by students. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P39. | | Pereira, J. (2021).  MDPI/ Science Direct  Electronics,  University of the Basque Country, Donostia, Spain | **Problem statement**:  There is limited research evidence of students’ contribution to Open Source Software (OSS) tools and coding repositories like Git Hub.  **Research objectives**:  To explore and document novel ways of supporting teaching of software engineering based capstones and their contributions to OSS projects  **Conceptual framework**:  Contribution of Final Degree Projects on Open Source Software projects. | **Research design:**  Cross Sectional  **Research methods:**  Mixed Methods  **Research type:**  Experience Report  **Data collection:** Questionnaire/ Survey  **Population/ Sample:** 4 Students were studied.  **Development methods/ software platforms used by students:**  - GiTHub  **Academic programme offered by students:**  Bsc. Computer Engineering | | **Curriculum Structure:**  In prior course, students are introduced to practical skills computer programming, data structures and algorithms, software engineering, networking, databases, project management, Third-party code comprehension, feature location, refactoring, program maintenance, version control, communication, writing skills for interacting in forums, code reviewing activities, issue management and/or mailing lists.  **The Capstone Project:**  - Students work individually in this project  - Projects take the number of weeks in a semester (15–16 weeks)  - Students work on the Google Summer of Code (GSoC) initiative as part of their projects.  -The Google internship program finances students to write code for open source projects.  - Students actively participate to build careers and earn professional experience  - Students are assigned a mentor from the industry  - Projects are supervised by a lecturer  - Each lecturer supervises up to 3 students  - An external committee is chosen to evaluate projects.  - Students gain experience through their immersion in the project. | **Findings**:  - Final Degree Projects (FDPs) oriented students towards enhancing Open Source Software projects  -Capstone projects introduce students into real world, giving them practical examples of SE principles  - Projects boost students’ confidence about their technical and communication skills  -Capstones help them build a portfolio of contributions to daily used worldwide open source applications.  Limitations: There were very few students involved in the study who were subjectively selected. The findings from the study cannot be comfortably generalised to all Open Source Capstone Projects. A more comprehensive study having a scientifically selected sample of participants is needed.  **Commercialisation**: Students only contributed code and bug fixes on existing OSS platforms (GiTHub). There was no novelty or creation of their own artefact and thus no commercialisation could happen. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P40. | | Licorish, et al., (2022);  Science Direct/ Elsevier.  The Journal of Systems & Software,  New Zealand and Cyprus | **Problem Statement**:  Previous research in capstone projects has not sufficiently explored students’  perceptions about their commitment and adequacy of effort spent on SE projects, their project performance and skills that are developed during course of these projects.  **Research Objectives**: To analyse the students’ efforts, commitment, skills, level of satisfaction, and their perception of performance on capstone projects | **Research Design:**  Cross Sectional  **Research type:**  Survey  **Research Methods:** Mixed Methods, deductive and inductive analyses  -Quantitative and qualitative methods  **Data Collection:**  **-**Web based survey/ Questionnaire  -Open ended questions for triangulation about skills, challenges faced by student developers.  **Development Approach, Software, Hardware, Technologies Used:**  Git (GitHub, GitLab), Travis CI, Jenkins, JUnit, PyUnit, Selenium, Eclipse, Pycharm, IntelliJ, Visual Studio, Flask, Diango, Angular, Trello, Slack, Discord, PHP editor, Taiga, Trello, NetBeans, JUnit, Android Studio, KanbanFlow, & Bootstrap | | **Curriculum Design**: The programme curricular are composed of courses that make a build up to capstone projects  - Earlier courses include: software engineering processes, analysis, design, programming skills, programming paradigms, testing, web & mobile development, & human computer interaction.  **Capstone Design**:  - The study concentrated on capstone projects across 4 universities in Cyprus and New Zealand.  - A total of 104 students were studied  - Courses run for 12-14 weeks.  - Teams used user stories, requirements and stakeholder analysis, design documents, UI prototypes, risk registers, (evolving) project plans, the actual product, user documentation, source code, technical documentation, unit tests, and acceptance tests.  - Teams came up with actual products  - Products included Web Applications, Mobile Apps, Desktop Apps, Web resource Apps, Browser add ones and scripting apps  - 75% males and 25% females  -  **Findings from the Study**:  - Students were more satisfied with their team’s collaboration performance than their technical contributions to projects;  - Junior students seemed to struggle with teamwork.  - Team work, team meetings and consistence improve the quality of software developed. | **Gaps/ Limitations & Future Research**:  The thoroughness and trustworthiness of student respondents cannot be objectively determined in this study since data was collected from students who were doing a project to attain a mark. They may have responded to the survey in way that pleases their instructor to pass the exam. This affected the validity of the responses. A further study may need to be conducted by researchers on respondents for which they have no influence or power.  **Entrepreneurial Value**:  Majority of the projects created had external clients that provided for an opportunity to upscale the products and transfer them onto the market. There was however no effort by the researcher to find out what students did with their artefacts or prototypes after the projects. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | | **Continued from previous** | **Conceptual/ Theoretical Framework**:  The IEEE and ACM 2014 Software Engineering Education Knowledge (SEEK):  Dimensions  Include:  Attendance, Activeness,  Task Difficulty,  Teamwork Responsibility,  Individual Work,  Quality of Work,  Willingness,  Negotiation,  Listening,  Project Management (PM) Skills,  Technical Skills,  Presentation and Teamwork. | **Academic Programme studied by Students:**  Bsc. Computer Science  Bsc. Information Science/Technology  Bsc. Software Eng.  Bsc. Information Science | | - 22 projects had external clients while 14 had internal clients. (Majority had external clients).  - Students dedicated around 11hours per week on projects.  - Majority felt project time was adequate  - Majority indicated that technical skills (coding, testing and deployment) were very important in capstone project success.  -Students gained skills in coding, meeting organisation, project mgt, planning, testing software and deployment skills. |  | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P41. | | Scott, et al., (2016).  Journal of Systems and Software  Science Direct/ Elsevier  ISISTAN Research Institute, Buenos Aires, Argentina | **Problem Statement**:  There is little evidence from SE education literature suggesting the use of the meshing hypothesis. There is need for more research on effective approaches that can be used to validate use of teaching methods that fit students’ learning style in SE.  **Research Objectives**: To present an evidence-based method of incorporating students learning styles in scrum projects.  **Conceptual Framework**:  Meshing hypothesis, involving the corroboration of Teaching and learning styles, with the Felder–Silverman Learning Style Model. | **Research Design**:  Longitudinal study between 2013-2014.  **Research Type**:  Experimental  **Research Methods**:  Mixed Methods  **Data Collection Modes**:  Questionnaires  Observation  Group discussions  **Research Respondents/ Population**:  73 students of BSc. SE. | | **Curriculum Design/ Structure**:  - Students are taught essentials of scrum  - Students are introduced to Felder–Silverman Learning Style Model (FSLSM)  - Classes are design in the context of user story definition, user story splitting, user story estimation and planning  - The aim is to enable students learn user story definition under the guidance of the product owner/ academic supervisors.  **Capstone Design**:  - The experiment was ran for 2 years, 2013, 2014  - The capstone project used a SE Workshop  - 73 Students divided into 2 groups for 2 years  - One group was a reflective group (control) and the other active group (study/ experimental group)  - One group given basic skills of scrum  - The other group was given skills necessary to complete a capstone project  - Both groups conducted a single sprint capstone to project to demonstrate skills learned.  - Teams use scrum method to develop software.  - Passive instructional method is used for the reflective group  The active instructional method is used for active students groups who prefer active learning  - Both groups are then taught same scrum principles. | **Gaps/ Limitations and Future Research**:  - Since the sample was only for 72 students, 35 in 2013 and 37 in 2014, the study only drew conclusions from this small sample. The findings may not be entirely generalisable.  - Some elements of the FSLSM model were not considered.  Further research may be required to close these gaps.  **Entrepreneurial Value from projects/Possibility of up scaling projects**:  The study does not indicate the kind of software that the students were developing. It rather concentrates on their level of learning, learning styles, team formation and the advantages of integrating scrum in capstone projects. | |
| No. | | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| Scott, et al., (2016).  Continued from previous | | | **Mentioned above** | **Mentioned above** | | **Findings from the Study**:  - Majority of the students were reflective  - The students who received scrum training suitable for individual learning performed better than the other group.  -Students’ learning is enhanced if a suitable learning style is used.  - Teaching scrum is an effective way to upgrade student learning and ensure achievement of practical and professional knowledge by learners.  **Development Approaches and Software Used by students**:  Agile Development  Scrum methodology  The Felder–Silverman Learning Style Model (FSLSM)  **Academic Programme attended**: BSc.  Systems Engineering |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 42. | Kudikyala, & Dulhare, (2015);  IEEE Library/ IEEE; Conference Paper: 2015 IEEE 3rd International Conference on MOOCs, Innovation and Technology;  Keshav Memorial Institute of Technology Hyderabad, India | | **Problem Statement**:  Computer Science and Engineering (CSE) and Information Technology (IT) students are not exposed to acquire soft skills required in the industry. Methods like scrum are not prescribed in their existent curriculum.  **Research Objectives**:  **Conceptual Framework**:  SCRUM approach to software development. | **Research Design:**  Design Science  **Research Type:**  Experience Report  **Methods:**  **-**Quantitative methods  **Population:** Computer Science and Engineering (CSE) and Information Technology(IT) students  **Data Collection:**  - Questionnaire with 5 point Likert scale. | | **Curriculum Structure**:  - Students enrol in Object-Oriented Analysis, Design course, Case Tools and Web Technology  Laboratory, Software Project Management  - Mobile Application Development course in previous semesters  - Programmes are 4 year courses  - Wikispaces was chosen for project collaboration  **Capstone Project**  - Scrum methodology was used  - Scrum is iterative and incremental  - Students were divided into groups  - Follows the scrum methods  - Scrum teams given tasks  - Work is done in sprints  - Each sprint takes between 2-4 weeks  - Scrum team has a Scrum master, product owner, scrum team and customer  - Project aims at developing a product with documentation  - Scrum was introduced to solve existing project problems like students complaints about lack of time, inability by students and supervisors/ guides to meet each other, among others.  - information about sprints is recorded on scrum backlogs  - There are daily meetings to measure progress  The project owners and customers guide project changes and progress. | **Gaps/ Limitations and future work**:  The study did not implement all scrum processes like daily sprint meetings due to time.  The teams were not cross-functional as recommended in scrum theory.  There is need for further research that applies all scrum methodologies and cross-functional teams to measure students’ performance in capstone projects.  **Commercialisation and entrepreneurial value**:  While teams came up with working products and documentation, **there were no efforts to commercialise the products** and sell them to customers. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued from previous….** | | |  | | **-**Wikispaces was used to create a homepage  -Homepage had project info, team members and internal project guides for each team  - Majority of projects were implemented using android platforms  - There was a project timelines online page on Wikispaces used to track progress  -Students were assessed internally via presentations, and a working product  - Team and individual performance was also assessed  - Most of the teams had one or 2 coders while the rest worked on documentation.  **Results from Study**:  - Majority of the students indicated that they knew about scrum before working on projects  - Majority of students agreed that they gained more knowledge using scrum  - Majority of students recommend scrum as a preferred method of project development  - Students indicated that scrum enabled them deliver a working product early in the projects  -Students indicated that scrum enabled them contribute equally to projects.  **Software, Hardware Used and Platforms**:  Web 2.0 Wikispaces  Wikis to convey feedback to students  - Scrum/ Agile development  -Google Analytics for website usage measurement  Laptops and Mobile devices  **Academic Programme:**  BSc. Computer Science and Engineering (CSE) BSc. Information Technology (IT) |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  |  | |  |  | | **Global Software Engineering Experience through International Capstone Project Exchanges. 2018 ACM/IEEE 13th International Conference on Global Software Engineering.** |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 43. | Rodríguez, (2016).  IEEE Xplore; IEEE Transactions on Education,  ISISTAN Research Institute (CONICET– UNICEN–Computer Sciences), Tandil, ISISTAN Research Institute, Buenos Aires, Argentina, | | **Problem Statement**:  Agile approaches to Software development do not usually provide sufficient assistance to students as they perform their required tasks. Students tend to write lengthy requirement documents, engage in waterfall like issues, and focus on delivery dates instead of product quality. Students need to be helped better understand scrum requirements.  **Research Objectives**: To examine “How  agile coaching influences student performance”.  **Conceptual framework**: Coaching Model for Agile Projects: | **Research Design:**  Cross Sectional  **Research Type:**  Case Study  **Methods:**  Mixed Methods  **Data Collection:**  Observation  Survey/ questionnaires  Group discussions  **Population/ Sample:**  81 Students  **Data Analysis:**  Microsoft Excel  Virtual Scrum | | **Curriculum Structure**:  - Software Engineering Workshop course  - Students were introduced to basics in software system design, object-oriented programming, operating systems and networks, and database management.  - Students are set up into 2 scrum teams  - Participants were randomly selected per group  -Students interact with 3 teachers with significant expertise in software engineering.  - **First teacher**: plays role of **Professor**  - **Second**: **Product Owner**  - **Third** plays the role of **Agile Coach**.  **Capstone Project**:  - Professor teaches the Scrum rules for performing recommended SE practices  - Prof provides students with guidelines to check their Scrum compliance.  - Product Owner defines and clarifies requirements of the software product, establishes requirement priorities, and validates results of each iteration  - Agile Coach helps student teams to adopt and improve the use of agile methodologies.  - Students divided into teams responsible for developing a set of user stories.  - Scrum Master role is shared by the students over the duration of the course.  - The agile coach works as a guide, conflict resolver, collaborator, problem solver.  -Agile coach helps students navigate the project  - Agile coaching improves agile practices, leads to better ways of working, improves teamwork, higher product quality, and lowers overall cost. | **Limitations/ Gaps/ and future research**:  - Since students were randomly grouped, this  might have impacted student performance in comparison to other strategies for group formation.  - Students may have been insincere in their responses during the survey due to fear of embarrassment.  - The scrum coach required experience in guidance and in scrum practices. It is difficult to know if their level of skill influenced the findings of the study.  -Similar case studies might be required to explore ways in which these statistical factors that may have affected the validity of findings can be avoided.  **Commercial Potential**:  In spite of the fact that 1297 artefacts were produced by the two student groups, none of these was upscale into an on-the market product. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | Previous | | Continued | **Continued** | | **Project execution:**  -The project is organized and prioritized according to the Product Backlog  -Project is divided into three 4-week Sprints  - Students work for about 2 h a day.  **Stages include:**  Initial Phase, Sprint Planning Phase, Development Phase, Sprint Review, Retrospective Phase, Product Delivery, Assessment Phase  - **Project Result:** Students created 12 epics of a Java-based virtual world that allows users to navigate the facilities of the University, play thematic games, and carry out social activities by using chat, e-mail, and a forum.  - In total, 1297 artefacts were produced by the teams  - Each student produced an average of 6 artefacts.  **Findings of the Study**:  - The main findings obtained from this research work are that 97% of students found the course useful and interesting and the Scrum-based process easy to follow.  - The results indicate that incorporating an Agile Coach in SE allows students to increase their coverage of SE practices.  - Agile-coached students (AC) gained more nontechnical skills than did non-agile-coached students (NAC).  **-**  **Applications/ Platforms/ Software/Hardware Used**:  - Scrum, Agile Development, Coach-based Scrum, Virtual Scrum, SVN1, Xwiki2, Junit3, and continuous integration (Jenkis4), Java  **Academic Programme**: B.Sc. Systems Engineering |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P44 | Zagar, et al., (2019);  IEEE Library  2019 IEEE Global Engineering Education Conference (EDUCON),  RIT Croatia, Zagreb, Croatia | | **Problem Statement**:  Special diagnostic equipment that needs to be used for a certain procedure is not available at every location. The existing system of data storage and transfer is complex and has limited sharing capabilities.  **Research Objectives**:  - To examine a students’ project aimed at improving a pre-existing Medical Imaging system  - To make it easier for doctors to share and consult with each other in order to get a precise diagnosis before starting a medical procedure. | **Research Design:**  Design Science  **Research Type:**  Case Study  Narrative research  **Methodologies:**  Qualitative  **Data Collection:**  Observation and Group discussions  **Population/ Sample:**  100 students randomly selected | | **Curriculum Structure**& **Capstone Project**:  - The course is run internationally over 3 campus in 3 countries  - A joint course for more than 100 students  - Course aims at preparing students for real IT projects that are based on distributed software development  - 3 instructors jointly work across 3 continents  - Students form teams of 6-7 students  - Teams are interdisciplinary and international  - Students do projects in Web and Mobile Computing (WMC), Computing and IT (CIT) & Human-Centered Computing (HCC) students.  - Students work on projects that are industry based, with sponsors located worldwide.  - Students work in distributed teams, project coordination, and customers.  -Sponsors include a technical team and a medical team  - Multiple projects were randomly divided on teams  - Each student team works on a single project  -Teams compete with each other.  - Projects mimic typical situation of multiple vendors bidding on a single project.  - Best team projects are implemented at sponsor sites at end of Capstone project.  - The project’s product enabled users are able to upload files to MIDOM. | **Limitations/ Gaps/ and future research**:  The case is based on a single course in 3 campuses of one University. It is highly unlikely that the findings are generalisable to other universities or academic institutions.  **Commercial Potential**:  - Students created a web interface that is easy to use and enables users to interact and share medical data. However, the project remained only an academic project with an external sponsor who did not take it up as a final product on the market. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | Continued | | **Contained**  **Conceptual framework**:  Not Included | **Continued** | | - The priority of this project was to make the solution easy to use  **Stages of Project:**  a) Short definition of project task; b) Data collection; c) Creating requirements list, Dividing team roles; d) Creating project plan, timeline & budget-line; e) Developing, testing& deploying final project, Documenting project; f) Planning for maintenance& further support; g) Students peer-review their team members at end of the course.  **Findings of the Study**:  - The developed systems enabled data storage in local PACS (Picture Archive & Communication System)  - Files stored in PACS are stored in high resolution imagery for easy sharing.  - Students very satisfied with experiences and knowledge gained during capstone course  **Applications/Platforms/Software/Hardware Used**:  - Web and Mobile Computing Applications  **Academic Programme**:  Bsc. IT, Bsc. Web &/ Mobile; Bsc. HCC. |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P45. | Olarte et al.,(2016)  IEEE Library  IEEE Transactions on Education  University of La Rioja, Spain | | **Problem Statement**:  There are divergences between students’ and lecturers perceptions of learners’ efforts and their performance in capstone projects.  **Research Objectives**:  To compare student and staff perceptions of key aspects of completing capstone project, such as project characteristics, student competencies, advisor involvement, and student perceived learning.  **Conceptual framework**:  The capstone project evaluation model including;  project characteristics,  student competencies and characteristics, advisor involvement,  and enhancing learning | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative, mean standard deviation, tables, charts, Cohen’s d  **Data Collection:**  Questionnaires with a 4-point Likert scale  **Population/ Sample:**  Population 75 capstone student projects completed between 2012 and 2013.  -57 projects for 57 students were accessed  - 20 supervisors  **Data Analysis:** Statistical analysis using SPSS v.19 statistical package | | **Curriculum Structure**:  - Students are prepared for the capstone project through courses like programming and systems development.  **Capstone Project**:  - Students performed project individually  - Each student had a supervisor  - Capstone project is conceived of as a course without classes  - Completed during final year of degree  - Students take approximately 600 hours  - Students supervised by an instructor  - Project proposals are made by the student  - Advisors are from academia and local industry  - Student must submit a portfolio describing their solution at end of project  - Students make a public oral presentation,  - A team of 3instructors grades students  -Projects are evaluated according scope, complexity, technological novelty, product  usefulness, and the need for training  - Projects of greater difficulty received better grades and were more likely to have been created for industry  - Less difficult projects can be seen to require more advisor time but slightly fewer student hours | **Limitations/ Gaps/ and future research**:  The only feature studied is the time spent on capstone projects. Further research should be done on other types of courses and larger samples.  **Commercial Potential**:  The study only analysed the performance of students and the effect of their supervision in capstone projects. No mention was made about the types of projects created and whether they were upscale to the next level. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued from previous** | | **Continued from previous** | **Continued from previous** | | **Findings of the Study**:  - Students’ perception of their learning is not always reflected in the grades obtained or student satisfaction  - Students with better competencies received better grades and did a higher proportion of industrial projects  - Students who can freely choose their project perform better  - Students with weaker competencies were also found to require similar advisor time and devote less time to the project  - 3 supervisory techniques were used:  “Student alone”, “Execution focused”, and “Global supervision”.  - Students supervised in the “Student alone” style, which requires less time from the advisor, did spend more hours on the project;  - More skilled students prefer to do industry projects; have higher levels of engagement and motivation, with a higher level of difficulty  **Applications/ Platforms/ Software/Hardware Used**: Not included.  **Academic Programme**:  Bsc. Computer Science Engineering |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P46. | Bastarrica, et al., (2023).  IEEE Library/ IEEE Access  Faculty of Physical and Mathematical Science, University of Chile | | **Problem Statement**:  Peer assessments by students on capstone projects leads to little incentive for improvement, which potentially jeopardizes the overall quality of the project outcome.  **Research Objectives**: To study the effectiveness of peer assessment as a tool of evaluating students’ contribution to capstone projects.  **Conceptual framework**:  Peer Assessment Models for capstone Projects | **Research Design:**  Longitudinal study over 4 semesters 2016-2019.  **Research Type:**  Experience Report  **Methodologies: Mixed methods:**  Quantitative and Qualitative  **Data Collection:**  Questionnaire  Peer assessments  **Population/ Sample:**  - 24 students- 4 teams, 6 students per team.  -Tutors who were former students of the course.  **Data Analysis:**  SPSS’s ANOVA, we decided to  Apply, Normality with  Shapiro-Wilk tests, Microsoft Word | | **Curriculum Structure**: The capstone project is reinforced by a strong technical background through courses like software engineering, databases, algorithms, programming languages, systems programming, among others.  - Each semester lasts 15 weeks.  **Capstone Project**:  - Teams are formed randomly  - Students graded according to software quality, project management, and peer assessment.  - Students have a strong theoretical background and some initial exposure to problem solving and software development  - Students lack real life experience in project development  - In 1st 2 weeks, students attend lectures where foundational concepts about the agile development are thoroughly explained  **Findings of the Study**:  - Peer assessment leads to greater team reflection, teamwork, quality products in a software engineering capstone courses.  - A new grading schema was proposed as a result of this study, and it considers teamwork quality, commitment, communication, coordination, attitude, contribution during projects.  **Applications/ Platforms/ Software/Hardware Used**:  - Iterative design  - Agile Development  **Academic Programme**: BSc. Computer Science. | **Limitations/ Gaps/ and future research**:  There are major threats to construct validity in this study. For instance the use of peer-assessments as the only parameter for evaluating teamwork quality. This presents a lot of bias.  There is need to undertake other studies that use a combination of assessment approaches to ensure fairness in capstone projects, proposed complementary approaches, such as self-assessments.  Moreover,  **Commercial Potential**:  Not included. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 47. | Jaime, et al (2020);  IEEE Library  IEEE Transactions on Education  Universidad de La Rioja, Logroño, Spain | | **Problem Statement**:  While internships and capstone projects are widely  used to integrate work-related learning in SE  education; the interaction between internship and capstone projects remains unexplored  **Research Objectives/ Questions**:  What is the effect of internships on the  development of a subsequent capstone project?  **Conceptual framework**: | **Research Design:**  Cross sectional  **Research Type:**  Quasi experimental case study  **Methodologies:**  Quantitative study  **Data Collection:**  Questionnaires  **Population/ Sample:**  - 166 students projects  - 25 advisors  **Data Analysis:**  SPSS | | **Curriculum Structure**:  No included  **Capstone Project**:  - Students were divided into 2 groups;  - Non-integrated group- internship without capstone  - Integrated group of internship with a capstone  - Integrated projects were located in the same company of internship  - Worked with an industry sponsor or partner  - Projects had advisors who had to fill out questionnaires at the end.  **Non-integrated projects:**  - 52 (31%) – industry projects  - 114 (69%) are academic projects  **Integrated Projects**  - 84 (77.8%) were industry projects  - 24 (22.2%) academic projects.- A larger amount of advisor involvement was devoted to meetings for industry projects  - Integrated projects were more complex than academic projects, since companies use  more advanced technologies  **Findings of the Study**:  -75% were males  - 25% females | **Limitations/ Gaps/ and future research**:  - Subjects were not randomly allocated to different experimental groups. This could have affected internal validity and caused bias;  - The study did not include any qualitative data from advisors to strengthen the results.  - The study did not include the students’ opinions about internship and its contribution to capstone projects.  **Commercial Potential**:  Not included | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued from previous** | | **Continued from previous** | **Continued from previous** | | **Findings of the Study**:  - Internships have a very positive impact on both industry and academic capstone projects.  - Internships prior to capstone projects improve student skills in autonomy, technology, methodology, and project management  - Internships help students increase the complexity and technological novelty of the capstone projects;  - Internships reduce advisor involvement in practical project execution  - There was an improvement in supervision style of the advisors: they invested more energy in activities related to monitoring student work, while collaborating less in developing the solution.  **Applications/ Platforms/ Software/Hardware Used**:  Not included  **Academic Programme**:  BSc. Computer Science Engineering |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P48. | Knudson, et al., (2018).  IEEE Library, Conference Paper: 2018 ACM/IEEE 13th International  Conference on Global Software Engineering,  North Dakota State University, Fargo, USA, Texas A& M University, United Sates. | | **Problem Statement**:  Traditional capstones do not prepare students with skills needed for the global environment.  Supervisors would have loved to conduct capstone experiences across different countries. However most of them do not have resources and expertise to do so.  **Research Objectives**:  To present the general concepts related to “International  Capstone Project Exchanges” models, where student teams are led by an industry sponsor residing in a different country. | **Research Design:**  Design Science  **Research Type:**  Case Study  Narrative Research  **Methodologies:**  Qualitative  **Data Collection:**  Observation  **Population/ Sample:**  Not included  **Data Analysis:**  Not included. | | **Curriculum Structure**:  - An international multidisciplinary study programme was set up in Europe, the Middle East and the USA  - Lecturers share experiences and skills across different countries  -Active involvement of sponsors from the industry  **Capstone Project**:  - The International Capstone Project Exchange program engages multiple global academic institutions and companies;  - Project allows multiple departments (CS, SE, Electrical E, Mechanical Eng, Agric Eng, Marketing, and Journalism) to engage efficiently;  - A flexible model for collaboration was developed  - Sponsors include companies like Ericson  - Sponsors can be large international firms, regional firms, mid-size firms or local SMEs.  - The model provides students a rare opportunity to experience different cultures internationally  - Enhancing employability  - Model has a total of 17 universities  - Capstone are either 1 semester or 2  - Students work in teams of 4, divided into 2 people in 2 countries  - Students choose their mentors  - Students submit their own project ideas and later select their favourite project ideas to work on  -Students develop software, design and build cars among other products. | **Limitations/ Gaps/ and future research**:  The study is based on projects coordinated in Europe, the Middle East and the USA, without covering the rest of the World.  The study did not seek the opinion of students who are the main target of such programmes.  **Commercial Potential**:  The study successfully developed a collaborative website which is being used. It is not clear however if commercial value has been derived from this site. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued** | | **Conceptual framework**:  International  Capstone Project Exchanges” model. |  | | - Sometimes sponsors sub-contract portions of a larger project to different universities  -Companies can also set up competing projects around the world to ensure the best product  - Use of professional Project Management and Engineering conventions ensures success  - Sometimes the projects are continued in the successive years  - Students also do collaborative exchange research projects  **Findings of the Study**:  The study resulted into the development of  an International Capstone Project Exchange  website ([www.ndsu.edu/cs/icpe](http://www.ndsu.edu/cs/icpe)) that aids universities in establishing their own international project exchange programmes.  **Applications/ Platforms/ Software/Hardware Used**:  Detailed engineering calculations, drawings (CAD), FEM analysis, simulation and prototyping, Web Development Software, Proejct Management Tools from PMI  **Academic Programme**:  Bsc. Agricultural Engineering  BSc. Computer Science  Bsc. Mechanical Engineering  Bsc. Electrical Engineering  BA. Marketing  BA. Journalism |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| P49. | Kim & Strimel (2020).  IEEE Library  IEEE Transactions on Education,  Purdue University, USA | | **Problem Statement**:  Despite of many attempts to examine entrepreneurial mind-sets of engineering students, little is known about the influence of entrepreneurial education on students innovative design thinking.  **Research Objectives**:  1) To study the perceptions of undergrad students on the relationship between entrepreneurial mind-sets and engineering design thinking;  b) Analyse how differently undergrads frame a design situation after courses. | **Research Design:**  **Cross-sectional**  **Research Type:**  Case Study  **Methodologies:**  Qualitative methods  **Data Collection:**  -Systematic data collection  -Semi-structured interviews  - Pre- and post-activities analysis focused on problem framing  **Population/ Sample:**  14 undergrad students | | **Curriculum Structure**:  - College offers wide range of tech and engineering majors to students  - Students study algebra, calculus, physics, engineering, and technology elective courses  - Project-based multidisciplinary design and innovation (MDI) course  - Courses studied include Project Based Design, Innovation and Problem solving  -Engineering students are taught how to identify problems, generate ideas, fabricate, and create innovative products.  - Students learn prototyping and business model development concurrently  - Course taught by a combination of engineering and entrepreneurship faculty staff  - Students met for 1 hour design/ prototyping course and 2 hours for entrepreneurship class  - Entrepreneurship course followed lean start-up model  - Use of a business model canvas in ideation  **Capstone Project**:  - Products on human-technology interaction  -Students generate their own ideas of how to develop products  - Ideas they had included:   * Development of a smart irrigation system * Creation of an education package to engage children in the applications of soft robotics * Smart phone application connecting college campus communities through dog walking. | **Limitations/ Gaps/ and future research**:  - The study had a relatively small number of participants  - Case study only concentrated on one course  **Commercial Potential**:  Not included, even though the study was about entrepreneurial framing of engineering problems. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | Continued | | **Continued….**  **Conceptual framework**: A Conceptual framework based on literature about cognitive operations for problem framing and entrepreneurial engineering mind-sets | **Continued** | | **Capstone Project Continued**:  - Use of brainstorming to generate ideas  - Students built, tested, and revised prototypes and biz models with a business model canvas. - At the end of the course, each team turned in a final portfolio  - Teams created a business model and the final prototype for their new product  - Teams presented their project at an innovation competition offered by the university.  **Findings of the Study**:  -Majority of students developed a customer-centric approach to design  - Students improved their problem framing skills  - Entrepreneurial mindsets made products more desirable for the market  -  **Applications/ Platforms/ Software/Hardware Used**: Not included.  **Academic Programme**:  Among the  BSc. Engineering and Technology  Education (ETE)  BSc. Organizational  Leadership (OL) |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 50. | Friess and Goupee, 2020;  IEEE Xplore;  IEEE Transactions on Education,  University of Maine, USA | | **Problem Statement**:  Since capstone courses are project and group based, it is difficulty is to fairly assess the individual  team member’s contribution toward the project.  **Research Objectives**:  To implement & evaluate a team project assessment technique that allocates individual  grades based on the individual team member participation  **Conceptual framework**: The ABET learning outcomes. | **Research Design:**  Cross sectional  **Research Type:**  Case Study  **Methodologies:** Quantitative  **Data Collection:**  Survey / questionnaire  **Population/ Sample:** Not shown  **Data Analysis:** Quantitative | | **Curriculum Structure**:  Students are prepared for the capstone thru:  ***Semester 1***: problem definition and conceptual design;  ***Semester 1***: detailed design & CAD package;  ***Semester 2***: manufacturing & operational handbook;  ***Semester 2***: design testing and evaluation  **Capstone Project**:  -The course is a combination of 2 courses in Fall and Spring  - Students are taught how:  - Function on multidisciplinary teams  -Work professionally & ethically  - Communicate (orally and in writing)  - Software developed allows students to continuously calibrate their own and their teammate’s expectations and improve their performance  - Students are introduced to guest lecturers  - Students hold weekly meetings and 1hr classes  - Review of previous week’s work from each team member.  - Peer evaluation of the work of each team member  - Discussion on the status of the project, problems, challenges, and updating the Gantt chart and project timeline.  - Team sets individual specific, measurable, attainable, realistic, and timely individual goals, within the scope of the required course time commitment.  -Software helps students to practice professional communication  -Students learn how to highly align projects with industry needs. | **Limitations/ Gaps/ and future research**:  Study based on a case study of a single program  Peer evaluations as fronted in the study are not very fair methods of evaluating students’ performance.  **Commercial Potential**:  Not included | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | Continued | | **Continued** | **Continued** | | **Findings of the Study**:  - Students designed a CAD tool as part of the deliverables of the project  - The study presents a novel assessment method based on weekly peer evaluation of the individual team member’s contribution,  which subsequently produces a participation factor (PF), in turn scaling the team grade in accordance with the individual student  performance.  - The weekly peer assessment allows timely adjustment of individual student effort to match the group expectations  - Method helps to fairly rewards high-performing students in a team.  -Elimination of free-riders in team projects.  **Applications/ Platforms/ Software/Hardware Used**:  Project Based Learning  Problem Based Learning  Computer Aided Design Tools  **Academic Programme**:  Not included |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 51. | Guardiola, & Dagli, & Corns, (2013).  IEEE Library,  IEEE Transactions on Education,  Missouri University of Science and Technology, USA | | **Problem Statement**:  Current engineering students face daunting tasks of demonstrating vast skills in an increasingly challenging and dramatically changing SE industry.  **Research Objectives**:  To analyse the application of systems engineering processes, tools, and analysis to  engineering design problems by students in capstone courses.  **Conceptual framework**: The DoD problem mgt model identified as Immersive Training Technologies | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Surveys/ Questionnaires/ Survey monkey  **Population/ Sample:**  52 students were involved  **Data Analysis:**  Quantitative | | **Curriculum Structure**:  Project simulates the real military training ground in Afghanistan  - Some students are taught how to work as civilians and as others military personnel.  **Capstone Project**:  - Students were brought into research and development world  - Students were introduced to a real problem that they had to decompose, organize, and analyse during the course  - Students were given simple need statement and tasked to find commercially available products that can be integrated to meet the customer’s need  - Project funded by the US Department of Defence (DoD)  - Students developed mobile wireless ad hoc sensor and communication network  - Developed system supports real soldiers’ military training in cultural and social issues found in complex battlefields.  -Course introduces a human chain of command, teamwork and project mgt skills.  -Students had to create a physical artefact and validate it  - Steps: Concept design, detailed review, and real world simulation, and deployment.  - Project managers were doctoral students  - Industry mentors from DoD. | **Limitations/ Gaps/ and future research**:  The participants were too few to provide a generalisable conclusion from the study.  **Commercial Potential**:  A mobile communication system was developed and piloted by the DOD. But was never commercialised | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  |  | | **Continued** | **Continued** | | **Findings of the Study**:  - Project developed used Immersive Training Technology, to build a vest- the Immersive Training Vest (ITV), capable of simulating real battlefield scenarios through the use of force-feedback supplied by mechanical components.  - Students indicated that the new learning methods enabled them to better understand  the basics of systems engineering  - Critical thinking was found to be very important in engineering  **Applications/ Platforms/ Software/Hardware Used**:  WebEx,  **Academic Programme**:  Bachelor’s degree in the science, technology, engineering, or mathematics. |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 52 | Lobo, (2021).  IEEE Education Society Section. IEEE Access,  New Jersey Institute of Technology, USA. | | **Problem Statement**:  The exponential growth of technology in unmanned vehicles (drones) has led to  societal concerns because drone pilots have no proper training and pose potential threats to safety and privacy.  **Research Objectives**: To develop  and assess educational interventions that engage students in  the content and provides them hands-on experience in drone development.  **Conceptual framework**: Active learning approaches. | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Mixed Methods  **Data Collection:**  Multiple assessment methods.  **Population/ Sample:**  215 Students registered for the course | | **Curriculum Structure**:  -Active learning approaches used  -learners introduced to programming using Indoor Drone, Federal Aviation Administration Remote Pilot License Test, and a Capstone Drone Technology Project.  -Students were guided by instructors and lecturers  **Capstone Project**:  - Team formation among 2-5 participants  - A template for a project proposal given to students  - Use of canvas model to generate ideas  - Project management techniques for collaboration  - Weekly project meetings were held  - Class project presentations by teams  - A video presentation alongside a project report was final deliverable.  **Findings of the Study**:  - 90% of the projects involved the actual fabrication of a physical drone.  - Around 10% of the projects involved 3D CAD, dynamic simulations, and computational fluid dynamics analysis. | **Limitations/ Gaps/ and future research**:  Then study did not highlight the causes of differences between students’ performance on projects. This needs further analysis.  **Commercial Potential**: Not included | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued** | | **Continued** | **Continued** | | **Findings:**  **-** The course has completed four successful iterations since September 2019.  - The course attracted students from various backgrounds  - Quantitative results indicated that most students excelled at the technical subjects covered in the class.  - Focus groups and video presentation analysis revealed that students found regular check-in meetings with the professor and teaching assistant crucial for the success of their capstone projects.  **Applications/ Platforms/ Software/Hardware Used**:  - Python programming- Integrated Development Environment (IDE)  - Computer Aided Design Tools for drones  - Robotics programming  - Software applications such as Solidworks and ANSY  **Academic Programme**:  Students from mechanical, electrical, computer, biomedical, chemical engineering, and the computer science (C.S.) departments | **Limitations/ Gaps/ and future research**:  **Commercial Potential**: | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 53. | Schneider, et al., (2020).  IEEE, 2020 IEEE/ACM 42nd International Conference on Software Engineering: Companion Proceedings  Deakin University, Geelong, Australia. | | **Problem Statement**:  Designing capstone projects is a difficult task, involving a number of constraints that need to be carefully considered.  **Research Objectives**: To propose a novel,  scalable model for managing capstone projects called ACE.  **Conceptual framework**: Spotify’s Squads and Tribes organization to an educational  setting | **Research Design:**  Design Science  **Research Type:**  Solution Proposal  **Methodologies:**  Quantitative  **Data Collection:**  Survey/ Questionnaire  **Population/ Sample:** 350 students  **Data Analysis: Not included** | | **Curriculum Structure**:  The course is structured to provide:  - Industry relevant experience  - Authentic learning experience  - Continuity of learning experience  - A successful client experience  - Scalability of approach  - Effective support of students  **Capstone Project**:  The group project follows the following approaches:  - **Squad**: the group of students who implement the project  - **Product Tribe**: a large, long-term product undergoes enhancements over a number of teaching periods;  - Guided by a **Product Owner** who is an industry representative  - **Tribe Leader**: an academic staff member with a specific interest in the project  - Project Supervisor: an academic staff member, who oversees the students’ work.  **Applications/ Platforms/ Software/Hardware Used**:  -Agile Software Engineering  - Problem Based Learning  **Academic Programme**: BSc. IT., and MSc. IT | **Limitations/ Gaps/ and future research**:  Paper did not detail how the new mode of managing capstones contributed to individual and group performance.  **Commercial Potential**: Not included  **Findings of the Study:**  - Most respondents felt that the capstone course created an experience similar to what is expected in industry  - The capstone experience improved students’ IT skills.  - Further, most students felt positively about the mentoring of Junior students by their Senior counterparts, | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 54. | Iacob & Faily (2019).  Elsevier/ Science Direct  Journal of Systems and Software,  University of Portsmouth, United Kingdom | | **Problem Statement**:  Social and teamwork issues have been consistently identified as serious problems in SE capstone projects.  **Research Objectives**:  -Examine expectations that students have in terms of teamwork at the start of a software development group project.  - Study the perceptions of undergraduate students of their past experience with teamwork in SE projects.  **Conceptual framework**: | **Research Design:**  Longitudinal study of 2 academic years  **Research Type:**  Case study  **Methodologies:**  Mixed methods  **Data Collection:**  Interviews and Focus Groups, Doc Analysis  **Population/ Sample:**  70 students (35 year)  **Data Analysis:** Qualitative and Quantitative | | **Curriculum Structure**:  Students introduced to the basics of team work in second year  **Capstone Project**:  -Students work in teams of 5-6 students  - There are 35 teams of students  - Students develop a medium size software system of their choice  - The project runs for 27 weeks  - Students submit deliverables over the academic year  - Steps of the Projects:  1) Project plan and proposal (Plan)  2) System requirements specs. document (SRS)  3) Design documentation (Design)  4) Prototype: includes a demo of the prototype, source code, and test cases written for the system.  5) Report/ Retrospective account of the project.  - No allocated clients for the projects  -Teams were allowed to choose a convenient programming language to use.  - Periodically submit video demos of the system  **Applications/ Platforms/ Software/Hardware Used**:  -Prototyping,  -BitBucket, GitHub.  **Academic Programme:**  **BSc. Software Engineering.** | **Findings of the Study**:  -Students observe that teamwork is a very important component of capstone projects  - Deadlines were reported to be very important in achieving project goals.  -Opportunistic behaviour affects performance  -Lack of leadership affects team performance  -Remote communication was found to be difficult as compared to face to face.  -Team enthusiasm reduced as the project progressed, due to stress of working with people they had not worked with before  -Informal communication may enhance team performance and team collaboration  -Often project deliverables deviated from initial plan; Due to team conflict and miscommunication  -Some team operated as one-man teams and this affected their performance  **Limitations/ Gaps/ and future research**:  The studies students to rate a limited number of scenarios, and did not ask them to foresee any other additional breakdown scenarios. The authors did not follow up the survey with interviews, so as to to clarify the quantitative data gathered.  A follow up study is needed in this regard  **Commercial Potential**:  Only prototypes were produced and never commercialised. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Curriculum Design, Capstone Structure, Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 55. | Do (2013)  Science Direct/ Mechatronics  Daegu University, South Korea | | **Problem Statement**:  Experience has shown that there are several practical problems in Capstone project management. E.g. differences between project plans & academic achievement; different students in the same group have different skills, experienced students complain about unfair assessments, and the design of mechatronics projects can be more expensive than students can afford.  **Research Objectives**: To explore results of a multi-objective model for students’ assessment in SE projects.  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Experience Report  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires  **Population/ Sample:**  **40 students**  **Data Analysis:** | | **Curriculum Structure**:  - Curriculum follows Accreditation Board of Engineering Education of Korea (ABEEK), similar to ABET of the United States  -Students taught the basics electrical/electronic eng. in the first 2yrs  -**Year 1:** Students introduced to introductory engineering design, computer programming, engineering maths, electric circuits, digital logics, technical writing, & physics  -**Junior Year:** Students study Automatic Control, Microprocessors, Power Electronics, Numerical Analysis, Instrumentation& Measurement, Sensor Systems, Signal & Systems  - **Senior Year:** ECEM program teaches advanced topics & application-oriented courses, Robotics, Artificial Intelligence, Intelligent Control, Digital Control, Digital Signal Processing, Embedded Systems, & Network for Automation.  - Students work in 2 incubation labs/ inculabs: Electronic Control Systems Inculab & the  Intelligent Automation Inculab.  -Projects supported by Samsung Software Membership club.  **Capstone Project**:  -Students choose a project objective they feel they have skills in accomplishing.  -Follow parallel or serial structure of project implementation | **Findings of the Study**:  - Over 92.5% of the students completed their projects managed using the parallel and serial structure  - 2 vision sensing projects were successfully implemented with three objectives with different difficulty levels.  - Outcomes from both projects were satisfactory.  - Students, including weak students, were quite motivated and actively worked to achieve their project objectives.  - Most weak students completed their work successfully, and this allowed them increase their confidence.  **Limitations/ Gaps/ and future research**:  The study did not consider the increased workload and instructional burden on the supervisors. This needs to be investigated further.  **Commercial Potential**: 2 projects were produced and incubated in the 2 labs. But these were only assessed as academic projects. Not commercialised on the market. | |
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|  | **Continued** | | **Continued** | **Continued** | | **Capstone continued**  **Projects ideas given to students include:**   * Sensors and automatic systems, sensor specifications. * Sensor data processing, error, least squares fit, redundant sensor fusion. * Vision sensors, vision system structure. * Various image formats. * Digital image processing techniques. * Camera calibration, 3D vision.   **Students in this project developed**:   * Fire-detecting mobile robot constructed for open-ended student design. * Rock-scissors-paper gamer robot   **Applications/ Platforms/ Software/Hardware Used**:  **Academic Programme**: BSc. Mechatronics Engineering- Electronic Control Engineering Major (ECEM) |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Curriculum, Capstone Structure, Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 56. | Jia, et a., (2019).  Elsevier/Science Direct  Science of Computer Programming  Beihang University, Beijing, China | | **Problem Statement**:  In agile projects, developers find it hard to assimilate and transform the  Original requirements into system functions in the form of user stories.  **Research Objectives**:  The study draws an understanding  of developers’ cognition, predicting and guiding software developers’ behaviours toward  achieving good quality requirements analysis.  **Conceptual framework**: Cognitive contexts of software developers. | **Research Design:**  Cross Sectional  **Research Type:**  Exploratory research  **Methodologies:**  Mixed: combination of qualitative and quantitative data was used  Mathematical modelling using equations.  **Data Collection:**  Audio discussions and recordings  **Population/ Sample:**  133 undergrad students  **Data Analysis:** Microsoft Excel**,** transcription of qualitative data | | **Curriculum Structure**:  - In the past eight semesters, students complete other compulsory courses for graduation, for example, data structure, algorithm analysis, C++ programming and Java programming, object-oriented programming, system analysis and design, and database design.  -These prepare them for the capstone course  **Capstone Project**:  - Students apply the theoretical knowledge in previous semesters in the capstone projects  - 17 project development teams  - Compulsory for all students  - 3 lecturers guide the students  - The capstone course is done as an internship at a software development company or lab  - Students work in teams of 7-9 people  - All teams were asked to develop a web-based email mgt system for an SME  - Use of Scrum methods  - Students used project crafts, including story  board, burn-down chart and emotion charts  -Students work for 8 hours a day  - Each team used an agile method to develop the project  -Work is divided into sprints  -Students collect requirements in the first sprint. | **Findings of the Study**:  - Study found that developers do not focus on requirements activities while defining user stories.  - Developers are still stereotyped as technical thinkers.  -Developers’ cognition is unfavourable to requirements analysis  - The few developers who focused on requirements found it easier to discuss and analyse roles and the business value of user stories than user story’s activity.  **Limitations/ Gaps/ and future research**:  Some teams of developers among students (37%) did not communicate in the projects and could not be recorded. This is because Chinese students are usually silent when conducting tasks. The cognitive behaviours of these could not be assessed. A further experiment involving all teams orally communicating is necessary.  The sample size was too small and thus not very generalisable.  **Commercial Potential**: Projects were successfully implemented but not commercialised by the students. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued** | | **Continued** | **Continued** | | **Capstone Projects:**  - Teachers act as users and provide requirements for the system  - Teachers provide original and crude business requirements  - requirements are given as a template of a user stories  **Applications/ Platforms/ Software/Hardware Used**:  Scrum and Agile Project mgt  Java programming, C++ programming, HTML  **Academic Programme**: BSc. Software Engineering. |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Curriculum Structure, Capstone Structure, Results of Project** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 57. | Baldassarre, et al, (2021).  Elsevier/ Science Direct  The Journal of Systems & Software  University of Bari, Italy | | **Problem Statement**:  The effect of incremental development approaches among novice system developers is usually difficult to ascertain.  **Research Objectives**:  To we investigate the effect of Test Driven Development (TDD), as compared to a non-TDD approach, as well as  its detainments (or retention) over a time span of (about) six months.  **Conceptual framework**:  TDD approach to systems development | **Research Design:**  Longitudinal Study  **Research Type:**  Experimentation  **Methodologies:**  - Quantitative, inferential statistics, convenience sampling  -Descriptive statistics and exploratory analyses  - Inferential Statistics. We used the Linear Mixed Model  (LMM) analysis method  **Data Collection:**  Online Questionnaire using Google Form  **Population/ Sample:**  30 novice developers (i.e., third-year  undergraduate students in Computer Science)  **Data Analysis:** Quantitative | | **Curriculum Structure**:  - Training sessions in TDD & systems testing  - Students participated in both face-to-face lessons and laboratory sessions  - Students also enrolled in a Software Quality course  - Students did not have prior knowledge of TDD  - Students had prior training in Procedural Programming, Object-Oriented Programming, Software Engineering, and Databases.  **Capstone Project**:  - 30 novice developers  - similar skills and experience  - Use of agile development methods  - All developers attend same TDD training  - 4 experimental sessions over 6 months  - Each participant had to perform developmental tasks using either TDD or non-TDD methods.  -Before 1st experiment, all participants practiced unit testing, iterative test-last development, & big-bang testing  - Students developed programing exercises called code katas:  - Bowling Score Keeper (BSK) App  - Mars Rover API (MRA)  - An API for a basic spread sheet | **Findings:**  - TDD affects neither the external quality of software products nor developers’ productivity.  - Participants applying TDD produced significantly more tests, with a higher fault-detection capability, than those using a non-TDD approach.  - TDD is retained by novice developers for at least six months  **Limitations/ Gaps/ and future research**:  - Participants in the study were volunteers.  This might have threatened the validity of the results because volunteers might be more motivated than the overall population  - Some participants might have exchanged results out of the lab setting  - Mono-method biases  **Commercial Potential**: Not included. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued** | | **Continued** | **Continued** | | Participants uploaded their tasks on GitHub at the end of each session  **Applications/ Platforms/ Software/Hardware Used**:  - Iterative designs  -Test Driven Development  -Agile Methods  Java programming language  JUnit and Eclipse were the testing framework  Integrated Development Environment (IDE), respectively.  -GitHub for project presentations  **Academic Programme**:  BSc. Computer Science |  | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
| 58. | Sasipraba, et al, (2020).  Science Direct/  Procedia Computer Science  Sathyabama Institute of Science and Technology, India | | **Problem Statement**:  One of the most challenging aspect is to formulate an assessment method for capstone projects in Outcome Based Education.  **Research Objectives**:  This paper discusses the assessment methodology and rubrics followed in capstone projects at an Indian University (Sathyabama Institute of Science & Technology).  **Conceptual framework**: OBE evaluation framework | **Research Design:**  Cross Sectional  **Research Type:**  Experience Report  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included. | | **Curriculum Structure**:  - Curriculum consists of Basic Sciences, Engineering Sciences, Humanities and Social Sciences, Program Core, Program Electives, Open Electives, Capstone Project and  - Professional Training. Research about COs attainment in various subjects like Data Structure, Engineering Chemistry, Micro Controllers, Automated Tool, Control System, Ethics  **Capstone Project**:  -Projects are divided into **Design/Simulation**  **projects, Application projects, Application projects** with an emphasis on **environmental sustainability and Industry.**  -Course Outcomes (COs) are framed based on both Cognitive and Psychomotor aspects  - Students must show comprehension of critical problems, Quality and stability, Control of Electrical drives, embedded systems, VLSI, signal/Image processing and IOT  - Students review literature to see weaknesses in existing models  - Implement a proposed methodology  - Develop a prototype  - Present the prototype in a Viva Voce | **Findings.**  - Rubrics developed helped define problem  definition and literature survey  -Defined rubrics helped in the assessment of  - The proposed assessment technique helps in accurate evaluation of the student’s performance and identifying gaps.  - Results obtained from the evaluation method can be used to increase the quality rate of students’ projects. | |
| No. | **Author, Year, Journal, Country, Database** | | **Problem investigated, Research Objectives,& Theoretical/ Concept Frame** | **Methodology** | | **Findings/ Results of Project** | **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** | |
|  | **Continued** | | **Continued** | **Continued** | | **Capstone Project**:  - External and internal examination of projects  **-Students must demonstrate an ability to communicate effectively about their project.**  **Applications/ Platforms/ Software/Hardware Used**:  Prototyping  **Academic Programme**:  Not included | **Limitations/ Gaps/ and future research**:  Based on a case study of only a few students.  **Commercial Potential**:  Students only develop prototypes that they never commercialise. | |

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| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| 59. | Fauzi & Andreswari (2022).  Elsevier/ Science Direct  Procedia Computer Science,  Telkom University, Indonesia | **Problem Statement**:  A number of issues occur during system analysis and development. These include deadlocks, lack of synchronization, superfluous activity, labelling issues, line crossings, and crooked alignment. It is difficult to know the role of different members of the system development team in averting these.  **Research Objectives**:  To identify the programmer's contribution in the software engineering course.  **Conceptual framework**:  SERQUAL Framework | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  -Quantitative  - Process Mining Techniques  - System log analysis  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included. | **Curriculum Structure**:  System development course structure  Students are introduced to soft and hard skills  **Capstone Project**:  - 7 department teams  - 3 programmers per team  - The team analysed programmers’ workflows on all teams  -Some programmers had been reported not be working according to their work schedules  - The team of researchers generated programmers workflows using a software called Apromore  - Event logs were generated and analysed  - Semantic, systematic and pragmatic issues were identified and analysed  - The project resulted in the creation and implementation of a Comprehensive Process Model Quality Framework (CPMQF).  - Each team goes thru these steps: Open, Implement Tasks, Resolved, Merge Branches & Close  **Software, development approaches, technologies used:** System Analysis and Design; Apromore  **Academic Programme:** Not included. | **Findings:**  **-** A Comprehensive Process Model Quality Framework (CPMQF) was developed  - 39 quality dimensions were identified  - 21 quality metrics  - 28 sub drivers of quality  - 64 realization metrics  - 15 concrete process objectives  It was found that programmers contributed less when compared to project managers and system analysts.  **Gaps/ Limitations/ Areas of further study:**  - Paper concentrated on the role played or not played by the programmer in causing issues relating to systems. Other participants of these system development projects were not analysed by the researchers.  There is need to make a more extensive study, analysing the role of each of the project development team in managing system quality.  **Level of Commercialisation**: Not mentioned in this paper. |

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| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| 60. | Ardis, Hole, & Manfredonia (2013).  Elsevier/ Science Direct  Procedia Computer Science  Stevens Institute of Technology, USA | **Problem Statement**:  Good capstone experiences involve sponsors with real needs. Finding and engaging such sponsors takes time and effort by faculty that might be better spent on other tasks.  **Research Objectives**:  This paper describes an on-going pilot project to develop a marketplace for multidisciplinary systems engineering capstone projects.  **Conceptual framework**:  Senior Design Marketplace Model at Stevens Institute of Technology | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  - 360 students  - 50 Staff members  **Data Analysis:** Not included. | **Curriculum Structure**:  ***In Year 1***:  - 50 faculty from 14 schools developed systems engineering courses and multi-disciplinary systems engineering capstone experiences for more than 360 students.  - **Introductory classes in**: Systems Planning, Research Development, & Eng. (SPRDE) Career Field/Systems, Engineering (SE) & Program Systems Engineer (PSE) competency model.  **Capstone Project**:  - Students from 6 different universities joined online SE projects  -Students applied to projects that were posted to the marketplace website by sponsors  - Sponsors from government and industry.  - Each team includes students from different disciplines and different schools.  - The aim is to determine the requirements for a global electronic marketplace and to develop guidelines for faculty, students & sponsors who would use it.  - 3 or 4 faculty members of different disciplines work with each design team  - Faculty help students to form teams, define problems, coordinate and supervise them, guide them on the project. | **Findings:**  - The developed project was posted as a potential Senior Design project for the EM class of 2012.  - Majority of the students preferred an interdisciplinary project  - 70% were interested in a central marketing place portal  - Three project ideas have been posted on the market place and partially sponsored  **Gaps and Future Study areas:**  The marketplace is still in its infancy and the team had not incorporated a team building option on the portal. There is need to review and improve the site to allow team members to collaborate and communicate more easily.  **Commercialisation Prospects: Partially implemented but not commercialized.** |

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| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Curriculum and Capstone Structure, Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
|  | **Continued** | **Continued** | **Continued** | **Capstone Project**:  - Some teams that work on similar artefacts are combined into larger teams and given more supervisors  - This comes with more supervisory effort from the faculty.  - The teams were multi-school  - The project encouraged collaborations across universities between staff and students  -Schools with more mature systems or teams were requested to team up with less experienced teams to get the best out of the project.  **Software, development approaches, technologies used:**  Google+, Twitter, Facebook for project ideas  HTML, PHP, and MySQL for web programming  Prototyping as a design approach  **Academic Programme:** |  |

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| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| 61. | Lin, et al., (2015)  Elsevier/ Science Direct  Procedia Computer Science  Purdue University, Indianapolis, Indiana, USA | **Problem Statement**:  Software testing is constrained by low budgets, release time, and large, complex domain of work beyond human intuition. This leads to incomplete, inconsistent, & erroneous software products released on the market.  **Research Objectives**:  To develop automated statistical software that sets quizzes & produces quantitative data quickly and easily.  **Conceptual framework**:  Sequence-based software specification and Markov chain usage-based statistical testing. | **Research Design:**  Design Science  **Research Type:**  Action Research  **Methodologies:**  Quantitative  **Data Collection:**  System Analysis  Mathematical modelling  **Population/ Sample:**  4 students  **Data Analysis:** Not included. | **Curriculum Structure**:  Students introduced to statistical modelling,  **Capstone Project**:  -Project undertaken based on the University of Tennessee Software Quality Research Laboratory (UTK SQRL)  - Students developed a BlackBoard Quiz Editor (BBQE) system that can write quizzes and save them in a format that can be imported in BlackBoard.  - The BBQE interface contains three main areas: ***a main toolbar, a quiz panel, and a question editor panel***.  -BBQE supports 11 question types  **Software, development approaches, technologies used:**  - Sequence-Based Software Specification (SDLC)  - Markov chain usage models  -Mathematical modeling and model analysis  - BlackBoard.  - Java GUI application  - J Usage Model Builder Library (JUMBL)  -Automated Testing Frameworks- HP’s Quick Test Professional (QTP)  **Academic Programme:**  BSc. Computer Science | **Findings.**  The software that was developed is being used by the client and many other instructors in Ball State.  - At the end of this process the researchers had built the ability to run large numbers of statistical tests,  - Development of an automated testing facility at low-cost, quick-turnaround testing and re-testing.  -Researchers indicate that their experiences demonstrate a solution of reduced cost of system testing and improved product quality.  **Limitations:** Study based on a case study of only 4 students. The sample was too small to make generalisable conclusions from the projects. A more comprehensive study of similar projects is needed.  **Commercialisation**: Project already being used by client. |
| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
|  | Spillane, Menold, & Parkinson (2020).  Elsevier/ Science Direct  Procedia Manufacturing  Pennsylvania State University, USA | **Problem Statement**:  Engineering domains that typically focus on computational projects, e.g. computer engineering (CE), computer science (CS), and Industrial Engineering (IE) do not receive the same benefit joining learning factories like mechanical and industrial engineers in the US.  **Research Objectives**:  To explore how  Learning Factory Environments provide hands-on experiences to a broader range of engineering fields, e.g. CS, CE, & SE.  **Conceptual framework**:  Learning Factory Models of Engineering | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included.  **Academic Programme:**  BSc. Computer Science, BSc. Computer Engineering, BSc. Mechanical Engineering &  BSc. Industrial Engineering | **Curriculum Structure**:  Knowledge of integrating manufacturing engineering skills in CS and SE.  **Capstone Project**:  - Students formed multidisciplinary teams  - The Learning Factory at Penn State University partnered with an industrial  provider to place 20 commercial sensors on traditional manufacturing equipment  - The LF is an industry-sponsored active learning environment which gives students an opportunity to experience real-world design problems  - Students work with an external client for their capstone project  - The projects are multidisciplinary and identified by administrators and clients  - Students select their preferred projects basing on their expertise, availability, and willingness to meet intellectual property requirements  - Students work in teams of 4 to 6.  - At the end of the project students must document their project & prototype, test their designs to produce a final product, poster, and report for the end of the semester  **Software, development approaches, technologies used:** CAD/CAM tools, IoT, MATLab, 3D Printers. | **Findings.**  - 6 capstone design projects completed by interdisciplinary teams of engineering students at Penn State  -Teams developed a virtualisation system for capstone projects, a remote monitoring system for printing resources in the factory, and an activity tracking system for the LF.  **Limitations & Future Work:**  Of the 250 projects undertaken annually at the University, the study only analysed 6 projects and only 3 projects were finally considered for the discussion. This sample was not representative of all SE capstone projects undertaken by Pen State University.  **Commercialisation**: Only a project report and prototype was released at the end of the projects. There was no commercialisation and up-scaling of the projects developed by students. |

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| No. | Author, Year, Journal, Country, Database | Problem investigated, Research Objectives,& Concept Frame | Methodology | Findings/ Results of Project | Findings of the Study/ Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project |
|  |  |  | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included. | **Academic Programme:**  BSc. Computer Science and Computer Engineering | **Findings.** |
| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study**/ **Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
|  | Zegura (2020).  Elsevier/ Science Direct  Procedia Manufacturing  Pennsylvania State University, USA | **Problem Statement**:  Engineering domains that typically focus on computational projects, e.g. computer engineering (CE), computer science (CS), and data science (DS) do not receive the same benefit joining learning factories like mechanical and industrial engineers in the US.  **Research Objectives**:  To explore how  Learning Factory Environments provide hands-on experiences to a broader range of engineering fields, e.g. CS, CE, & SE.  **Conceptual framework**: | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included. | **Curriculum Structure**:  **Capstone Project**:  **Software, development approaches, technologies used:**  **Academic Programme:**  BSc. Computer Science and Computer Engineering | **Findings.**  Zegura, E.W. () Achieving and Assessing Service in Computing Service Learning: Lessons from Computing for Good Professor, School of Computer Science Georgia Tech Atlanta, GA, USA. International Journal for Service Learning in Engineering Special Edition, pp. 424–438, Fall 2014 ISSN 1555-9033 424 |

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|  | Nanda, G., Lehto, & Nof (2014)  EBSCOHOST.  Human Factors and Ergonomics in Manufacturing & Service Industries, | **Problem Statement**:  **Research Objectives**:  To determine the most important WEB 2.0 Collaborative features of HUBzero, a prototype used in managing capstone projects.  **Conceptual framework**: | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative  **Data Collection:**  Questionnaires and final project evaluations  **Population/ Sample:**  50 students  **Data Analysis:** Not included. | **Curriculum Structure**:  **Capstone Project**:  **Software, development approaches, technologies used:**  - Prototyping  **Academic Programme:**  BSc. Computer Science and Computer Engineering | **Findings.**  Nanda, G., Lehto, M. R., & Nof, S. Y. (2014). User Requirement Analysis for an Online Collaboration Tool for Senior Industrial Engineering Design Course. Human Factors and Ergonomics in Manufacturing & Service Industries, 24(5), 557–573. https://doi.org/10.1002/hfm.20551 |

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| No. | Author, Year, Journal, Country, Database | Problem investigated, Research Objectives,& Concept Frame | Methodology | Findings/ Results of Project | Findings of the Study/ Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project |
| 62. | Shaikh, M.K. (2021)  Science Direct/ Heliyon  Federal Urdu University of Arts, Science & Technology,  Federal Urdu University of Arts, Science & Technology, Karachi Pakistan | **Problem Statement**:  After a preliminary review of 19 research articles on SE capstone project team building, none of these articles were conducted with the students, and none of them proposed team building criteria for the students.  **Research Objectives**:  To describe how students can select by themselves their project team members in order to form a cohesive team.  **Conceptual framework**:  The Knowledge, Skills, Abilities and Others (KSAO) framework | **Research Design:**  Cross Sectional  **Research Type:**  Experiment (Randomised Control Trial)  **Methodologies:**  Mixed Methods: Quantitative & Qualitative  Experimentation  **Data Collection:**  - Student Interviews  - Questionnaires  - Review of student literature (using the Knowledge, Skills, Abilities and Others (KSAO) framework proposed in Shaikh *et al* (2018).  **Population/ Sample:**  200 students  **Data Analysis:** Not included. | **Curriculum Structure**:  Not included.  **Capstone Project**:  - Students perform their projects in groups  - 2 large groups (classes) of students were analysed from which project teams are drawn  - One group of 100 had graduated from the capstone the previous year without using the proposed team formation framework (control group)  -The other was the current lot that was required to use the KASO framework  **Software, development approaches, technologies used:**  - System Design  - Project Management approaches  -Team building and Interpersonal Approaches  - Psychographd- a software developed for  recording the responses of the students on the psychographic self-evaluation questionnaire.  **Academic Programme:**  BSc. Software Engineering | **Findings.**  - The **level of cohesion in teams that were formed using the proposed team building criteria was found to be higher**.  - 128 team building criteria were proposed for forming self-managing teams of software engineering capstone project students  **Research Contribution**  The criteria are first of their kind to be proposed for the SE students under the guidance of a conceptual framework developed for guiding this research.  **Gaps/Future work:**  - The study was undertaken at before covid 19 and done physically. It would be interesting to see a similar study these criteria in an online collaborative working environment, and use of them in a software house setting.  **Commercialisation Possibility**: Not included. |

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|  | Centea et al., (2020).  Science Direct/ Procedia Manufacturing  McMaster’s University by the School of Engineering Practice and Technology (SEPT), Canada | **Problem Statement**:  Engineering graduates find it hard to implement Industry 4.0 concepts in SMEs, since they are not usually equipped with multidisciplinary capabilities & skills. Canadian manufacturers (who employ these graduates) thus face competition from South East Asian competitors since they have not quickly adopted IoT  **Research Objectives**:  To introduce elements related to Internet of Things and Industry 4.0 concepts.  **Conceptual framework**: Application of Industry 4.0 (IoT) and a Learning Factory Model in an SME production line. | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Qualitative methods  **Data Collection:**  - Observation  -System analysis  - Narrative case study  **Population/ Sample:**  2 students  **Data Analysis:** Not included. | **Curriculum Structure**:  - A partnership btn a local SME and SEPT  - SME wanted to solve its production challenges  - An opportunity to for students to implement an industrial automation in real production.  - Introduction of learners to industrial prototyping, CAD systems, Design thinking, Social analysis  **Capstone Project**:  - Students started by an analysis of production challenges identified by the SME. - They identified problems, proposed solutions  - Ranked priorities of solutions from both client and student’s perspective.  - An analysis showed that the problems could be solved by automating the process line.  - They used a Learning Factory Approach  -Students implemented Industry 4.0 manufacturing paradigm in the SME.  - System modelled data access and supervisory control applications implemented locally, IoT applications that allow moving data to a remote location, and AI.  **Software, development approaches, technologies used:**  - Industrial Prototyping, Problem Based Learning, Netowrking with Ethenet cables, OPC (Object linking and embedding for Process Control) Data servers, Artificial Intelligence (AI) & IoT, MatLab Software, CAD, Social analytics (empathy, HC Design, etc.).  **Academic Programme:** BSc. Manufacturing Engineering. | **Findings:**  Study demonstrates that SMEs can grow and become examples of applying Industry 4.0 tools which increase optimization of production processes and improvement of quality of their business.  **Research Contribution**  The study introduces a collaborative framework between IT/ SE faculties and businesses. The model demonstrated helps SMEs automate their systems and achieve competitiveness.  **Gaps/Future work:**  Only 2 students working with a partnering SME were studied. This is a very small sample and not representative of collaborative capstone projects.  **Commercialisation Possibility**:  Not included |
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| 63. | Khakurel, J., & Porras, J. (2020).  IEEE Library  *32nd IEEE Intl. Conference on Software Engineering Education & Training*  LUT University, Finland | **Problem Statement**:  While research suggests that employers highly value various soft skills when recruiting software engineering (SE), most SE graduates tend to lack these skills.  **Research Objectives**:  To examine the effects of a capstone course with a problem/project-based approach in the acquisition of soft skills.  **Conceptual framework**:  Problem Based Approaches to attainment of soft skills in capstone projects. | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Qualitative methods  **Data Collection:**  - Thematic analysis of students reports  - Description, analysis, and reporting of themes and patterns in data  -Emails and phone call interviews from clients/ external customers  **Population/ Sample:**  74 participants  -48 students plus  -26 respondents from the software industry  **Data Analysis:**  Basic Content analysis, extraction of categories and themes. | **Curriculum Structure**:  Not included.  **Capstone Project**:  - Human-centric projects are developed  - Projects span a full academic year  emphasize group work (5-6 students)  - Emphasize real implementation beyond concept implementation.  -Projects have real customers other than the supervisor  -Customers set requirements and students strive to meet them  - Projects range from mobile applications, online tools, digitalization processes, financial mgt tools, recruitment platforms, hardware and software updating tools, gaming tools, digital services platforms  -Students face problems implementing their projects due to busy schedules  - Students followed an iterative design process  - Students implement systems from scratch  At the end of the projects all students were told to write reports about their experiences.  **Software, development approaches, technologies used:** GiTLab, Design Thinking  Agile Methods  **Programme:** BSc. Manufacturing Engineering.  **Commercialisation Possibility**: Although the projects undertaken had real industry sponsors, they were never commercialised. | **Findings:**  - The 15 soft skills that were identified included:  -External; and internal communication; interpersonal; responsibility; eagerness to learn; critical thinking & problem-solving; teamwork & collaboration; organizational; ability to work independently; working under pressure; openness to change & adaptability; motivation; leadership; customer orientation;& conflict management.  - Majority of identified soft skills in this course correspond to industry-preferred soft  - The most important skills were external and internal communication, and organisational skills.  - The least preferred skill was working under pressure  - The PrBL approach to capstone projects is a powerful way of improving soft skills of the graduate students to meet the needs of employers, and increase employability.  **Research Contribution**  **Gaps/Future work:** The study concentrated on data provided by students in their reports, rather than examining them and identifying the said skills throughout the Project Life cycle. The data provided by students may not have been reliable enough. Data from customers was collected by phone calls and emails and its authenticity could not be easily verified. |

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| 64. | Janse van Rensburg & Goede (2020).  Emerald Insight  Higher Education, Skills and Work-Based Learning  North–West University, South Africa | **Problem Statement**:  While research suggests that employers highly value various soft skills when recruiting software engineering (SE), most SE graduates tend to lack these skills.  **Research Objectives**:  To present an intervention strategy for promoting career awareness among information technology (IT) students in a South African context  **Conceptual framework**:  Problem Based Approaches to attainment of soft skills in capstone projects. | **Research Design:**  Design Science  **Research Type:**  Experience Report  **Methodologies:**  Qualitative methods  **Data Collection:**  - Interpretive Questionnaire sent via a Google Form  - Open Ended Questions  - Thematic analysis of students reports  - Description, analysis, and reporting of themes and patterns in data    **Population/ Sample:**  There were 82 South African graduates included in the analysis.  Only 32 completed the questionnaire  **Data Analysis:**  Basic Content analysis, extraction of categories and themes.; Atlas.ti version 8.4 | **Curriculum Structure**:  -Students undergo a 3 year programme in IT  -Students elect to go for a fourth year in graduate studies and employment to get experience  -Students are taught a combination of technical skills in programming and soft skills  -Technical Skills: C++, C, C#, Python, Java, Javascript and DevOps  -Soft Skills: Written & verbal communication, problem solving, creativity, time management, team work and willingness to learn  -Some do internships of 10-16 weeks.  **Capstone Project**:  Students work with companies like Microsoft, Accenture, Standard Bank, IBM, Amazon, First National Bank, Deloitte, PwC  -Project based model to the capstone  - Project developed based on industry standards  - Work integrated learning is used  - Reflective learning: students reflect on which approaches are most appropriate in the industry  - Students uploaded finished projects on LMS  - A central folder with job opportunities was created on the LMS and students posted their skills acquired from the projects.  **Software, development approaches, technologies used:** Project Based Learning, Reflective Learning, C++, C, C#, Python, Java, Javascript and DevOps  **Programme:** BSc. Information Technology. | **Findings:**  - The final year project made students more productive and raised career awareness among IT students about participating in the industry participation;  - Students became aware of their employability, limitations& preferred career paths;  **Research Contribution**  The paper provides an instructional design module for bridging IT theory and practice, and raising career awareness among students.  **Gaps/Future work:**  Only 32 of the 82 students were involved in the study. The sample was too small for results to be generalisable.  The study did not highlight how to ascertain individual contributions of team members to a project, and this should be addressed by using tools for source control.  **Commercialisation Possibility**: Not included. Much emphasis was on improving employability of graduates and not on encouraging entrepreneurship and commercialisation of projects. |
| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study/ Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
|  | Gilbert & Wingrove, (2019).  Emerald Insight  Higher Education, Skills and Work-Based Learning  Royal Melbourne Institute of Technology University, Melbourne, Australia | **Problem Statement**:  While it is known that capstone projects contribute to students transition into employment, it is not clear how learners perceive the development of employability as a result of a capstone course.  **Research Objectives**:  To explore and compare students’ perceptions of their employability through their experience of a  simulated or real-life project.  **Conceptual framework**: | **Research Design:**  Longitudinal Study of 3 years  **Research Type:**  Case study  **Methodologies:**  Qualitative methods  **Data Collection:**  Questionnaires  **Population/ Sample:**  131 students  **Data Analysis:**  IBM SPSS | **Curriculum Structure**:  -The project planning and management course is taught to equip students with PM skills like scheduling, formulation and management of budgets and procurement, plus other soft skills.  **Capstone Project**:  - Project is part of the Project planning and Management course  - The project seeks to challenge existing  assumptions, beliefs and knowledge  - Project designed to foster employability and transferable graduate attributes, including professional communication, interpersonal and leadership skills.  -Students engage in real world problem solving  -Experiential and student-centered learning is emphasized  - Students either choose a simulated project or a real life project  - Students take ownership as decision makers in their learning experiences  -Continued reflection on learning is emphasised  -The project aims at enabling the integration and application of knowledge and skills.  - Course runs for 12 weeks in the final semester  - Students do the work in groups  - Course is compulsory for all students  - Projects undertaken include:  - fund raising events for charities;  - Renovation of communal space for young people at risk of homelessness  - Associated website;  -Designing, manufacturing and implementing a project management game  for high school students,  -Making a video featuring project management staff, students and alumni.  - The projects are scored based on cost, time, quality, morale and efficiency.  **Software, development approaches, technologies used:** Project Management Approaches, PM software  **Programme:** e Bachelor of Applied  Science (Project Management). | **Findings:**  -Students undertaking a real-life project which makes a social contribution reported a significantly stronger development of work-ready skills in managing projects than students undertaking a simulation project.  - Interaction with industry and leadership were reported to be more developed in the projects.  **Gaps/Future work:**  The study did not establish the level of confidence students had in their work readiness before or at the start of the capstone course.  Future studies can be done to measure a student’s perception of their work readiness at several points throughout the capstone course and to investigate the choices that students make.  The study concentrated on one academic discipline and the study group was treated as homogenous. A more encompassing study having multi-disciplinary teams can be considered.  **Commercialisation Possibility**:  The study concentrated on employability of graduates and not commercialisation of their innovations. No single project was commercialised or taken onto the market. |

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| P66 | Chang, Shih, & Liao (2022).  Emerald Insight/ Emerald Publishing Limited  Education and Training,  National Taipei University of Technology, Taiwan. | **Problem Statement**:  28% of university  students do not know how to present an oral report, and 38% of them cannot write a report.  **Research Objectives**:  To study an industry-oriented capstone course aimed at increasing the employability of students in technological university.  **Conceptual framework**:  Not included | **Research Design:**  Cross Sectional  **Research Type:**  Quasi Experimental Case Study  **Methodologies:**  Qualitative methods  **Data Collection:**  Questionnaire (employability scale)  **Population/ Sample:**  48 students   * 22 students in the experimental group * 26 students in the control group   **Data Analysis:** SPSS | **Curriculum Structure**:  -An introductory course in Capstone Introduction”, “Report Writing”,  “Data Analysis Methods”, “Presentation Production Skills”, “Verbal Report Skills” and  “Achievement Exhibition and Evaluation is undertaken by students.  **Capstone Project**:  -4th year EECS students participated in the project  - divided into 2 groups  - Project took 30 weeks  - An employability scale pre-test and post-test scale administered to the experimental &  control groups to measure changes in the employability of the students.  -Course uses project management and problem solving techniques  **Software, development approaches, technologies used:** Project Based Learning, Problem Solving Techs,  **Programme:** BSc. Electrical Engineering and Computer Science (EECS). | **Findings:**  - Industry-oriented capstone courses can improve students’ employability,  - Capstone projects improve graduates behaviour and attitude.  - Capstones help students gain soft skills  **Researcher(s) Contribution:** This study provides evidence that industry-oriented capstone courses can improve EECS students’ employability    **Gaps/Future work:**  This was an experimental teaching project with a very small class size and the findings are constrained by the small sample  - This study was only able to randomly assign one class as the experimental group and one class as the control group, but it was not possible to increase the number of subjects, which may result in data bias.  - The questionnaire used may have data deviations due to social expectations and other phenomena; therefore, the interpretation of data should focus on the comparison of score differences.  **Commercialisation Possibility**: The study concentrated on employability of graduates and not commercialisation of their project. |

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| 67. | Meisel & Williams (2015).  Emerald Insight/ Emerald Group  Rapid Prototyping Journal  Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA | **Problem Statement**:  Due to cost, access to Additive Manufacturing (AM) technologies at academic institutions tends to be limited to upper-level courses to support project-based coursework. However, with the decreasing cost of desktop-scale AM technology, there is potential to improve student access to these technologies and provide more learning.  **Research Objectives**:  To present the design and implementation of a novel vending machine concept based on desktop-scale extrusion additive manufacturing (AM).  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Experience reports  **Methodologies:**  Mixed methods  **Data Collection:**  Questionnaires  System reviews  **Population/ Sample:**  268 respondents  **Data Analysis:**  Not included | **Curriculum Structure**:  - In the initial years students learn Print systems, CAD machines, and AM technologies.  **Capstone Project**:  - The project intended to design and implement an AM “vending machine” that is powered by  desktop-scale extrusion-based AM systems.  - Project aimed at lowering access barriers to AM technologies  - The DreamVendor vending machine system is housed within a single case or cabinet Vending machine was installed on Market Bot Interface  **Software, development approaches, technologies used:** MakerBot Thing-O-Matic (TOM) desktop-scale extrusion systems, 3D printers, SD Card, DreamVendor, Automated Build Platform with Conveyor Belt, Replicator G Software, G-Code, Android Software  **Programme:** BSc. Mechanical Engineering | **Findings:**  - This system developed provides students broad, unrestricted access to entry-level AM tools and promotes informal learning opportunities.  - 75 per cent of students are created their own designs rather than simply printing found design files.  **Gaps/Future work:**  **–** Study did not consider ease of use when designing system.  Future work must focus on improving the system’s ease-of-maintenance, lowering the barrier to entry with a simpler user interface and establishing a method for better recording part and user information  **Commercialisation Possibility**:  The developed system was installed onto the side of the vending machine and allows for assessment and feedback of student use of the DreamVendor. It is being used by the University. But not commercially available on the market. |
| No. | **Author, Year, Journal, Country, Database** | **Problem investigated, Research Objectives,& Concept Frame** | **Methodology** | **Findings/ Results of Project** | **Findings of the Study/ Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| 68. | Tang, Brockman, & Patil, (2021).  ACM Library  ACM Transactions on Computing Education  Indiana University Bloomington, United State | **Problem Statement**:  Most software produced today hinges on the need for privacy and security. However, the application of privacy ideation cards in real-world software projects has not yet been systemically investigated.  **Research Objectives**:  To examine the effectiveness of ideation cards as a pedagogical tool in software engineering.  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Qualitative and Quantitative methods  **Data Collection:**  Video recording or ideation sessions  Post-session report analyses  Quantitative analysis of data  **Population/ Sample:**  -106 students  **Data Analysis:**  Basic Content Analysis | **Curriculum Structure**:  -  **Capstone Project**:  -The project was aimed at investigating how teams of undergraduate students applied privacy ideation cards in capstone projects  - The teams were building real-world software for industry sponsors.  - Ideation and problem solving was used.  - 3 iterations of ideation sessions using Privacy Ideation Card (PICs) in undergraduate capstone courses involving real-world projects.  - Each iteration involved 1 cohort of software students who engaged in team sessions in which the teams applied PICs  - PICs were used as practical design tools intended to stimulate reflection and creative thinking  - The capstone took 2 terms/ semesters  - Done to help students gain hard and soft skills  - Students work in teams of 4 to 6  - Students work with an external sponsor, e.g. corporations, gov’t organizations, educational institutions, and non-profits.  -24 teams were studied  - Students created email schedulers, improved User Interface (UI) design of video games, and conversational applications, mobile apps, desktop apps, chrome extensions, database dashboard, web applications, smart office assistants, etc.  - Students implemented project up to a functional prototype or proof-of-concept, along with associated documentation such as requirements (in the form of use cases or user stories).  **Software, development approaches, technologies used:**   * Privacy Ideation Cards, * Reflective Learning Models, * Problem Based Learning, Unified   Modelling Language [UML] diagrams  UI/User eXperience [UX] mockups.  **Programme:** Not included | **Findings:**  The study found that privacy ideation cards fostered greater consideration and understanding of the need to align SE projects aligned with privacy regulations.  - 3 main themes from student discussions of privacy compliance:  (i) defining personal data;  (ii) assigning responsibility for privacy  (iii) determining & exercising autonomy.  - Pedagogically, ideation cards can facilitate low-level cognitive engagement (especially the cognitive processes of meaning construction and interpretation) for specific components within a project.  - Higher-level cognitive processes were comparatively rare in ideation sessions  **Gaps/Future work:**  - The study did only one ideation session during each offering of a two-term course. Therefore, the results do not present a comprehensive view of privacy compliance as an on-going practice throughout the software development lifecycle.  -Future studies could repeat the ideation sessions multiple times during a project and examine the changes across the stages in privacy compliance proficiency and processes.  - The study participants were university students, who were not yet industry professionals.  Future studies with industry professionals could help understand the generalizability of PICs as a training tool for experienced developers.  **Commercialisation Possibility**:  Not commercialised since the study concentrated on the capstone project before participants’ entry into the industry. |

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|  | Parker, R., Sangelkar, S., Swenson, M., & Ford, J.D. (2019).  International Journal of Engineering Education  University of Colorado at Boulder, USA. | **Problem Statement**:  **Research Objectives**:  To apply industry-oriented capstone courses in increasing the employability of electrical engineering and computer science (EECS) students in technological university.  **Conceptual framework**:  Not included | **Research Design:**  Cross Sectional  **Research Type:**  Case Study  Quasi Experimental Design  **Methodologies:**  Qualitative methods  **Data Collection:**  Questionnaire (employability scale)  **Population/ Sample:**  140 students  **Data Analysis:** SPSS | **Curriculum Structure**:  -  **Capstone Project**:  -  **Software, development approaches, technologies used:**  **Programme:** BSc. Electrical Engineering and Computer Science (EECS).  Parker, R., Sangelkar, S., Swenson, M., & Ford, J.D. (2019). Launching for Success: A Review of Team Formation for Capstone Design. International Journal of Engineering Education Vol. 35, No. 6(B), pp. 1926–1936, 2019.  ELIMINATED CAUSE NOT INDEXED IN ABCD and its latest quartile is Q3. | **Findings:** Industry-oriented capstone courses can improve students’ employability, especially general ability, behaviour and attitude.  **Researcher(s) Contribution:** The study provides evidence that industry-oriented capstone courses can improve EECS students’ employability.    **Gaps/Future work:**  **Commercialisation Possibility**:  University of Colorado at Boulder, 1111 Engineering Drive, Boulder, CO 80309, USA. E-mail: rick.parker@colorado.edu Mechanical Engineering, Rose-Hulman Institute of Technology, 5500 Wabash Ave., Terre Haute, IN 47803, USA. E-mail: sangelka@rose-hulman.edu Mechanical Engineering, University of Idaho, 875 Perimeter Drive, Moscow, ID 83844, USA. E-mail: swenson@uidaho.edu |

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| 69. | Posthuma, Pieterse, & Baror, (2019).  Conference Proceedings: ACM Library  Computer Science Education Research Conference Larnaca,Cyprus (CSERC ’19),  University of Stellenbosch & University of Pretoria, South Africa | **Problem Statement**:  Due to inexperience in software engineering, students usually make poor decisions regarding how to conduct their capstone projects. Students usually learn more about how not to do things rather than gaining experience in how to do the project right.  **Research Objectives**:  To describe a software development capstone project and the software metrics used to assess students.  **Conceptual framework**:  The micro-project cycle | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative methods  Software and code analysis  Observation  **Data Collection:**  Questionnaire (employability scale)  **Population/ Sample:**  100 students  **Data Analysis:**  Code analysis  Software Quality Assessments | **Curriculum Structure**:  - The class is usually between 80-100 students  - Students undertake a class project during the first 8-10 weeks to prepare them for their capstone projects  -Students undertake an intense pre-capstone project to prepare them  - Students gain insights in SE concepts, practices, tools and the social skills required for completing the capstone project.  - Students are taught the software development life cycle in a hands-on manner  -Taught how to programme, plan, manage teams and document the projects  **Capstone Project**:  - All members of the class were involved in developing a single software  -2 academic years were observed, 2017 when a prior project was undertaken and 2018 when there was no prior project  -Students do their project during the third year  - Students design and implement a software system for an industry partner over a period of approximately five months.  -The relatively large authentic systems developed are meant to solve open-ended problems.  -Students undertake micro projects in small teams and them integrate them into a single project  - Tasks for the micro-projects are:  (1) Requirements specification.  (2) Design and deployment planning.  (3) Implementation and testing.- Students do dependency injection, unit testing with mock objects, and integration testing.  -Students change team per stage to experience different personalities  -Students are allowed to make mistakes during the projects to learn  -Teams engage in structured reflection about lessons learned after project completion  - The capstone project provide a guided learning experience for students to master the software development life cycle  -The project also helps them to develop employability skills, get along with people of  different persuasions; define team member roles,  identify their strengths and weaknesses, and be able to lead teams effectively.  -Students are assessed using software metrics and other quantitative measures  - Source code analysis was used for the lines of code written by students  - McCabe’s Cyclomatic Complexity metric and flow chart was used to measure code complexity  **Software, development approaches, technologies used:**  The software development Life Cycle  Java, JavaScript, and Python programming languages, Randon,  **Programme:** BSc. Software Engineering | **Findings:**  The class project provides a unique opportunity for students to get hands-on experience in the development of real-world software for industry.  -Formation of effective capstone teams in the class increases students’ experience their work-styles.  -Capstone projects contributes to a class spirit and motivation to work together  - Better mastery of technical skills, development of social skills  - Better design of capstone projects  - Teamwork improves code quality in capstone projects  - The overall achievement of students who had participated in the prior class project is higher than those who had not participated in class project.  - Source-code written by students who participated in a prior class project was more  Difficult, complex and was likely to require more effort when compared with the source-code written by students who did not participate in a class project.  **Researcher(s) Contribution:** The study contributed evidence to support the idea thatengaging in a prior, preparatory project has a positive effect on students’ confidence and technical knowledge  to carry out their final capstone projects  **Gaps/Future work:**  The study only concentrated on studying the effect of engaging in a preparatory project and not other methods of instruction like team formation mechanisms and the performance of individual students. Further research can be done in these respects.  **Commercialisation Possibility**:  Not included. Projects not commercialised |

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| 70. | Zizyte, T., & Tabor (2022)  ACM Library  4th International Workshop on Robotics Software Engineering (RoSE’22),  Pittsburgh, PA, USA. ACM, | **Problem Statement**:  Due to inexperience in software engineering, students usually make poor decisions regarding how to conduct their capstone projects. Students usually learn more about how not to do things rather than gaining experience in how to do the project right.  **Research Objectives**:  To compile an updated list of robotics bachelor’s degree programs in the US and measure whether curriculum of each program claims to teach a specific practice.  **Conceptual framework**:  The micro-project cycle | **Research Design:**  Cross Sectional  **Research Type:**  Exploratory  **Methodologies:**  Mixed Methods  **Data Collection:**  Document analysis  Counting mentions of SE practices in course curricula  **Population/ Sample:**  17 University programmes analysed  **Data Analysis:**  Code analysis | **Curriculum Structure**:  -Students introduce to robotics programming and soft skills like project report writing and documentation  - Students learn Object Oriented Programming, while no program mentioned Code Reviews  - Most courses do not mention Agile Processes, Code Reuse, and the QA practices of Integration/Systems Testing, and Code Reviews, by name, but students perform these tasks in other courses and the capstone.  **Capstone Project**:  - Capstone-style courses in these universities are dedicated design or project course that involves a long-running group project taken from conception to implementation.  -Most capstones are 2 terms/ semesters long  - Capstone presentation are made to a panel  of engineering faculty or industry representatives in some schools  -Some capstone-style have industry representatives at final presentations;  -Some capstones include a co-op practicum, where students worked part-time off-campus in an industry job;  -Capstone courses are used to expose students to industry partners.  -Most capstones use agile methods, documentation, requirements engineering, and testing  - Teamwork, communication, prototyping were soft and hard skills common in the capstones  **Software, development approaches, technologies used:**  Waterfall  Hybrid (e.g., V-Model, Spiral)  Agile (e.g., SCRUM, Extreme Programming)  **Programme:**  BSc. Mechatronics and  Robotics Engineering  BSc. Robotics and  Control Engineering  BSc. Robotics Engineering  BSc. Robotics and  Manufacturing  Engineering Technology | **Findings:**  - Capstone courses enable engineering students obtain soft skills.  -Students interface with industry in their capstone course, and this enables them to get real-world feedback on the applicability of the practices taught.  **Researcher(s) Contribution:** Authors contributed to how general SE education aligns with the industry and how students can obtain soft skills through capstones.  **Gaps/Future work:**  The study only focussed on Robotics engineering programmes and yet there are very many other IT-related fields that engage in capstones. A more encompassing study may be necessary.  Participating universities and programmes were not objectively selected.  **Commercialisation Possibility**:  Not included. Projects not commercialised |

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| No. | Author, Year, Journal, Country, Database | Problem investigated, Research Objectives,& Concept Frame | Methodology | Findings/ Results of Project | Findings of the Study/ Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project |
| 71. | Zheng, Zhang, & Li (2015)  ACM Library.  SIGITE'15, September 30-October 03, 2015, Chicago, IL, USA.,  Kennesaw State University, USA. ACM, | **Problem Statement**:  Soft skills are often difficult to be practiced and evaluated in the IT curriculum, yet they are very important for IT professionals.  **Research Objectives**:  To present we present experiences and findings on capstone curriculum improvement and students’ soft skills  development and assessment.  **Conceptual framework**:  Not included | **Research Design:**  Design Science  **Research Type:**  Experience report  **Methodologies:**  Mixed Methods  **Data Collection:**  Quantitative and qualitative  **Population/ Sample:**  30 students  **Data Analysis:**  Template Analysis of responses, theme development, and Quantitative meaning added to themes | **Curriculum Structure**:  -Students are introduced to technical skills like programming, and the importance of soft skills in software engineering.  **Capstone Project**:  - Undergraduate students work in teams to develop a real-world IT solution  -Students integrate knowledge acquired in preceding IT courses.  - The project takes 3 months,  -Students work in teams of 3 to 5  -Take at least 120 hours of total project time per person  - Students to technical design, research, documentation, project management, leadership, team work, and communication skills.  -Final deliverable of the capstone project is an IT solution addressing a typical business or organizational need  -Students develop solutions for data management or networking  -Projects are evaluated by faculty members, Industrial Advisory Board (IAB) members, and project owners.  **-**Students give individual reflections on their level of learning at the end of project  **Software, development approaches, technologies used:** Not included  **Programme: Bs**c. Information Technology | **Findings:**  - Capstone projects help students get an opportunity to experience many non-technical challenges such as requirement ambiguity, communication difficulty, and scheduling conflict.  **Researcher(s) Contribution:** Authors redesigned the curriculum structure of a capstone course, providing a more systematic way of facilitating the development of soft skills and assessing the students’ competence on such skills.  The study identified 8 major soft skills that are important for software engineers and IT professionals:   * Communication, Presentation, Planning, Team work, Time management, Dealing with challenges, Learning, & Writing   **Gaps/Future work:**  The sample studied was too small and not representative of capstone projects in the University.  **Commercialisation Possibility**:  Not included. Projects not commercialised |

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| 72. | Porras et al., (2018)  ACM Library.  SIG Proceedings Paper in word Format. In Proceedings of ACM ICSE  Lappeenranta University of Technology, Finland | **Problem Statement**:  Current research has failed to adequately compare code camps and hackathons  with respect to who benefits, which stakeholders are  involved, and what the practical arrangement differences are between them.  **Research Objectives**:  To present a taxonomy for hackathons and Collaborative Code Camps, based on researchers’ experiences, and help practitioners decide the most suitable approaches for them, depending on their industry and educational needs.  1. To explore various approaches to implementing  hackathons and their outcomes for different stakeholders in the  context of software engineering education  2. To present taxonomy, based on experience, for the various types of collaborative learning events.  **Conceptual framework**:  Collaborative Code Camps and Hackathons as models for capstone projects. | **Research Design:**  Experimentation  **Research Type:**  Case Study  **Methodologies:**  Qualitative Methods  **Data Collection:**  Qualitative literature review  Personal Experience assessments  **Population/ Sample:**  30 students  **Data Analysis:**  Template Analysis of responses, theme development, and Quantitative meaning added to themes | **Curriculum Structure**:  -Students introduce to learning by doing in their freshman years  -Students bond with each other and learn to work together  -Students get a glimpse at different technologies that can be used in capstones.  **Capstone Project**:  - The University implements short-span hackathons instead of lengthy traditional capstones  - Hackathons are 24 hour to week long coding camps  - Students are introduced to new topics like learning by doing  - Students test the skills they learned through a real life project  -Students choose their team mates freely to avoid the free-rider problem  -Projects have different stakeholders including students, citizens, universities, companies,  -Students implement prototypes in a fast and effective manner  -Development of deep prototyping knowledge at coding events  - Students compete with each other under the guidance of mentors and companies  -The hackathons work on providing a solution to a partner company  -Solutions must be operable in the organisational environment.  **-** Students get recognition of their effort, skill and competences by presenting their projects to industry players.  **-** Projects undertaken in collaboration with interested companies like Nokia, IBM, Microsoft, SUN, Google, CGI, etc.).  **Software, development approaches, technologies used:**  Intensive collaborative working events  real-life problem solving  Collaborative code camps  Hackathons  24-hour innovation  Workshops  Technologies: NET, Maemo, Meego, Qt, AR, ReactJS, etc.)  **Programme:**  BSc. Software Engineering  BSc. Computer Science | **Findings:**  - Intensive hackathons extend core content, such as IEEE/ACM curricula guidelines, without overstressing the curriculum. Hackathons are a new way to evaluate skills and competencies in a real environment,  -The projects gives student truly meaningful way to test of their skill and ties their experiences to real life.  -Compared to code camps, hackathons do not put a lot of pressure on students  - Hackathons are more healthy learning experiences than code camps and traditional capstones  -Capstones undertaken as hackathons enable intensified stakeholder collaboration  **-** Hackathons require more preparation in terms of logistics, recording outcomes, management, and industry communication.  **Researcher(s) Contribution:** The study explored and presented a model of increasing collaboration and active learning of SE students through the hackathon approach. Students came up with products and new technologies that were given more visibility by citizen and industry participants.  **Gaps/Future work:**  The hackathon model to SE and capstone project studied only takes one week or a few weeks and students do not get adequate technical learning. The study did not do a thorough comparative analysis of the strengths and weaknesses of the different instructional models.  While the study analysed hackathons, code camps and collaborative events, the researchers did not examine the diversity of these approaches in terms of arrangements, participants and goals. Future research is required in some of these issues.  The analyses made are partly based on the authors’ experiences. These are subject to bias in reporting.  **Commercialisation Possibility**:  Not included. Projects not commercialised |

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| 73. | Hundhausen, et al., (2021)  ACM Library, Proceedings of ACM SIGCSE Symposium (SIGCSE’21),  Humboldt State University (HSU), University of  California, Santa Barbara (UCSB), and Washington State  University (WSU). | **Problem Statement**:  Many undergraduate courses include a team-based  software development experience in which each team works on a different software project. This raises significant challenges for  assessing student work and measuring the impact of pedagogical  interventions.  **Research Objectives**:  To present a collection of metrics developed using the Goal- Question Metric framework from the empirical software engineering  literature,  **Conceptual framework**:  Goal- Question Metric framework. | **Research Design:**  Experimentation  **Research Type:**  Case Study  **Methodologies:**  Quantitative Methods  **Data Collection:**  Online data collection on GITHub  **Population/ Sample:**  23 teams of 94 students  **Data Analysis:**  Template Analysis of responses, theme development, and Quantitative meaning added to themes  Comparative analysis of cases at 3 universities. | **Curriculum Structure**:  participants were introduced to software engineering as a course and agile methods like Scrum and Kanban  **Capstone Project**:  - Students work in teams to write commit messages that are consistent with industry expectations for quality.  - Students specify software requirements (in the form of issues on a Kanban board in consistence with industry expectations for quality.  -Students produce software products of high quality  - Students do Mobile apps Soft. Eng. Web Dev;  -Use of Scrum and GitHub for version control and project collaboration.  -Worked in teams of 2-3, 1-5 and 4-6  -Supervised by an instructor  -Projects ranged from 4 to 9 weeks  - 3 Universities were studied  -Students had to do a live demo of the product after the project  - Projects assessed for complexity, reliability, usefulness, & overall quality by 2 instructors.  -The projects were undertaken at Humboldt State University (HSU), University of California, Santa Barbara (UCSB), and Washington State  University (WSU)  **Software, development approaches, technologies used:** Agile Methods, Scrum, GITHub.  **Programme:** BSc. Software Engineering. | **Findings:**  - The results demonstrate that metrics are sensitive to differences in the quality of teams’ commits, issues, and products  **Researcher(s) Contribution:** This study This work contributes a new metric-based approach to evaluating key aspects of software development processes and products in a wide variety of computing courses.  **Gaps/Future work:**  The data collected may not have been representative, leading to bias.  Only one online software GitHub, was used for software assessment and data collection. It is not clear if authors considered the limitations of GitHub.  **Commercialisation Possibility**:  Not included. Projects not commercialised |
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| 74. | Hundhausen, *et al.,* (2023)  ACM Library, ACM Transactions in Computing Education  University of California, Santa Barbara (UCSB), and Washington State  University (WSU)United States | **Problem Statement**:  Assessing team software development projects is very difficult and typically based on subjective metrics. It is necessary to make assessments more rigorous.  **Research Objectives**:  To explore the relationships between subjective metrics based on peer and instructor assessments, and objective metrics based on GitHub and chat data.  **Conceptual framework**:  Goal- Question Metric framework. | **Research Design:**  Cross-Sectional  **Research Type:**  Case Study  **Methodologies:**  Quantitative Methods  **Data Collection:**  Online data collection on GITHub  Code repositories on GitHub  Collection chat messages from their Slack and Microsoft Teams channels  Peer evaluation ratings from the CATME peer evaluation system  Analysis of individual assignment grades from the courses  **Population/ Sample:**  23 undergraduate software teams (n = 117 students)  **Data Analysis:**  Pearson analysis | **Curriculum Structure**:  Students are taught advanced mobile APP development and team formation, web programming through lectures, live coding demos, and a series of individual assignments  **Capstone Project**:  - Course was undertaken in 2 undergraduate computing courses in 2 North American research universities.  -Both courses were conducted online, during the pandemic  **Course A: UC Santa Barbara**  Course undertaken thru advanced application Development was taught by the second author at,  - 10 week course taken primarily by second and third year undergraduate computer science majors.  - Project focuses on development of full-stack web applications through a team project lasting the duration of the term.  - The course emphasizes both technical skills and soft skills related to Agile practices (stand-ups, sprints, Kanban, user stories, acceptance criteria) and GitHub worklows (pull requests, code reviews).  **Course B: Web Development at Washington State University**.  -A 15 week advanced undergraduate course in full-stack web development.  - 1ST 10 weeks, students learn web programming through lectures, live coding demos, and a series of individual assignments  -Students produce a full-stack web app of their choice  -Students learn about the same Agile practices and GitHub workflows emphasized  -3-4 week sprint cylces  -Project meetings were held synchronously through Zoom and Microsfot Teams  **Software, development approaches, technologies used:**  Agile Methods, Scrum, Web Development,  GITHub, Slack, Zoom, MS Teams for collaboration  **Programme:**  BSc. Software Engineering  BSc. Computer Science | **Findings:**  - There were significant positive correlations between team members’ GitHub contributions, chat contributions, and peer evaluation ratings.  - The equality of teams’ GitHub contributions was positively correlated with teams’ average peer evaluation ratings, and negatively correlated with the variance in those ratings.  -There was no positive correlations between the equality of teams’ chat contributions and their peer evaluation ratings.  **Researcher(s) Contribution:** The study extends previous research results by providing evidence that team members’ chat contributions, like their GitHub contributions, are positively correlated with their peer evaluation ratings.  **Gaps/Future work:**  The conclusions drawn from this study are limited due to its correlational nature  **Commercialisation Possibility**:  Not included. Projects not commercialised |

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| 75. | Genevera (2021).  In The 52nd ACM Technical Symposium on Computer Science Education (SIGCSE ’21)  ACM Library,  Rice University, United States | **Problem Statement**:  While many universities have realised the need to develop robust data science programmes, there is little literature describing how these capstones should be structured or their curriculum.  **Research Objectives**:  To discuss experiences with developing an interdisciplinary, client-sponsored  capstone program in data science and machine learning  **Conceptual framework**:  Not included | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative Methods  **Data Collection:** Questionnaires  **Population/ Sample:**  76 students  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  Students are introduced to some background courses in data science like programming, data management, manipulation, and cleaning, statistical modelling and inference, data visualization, signal processing, operations research, or machine learning.  -Curriculum is based on project-based learning.  -Introduce students to project communication  **Capstone Project**:  - The capstone was set up as a client-sponsored project in Engineering and CS  - Each capstone project solves a real-world problem using real data set sponsored by a client  -The client invests in the outcome of the project.  -Teams of 5 students per project;  –The course is based on a program that builds relationships and solicit projects from partners;  -Partners include companies, community organizations (e.g. non-profits and government agencies), and researchers from other disciplines.  - The projects are based on a sponsored research agreement that governs how companies share their data with students.  -The legal agreement is structured to ensure certain data security and protection of intellectual property;  -The project is interdisciplinary capstone program, consisting of vertically and horizontally integrated teams from different degree program;  -Some teams are both undergrad and masters;  - Multiple teams ensure multiple skillset in each team;  - The projects require strong programming skills in Python and R programming  - Students work with clients to frame their problems and sponsors help guide them to develop appropriate capstone projects;  - Projects helped students work with real world large sets of data;  -Most time is spent by tutors mentoring students  -Projects developed using data science pipeline  - Students write reports, make oral presentations, and software documentation after the projects.  -Students are assessed both at individual and team levels.  -15 capstone projects were presented by the students  **Software, development approaches, technologies used:**  Problem Based Learning, Experiential learning,  Python Programming, R programing  **Programme:**  BSc. Applied Mathematics  BSc. Computer Science  BSc. Statistics  BSc. Electrical Engineering | **Findings:**  - Majority of the participants were male  - 15 teams were studied  - Most teams had conflicts among participants  - Teams produced working prototypes  -The larger sponsors recruited some of the participants  - There was a clear correlation between project outcomes assessed by the sponsors and outcomes assessed by the instructors.  -Majority of students rated their capstone experience as outstanding  - 87% of students reported the capstone course to be extremely or very challenging.  **Researcher(s) Contribution:** The study developed an interdisciplinary, client-sponsored data science capstone program using evidence-based approaches and best practices from engineering, business, and computer science curricula. The program was reported to offer meaningful experiential learning opportunities that allow students to work on real-world problems and data sets from a variety of industries and disciplines.  **Gaps/Future work:**  The study is based on experiences of authors in developing a new capstone project. This is subject to bias.  **Commercialisation Possibility**:  Not included. Study was a curriculum review paper and not focussed on developing a market-targeted product. |

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| P76. | Braught & Siddiqui (2022).  Proceedings of the 27th ACM Conference on Innovation and Technology in Computer Science Education, ACM Library,  Dickinson College, Carlisle, PA, United States | **Problem Statement**:  While many universities have realised the need to develop robust data science programmes, there is little literature describing how these capstones should be structured or their curriculum.  **Research Objectives**:  To analyse data from  5years of a 2-semester capstone experience in which students consider a number of Free Open Source Software (FOSS).  **Conceptual framework**: Free Open Source Software (FOSS) and Humanitarian FOSS for capstone projects. | **Research Design:**  Longitudinal- over 5 years.  **Research Type:**  Exploratory study  **Methodologies:**  Quantitative Methods  **Data Collection:** Questionnaires/ survey  **Population/ Sample:**  74 students  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - Students were introduced to FOSS principles, processes, tools and the developer and user communities that exist around them.  **Capstone Project**:  -2 year project  - 5 academic years were analysed  - 3 phase project selection process including exploration, review & ranking & choice phases and is most closely modelled;  - Projects may be selected from online repositories.  **Software, development approaches, technologies used:**  GitHub / GitLab  **Programme:**  Not Included. | **Findings:**  **-** Projects with humanitarian goals are preferred by both women and students with lower confidence in their software development and teamwork skills.  - African American, Black and Hispanic students show preferences for humanitarian projects  - Gender, race/ethnicity, student confidence and perceptions of community influence project selection.  **Researcher(s) Contribution:**  The study paid attention to capstone experiences of vulnerable communities of people in the US’ racial backgrounds, like women, Black, Indigenous, and People of Colour (BIPOC) and lesser experienced students in the USA, using Free Open Source Software and Humanitarian Free Open Source Software.  **Gaps/Future work:**  The student participants in the study were self-selected and thus may not necessarily represent the broader perspectives of the student community.  **Commercialisation Possibility**:  Not included. |

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| 77. | Bütt, Person, & Bohn, (2022).  International Conference on Software Engineering: Software Engineering  Education and Training(ICSE-SEET ’22), ACM Library,  University of Nebraska – Lincoln, United States | **Problem Statement**:  Undergraduate students in all disciplines sometimes struggle to relate what they learn in class and its importance in the field.  **Research Objectives**:  To describe the processes, practice and timeline we followed for a student-sponsored capstone team.  **Conceptual framework**: Not included | **Research Design:**  Longitudinal- over 5 years.  **Research Type:**  Case Study  **Methodologies:**  Qualitative Methods  **Data Collection:** Observation and project analyses  **Population/ Sample:**  9 students  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - The 1st 2 years (four semesters) teach fundamental computer sciences topics in integrated with Software Engineering.  - SE course includes a weekly lab section in which students work in pairs to practice concepts taught in class.  - At the end of 1st 3 core course, students complete a team software development project.  -4th core course incorporates communication skills  **Capstone Project**:  - A capstone experience in which students work in teams to contribute to an open source software project.  - The program follows a cohort model  - Student teams are set by the instructors so that students have an opportunity to work with many of the students in their cohort.  - After students complete the core courses, they take 2 years of the capstone course (our other computing majors are required to complete only a single year of study.  - They are also taught parallel SE courses that help them in the capstone like requirements elicitation, software testing, software design and architecture  -Students work on paid and unpaid projects sponsored by industry, government, non-profits, and faculty from department and the university;  -Students do the project in a start-up environment;  -A team of faculty, professional project management staff, and a director are responsible for soliciting projects, as well as guiding and assessing student work.  -Volunteer project coaches form the industry guide the projects  - 25-30 projects are undertaken in a year  - Students choose their own projects based on individual preferences  -Project sponsors take 2-3 hours a week meeting teams  - Students follow agile practices  - Work is done in cycles  - Students work on web development, mobile apps, data analytics, virtual reality, and a host of other technologies  -Students also gain non-technical skills, including time management, negotiation, communication, and leadership.  -Students were also taught business law, entrepreneurship, and other relevant topics to commercialise their products.  **Software, development approaches, technologies used:**  Agile Practices  GitHub / GitLab  **Programme:**  Bsc. Software Engineering | **Findings:**  **-** Practicing teamwork and collaborative development in a self-organized team prepares students to work in industry or a start-up post-graduation  - Balancing technical development and business tasks is challenging for students  - The benefits students receive from their capstone experience correlate directly with what the students are willing to invest.  - Team cooperation and cohesion are paramount in a self-sponsored team.  -Lecturers should be willing to let the students fail along the way (reassure students it’s OK to fail)  **Researcher(s) Contribution:**  The study introduced the concept of student sponsored capstone projects that are a departure to the traditional capstones.  **Gaps/Future work:**  Sample of 9 students was too small and not representative of population of SE students.  **Commercialisation Possibility**: Students chose not pursue outside investors as part of  their capstone project, so there was no chance of commercialising projects. |

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| 78. | Pembridge, J.J., & Paretti, M.C. (2019).  Journal of Engineering Education  EBSCOHost  Virginia Tech, United States | **Problem Statement**:  There have been a few studies that systematically explore capstone teaching, leaving a significant gap in  concretely describing faculty practices and relationships between teaching practices and learning outcomes of these courses.  **Research Objectives**:  To develop a comprehensive  description of pedagogical practices used by capstone design faculty from a functional perspective.  **Conceptual framework**: Kram's model of mentoring | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Qualitative Methods  **Data Collection:** Observation and project analyses  **Population/ Sample:**  42 faculty members  **Data Analysis:**  Basic Content analysis with MAXQDA (Standard Version 12; 2016) software, used for transcription and coding | **Curriculum Structure**:  - Curriculum based on ABET (2017), engineering curricula which emphasises the inclusion of a major design experience for students, based on the knowledge and skills acquired in earlier course works.  **Capstone Project**:  - Participants being by describing, creating, soliciting, and shaping projects that will challenge them and prepare them for the workforce.  - All projects must integrate previous learning, promote new learning, and provide realistic experiences that address full project cycles, incorporate authentic constraints, and are open-ended  -Projects necessitated protection and counselling by coaches and role models;  - Focus on employability, exposure, & acceptance in the industry  - Teams avoid inappropriate project scope, poor time management, dysfunctional team dynamics, lack of sponsors, or poor technical execution;  - Teams worked with external & internal sponsors  - Balanced teams based on past academic performance and/or personality types,  -Projects are matched to student interests to ensure sustained engagement  - Matching skill sets to project requirements.  -Staff help students identify online resources and articles to use  -Linking students to prospective employers  -Coaches and mentors use several approaches to monitor teams and projects, like formal reporting structures, regular meetings, observations of teamwork sessions, & comparisons across teams.  - Faculty provide direct instruction in project mgt and feedback on students’ work  - Projects provide marketable skills, experiences, and materials  -Students mimic the workplace  - Students demonstrate their project outcomes to faculty, industry professionals and the public at the end.  **Software, development approaches, technologies used:**  Not included.  **Programme:**  BSc. Civil, Environmental  Bsc. Architectural Engineering;  Bsc. Chemical Engineering;  Bsc. Electrical And Computer Engineering  Bsc. Industrial Systems & Manufacturing Engineering;  Bsc. Mechanical, Aerospace  Bsc. Ocean Engineering. | **Findings:**  **-** Capstone education moves beyond teaching design to include socializing students into the norms and expectations of the industry  - Students can identify role model engineers among professionals they collaborate with in the capstone  - Students learn, explore options, and reach  decisions on their own  -Capstone courses help in creating rapport for students in the industry.  **Researcher(s) Contribution:**  The study created a model of capstone design teaching that includes nine functions (challenge, protect, coach, promote employability, provide exposure, provide role models, accept and confirm, counsel, and build rapport) and 28 associated practices.  **Gaps/Future work:**  Sample only included 40% of all accredited engineering professionals that could be reached. It was not representative  - The taxonomy created was based on retrospective self-reports by faculty members. Their ideas may have been influenced by bias. Students were not interviewed, yet they are major stakeholders in capstone projects.  **Commercialisation Possibility**: Not included. Not commercialised. |

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| 79. | Stahr, & Davis (2021);  EBSCOHOST  Communications of the Association for Information Systems  Miami University, Oxford OH, USA | **Problem Statement**:  The rapid transition to remote instruction during the COVID-19 pandemic created many challenges for students, instructors, and, and especially in capstone software development courses, for clients of project teams.  **Research Objectives**:  To describe an approach for creating and delivering a successful online capstone involving all stakeholders.  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Quantitative Methods  **Data Collection:** Survey questionnaire  **Population/ Sample:**  157 students  21 faculty members  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - Not included  **Capstone Project**:  - The capstone comprises a two-course sequence that students take in their final year.  - Projects have external and faculty clients  - Team based software development over a span of an academic year.  - Learning outcomes include working as a team to solve an open-ended problem, demonstrating written and oral communication skills with technical and non-technical audiences, and displaying professionalism.  - Use of project-based learning  - Instructors engaged the university’s eLearning staff to discuss particular ways to engage with the project teams.  - Brainstorming for an online alternatives of undertaking the capstone  -43 project teams who presented their work at the end.  -Work was presented in a virtual expo  - Projects present a video containing a problem statement, project scope, high-level requirements, product design, & demonstration of final product.  **Software, development approaches, technologies used:** Open Broadcast Software (obsproject.com) to present; Word press; Webex Events for event scheduling, Google Hangout, Google Form for assessment rubric  **Programme:** Not Included. | **Findings:**  **-** The site was created to manage capstone projects had 947 views on the day of the Q&A session and 2,050 total views since its publication date.  - Of the 18 projects with external clients, 17 had client attendance at the expo for a total of 21 people.  - All of the clients for the 25 internal projects attended along with 14 non-client faculty;  - 42 of 43 teams had a non-client faculty attend their Q&A session.  - Students need to engage in remote collaboration and presentations to develop their workforce skills  **Researcher(s) Contribution:**  The study met the course learning outcomes during the transition to remote instruction. Student teams collaborated to solve an open-ended problem and to professionally communicate their solutions in both videos and online conferencing.  **Gaps/Future work:**  Students need to be able to engage in remote collaboration and presentations to develop their workforce skills.  **Commercialisation Possibility**: Not commercialised. No mention. |

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| 80. | Mertz & Quesenberry, (2018).  *IEEE Explore,* 2018 World Engineering Education Forum - Global Engineering  Deans Council (WEEF-GEDC);  Carnegie Mellon University, United States | **Problem Statement**:  There are apparent challenges in partnerships between SE students and community clients, for example in defining and assessing curricula learning goals, evaluating community impact of projects, and achieving significant scale, all without overwhelming faculty schedules.  **Research Objectives**:  The goal of this paper is to describe a student-client engagement model and how it has been used in three different modes of experiential learning: an elective consulting course, a summer experience working abroad, and a core required team-based project course.  **Conceptual framework**: Schein’s process  consulting model and participatory research | **Research Design:**  Design Science  **Research Type:**  Solution Proposal  **Methodologies:**  Qualitative Methods  **Data Collection:** Survey questionnaire  **Population/ Sample:**  5 students  **Data Analysis:**  Qualitative analysis | **Curriculum Structure**:  Students undergo training in some of these courses:  - Relationship management  - Structuring unstructured problems  - Researching alternatives and best practices  - Proposal writing and designing scope of work  • Project and team management  • Communicating technical ideas  • Capacity building and sustainability  • Documenting and analysing outcomes  **Capstone Project**:  - The students work as consultants in partnership with, not for, a client.  - The student consultant is expected to lead the partnership through a process exploring and bringing structure to a problem;  - Students identify alternative technical solutions, analyse alternatives and recommend a solution to clients  - Students then design and implement the solution  - The client is kept involved in all decisions that will impact their ability to use, maintain and sustain the solution.  - Capacity building in terms of both individual learning and organizational change in the client organization are critical parts of the project.  - Students are responsible for relationship mgt, project mgt, and communication.  - Faculty play a role of advisors.  -Students must step into a leadership role.  - Faculty advisors focus on how the team is managing relationships, process, & communication, and less on the project itself.  - Class size of 15-20 is typical, but sometimes 30. - The faculty role is to teach, twice a week, provide extensive feedback on the proposal and final report drafts, manage teaching assistants (TAs),  -Lecturers meet with students when special situations arise, and occasionally check in with clients  -Some students embarked on these projects as international partnerships  **Solutions developed:**  -A database for a local parks conservancy to  store  -A cloud-based customer relationship management (CRM) system  -An analytics strategy to monitor and improve constituent and donor engagement.  - A movable Skype cart to facilitate communication between hospital residents, staff, and their families.  - A support-ticket tracking software for collaboration and co-managing.  -A hybrid tablet app to help teachers create lesson plans  - A robotics curriculum for a high school  - A sustainable web presence  - A Farm Information System  **Software, development approaches, technologies used:** Collaborative Project Management, Agile Development, Web Development, Database Management, Robotics.  **Programme:** Not Included. | **Findings:**  The proposed model was applied in 3 ways.  - A consulting course in which individual students work one-on-one with clients;  - A summer internship program in which students consult with partners in developing communities;  -A large required course in which small student teams develop custom software solutions for community clients.  **Researcher(s) Contribution:**  The study presents a model for collaboration between SE students and clients from community that has been developed over 20 years and used in multiple modes. The proposed model defines students’ roles in consulting terms, which allows enables them to widen their perspective. The mode can help organizations solve problems, and expand their responsibilities beyond just implementing information systems.  **Gaps/Future work:**  - Very few students studied (5)  - Focus was more on the relationship and defining responsibilities for students, faculty, and clients. Less emphasis on the technical processes of developing a system.  **Commercialisation Possibility**:  Not commercialised. No mention. |

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| 81. | Gustavsson, H., & Brohede, M. (2019)..  OpenSym '19, Conference,  ACM Library  University of Skövde, Skövde, Sweden | **Problem Statement**:  Collecting metrics of students performance from publically available platforms and tools like GitHub can be challenging for SE educators.  **Research Objectives**:  To propose an approach for continuous assessment and self-assessment using data collected from the source code repository and from the issue management tools on GitHub.  **Conceptual framework**: Not included | **Research Design:**  Longitudinal Design Science Study  **Research Type:**  Solution Proposal  **Methodologies:**  Quantitative Methods  **Data Collection:** Online source code collection of GitHub API  **Population/ Sample:**  170 students  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - Course combines a comparatively large project  with open source / inner source work processes,  -Taught by a team of teachers with backgrounds  in software engineering and computer science.  -Students are introduced to programming, web programming and computer graphics.  **Capstone Project**:  - Project undertaken by groups of 10  - Students continuously work on a large project over a number of years  -Students progressively contribute to the previous years’ projects  - Each group works a different aspect of the same artefact  - Every year, students continue working on the same code base  - Students improve project deliverable produced by the students from the previous year.  -The end-users/ clients are other students using the system for managing programming and other assignments across a wide range of web-technologies.  -Working on an already available system makes requirements collection easy.  - The project exposes students to real in-use systems of considerable complexity without having to find companies that are willing to work with or provide it publicly.  -Students proactively manage problems in design and development  The students also create a self-assessment tool as part of the project  **Software, development approaches, technologies used:**  Agile Development  Iterative Design  Open Source Software, GitHub  **Programme:**  Web development Bachelors  Program  BSc. Computer Science | **Findings:**  **-** The authors note that continuous summative assessment feedback to students on how they are performing in SE project ensures active students’ participation for the duration of the project course.  **-** The authors present how we display metrics for of students’ performance in relation to some of the requirements of the capstone course.  **Researcher(s) Contribution:**  The paper proposes an approach of continuously collecting information from a GitHub source code repository and collaboration tool, and using this data for assessing student contributions and the entire course from the teacher’s perspective.  **Gaps/Future work:** The study concentrated on tracking individual contribution and performance in the course. There was little attention paid to assessing and tracking progress of each project group of students as well as the whole course. Future research may be required in these two areas.  **Commercialisation Possibility**:  Not commercialised. No mention. This was more of a course administration paper and the results do not focus so much on the deliverables from the capstone projects by students. |

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| 82. | Paasivaara, Vanhanen, & Lassenius, (2019).  IEEE Xplore; 2019 IEEE/ACM 41st International Conference on Software Engineering:  Software Engineering Education and Training (ICSE-SEET),  Aalto University, Finland | **Problem statement:**  In spite of the fact capstone courses are popular in teaching SE skills, and that collaborations between universities and the industry are necessary, there is insufficient information on how these collaboration should take place in practice. The customer’s point of view on the collaboration is missing.  Research Objectives: | **Research Design:**  Design Science  **Research Type:**  Case Study  **Methodologies:**  Qualitative Methods  **Data Collection:** Semi-structured interviews  **Population/ Sample:**  116 students  13 industry experts  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - Prior to the course, the teacher collects plenty of topic proposals.  - The opportunity to propose a topic is marketed  by e-mail to roughly 200 people who have over the years been acting as clients on the course.  - Before the course begins, each client must prepare a 2–4 pages long project proposal according to a template, which  covers the project background, goals, technologies, legal issues, and possibly promises of some special support given to  the team  -Students are introduced to basics of scrum  **Capstone Project**:  - Students form teams of 7 -9 members  - Teams guided by a Scrum master who is a Masters Student/  -Scrum master is not part of the development team  - The projects are undertaken in collaboration with software companies  - The main reasons for the involvement of companies were to recruit graduates, develop new software and research new technologies.  - Customer representatives used a few hours per week for the projects and mostly collaborated with the team on the customer’s premises  -14 projects were undertaken  -Projects take 6 months.  - Sponsor offers a quality award at the end of project  -Some teams formed their own groups while others were chosen by scrum masters  - Each project has a real client from the industry  - Industry representative was the Project Owner  - The Product Owners participated at least in creating the Product Vision, Sprint Planning meetings, Sprint Reviews, grading, and perform acceptance testing  -The teams work with a contract that they sign with the clients  -Teams sign an NDA and an Intellectual Property Rights agreement with the client organisations  - Project is implemented through series of events divided as sprints  - The teams must have a Product Backlog which contains items that have a description, priority  order, and effort estimate.  Students developed mobile apps, crawler data retrieval software, mixed reality IoT games.  -A little less than half of the customers provided the teams the possibility to work on their premises.  **Software, development approaches, technologies used:**  Agile Development, Scrum, Microsoft Excel, Raspberry Pi, Amazon WS Cloud,  Most teams used some form of instant messaging (IM) tool, like Slack, Skype, Telegram, Riot or WhatsApp for team communication and collaboration with clients.  **Programme:** BSc. Computer Science | **Findings:**  **-** A good project topic, according to customer companies, has a clear vision, is suitably important for the customer company, is realistic with enough challenge, is motivating and illustrates the work at the company.  - Customers emphasized the importance of spending enough time with the teams and actively collaborating and communicating with them.  **Researcher(s) Contribution:**  The team interviewed customers and identified 13 points that can be used by future customers who partner with universities on capstone courses to improve outcomes.  **Gaps/Future work:**  The study used only qualitative analyses which are subject to bias. Secondly most partner companies were only focussed on identifying good students and having them recruited intro their firms. More research is needed suing quantitative methods and focussing on the products developed and not only the students developing them.  **Commercialisation Possibility**:  Some of the companies that participated reported that their main objective was not to get actual software developed. This meant that the focus of most companies was on the students and having them recruited into the firms, and not the software they were developing. None of the artefacts developed was commercialised. |

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| 83. | Paiva, S.C., & Carvalho, D.B.F. (2018)  ACM Library  In XXXII Brazilian Symposium on Software Engineering (SBES 2018),  Universidade Federal de São João del-Rei, Brazil | **Problem Statement**:  Several studies indicate a deficiency in student training regarding the practical application of concepts and techniques required to develop and evolve of software with quality.  **Research Objectives**:  To present an approach to teaching software creation as a capstone course that provides practical & business-oriented experience for students in computer science programs.  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Solution Proposal  **Methodologies:**  Mixed Methods  **Data Collection:** Survey questionnaire  Document Review  **Population/ Sample:**  50 students  **Data Analysis:**  Quantitative analysis | **Curriculum Structure**:  - Students undergo a “warm-up period” of around  10-15% of the classes  -They review SE, HCI and entrepreneurship concepts to be used throughout the project.  -They are encouraged to search for potential problems and applications to be addressed at the project creation and development stage.  **Capstone Project**:  - The student do the capstone as a "Software Creation Workshop," intended to teach academic content, and also prepare for the professional practice of software development;  - The workshop has two distinct moments: Warm-up and the Software Creation Process  -Students must propose projects to be developed and present them as in an elevator pitch.  -Learners then undertake a hands-on development course in which the instructors act as mentors.  -During the Software Creation/ Capstone Project Development Process students Define problems, they plan projects, Develop, and Deliver artefacts  -Takes 18-20 weeks  - Students start by defining Product Backlogs,  Describing user stories, and then determining the required functionalities  - Development goes thru Scrum sprints of 3 to 4 weeks each.  - 14% of the classes dedicated to the Warm-up;  - 86% dedicated to the Software Creation Process in the workshop, in which:  – 12% of classes dedicated to Definition stage;  – 8% dedicated to Planning stage;  – 58% dedicated to Project Development stage, being approximately 19.3% for each sprint;  – 8% dedicated to the Delivery stage.  -Project model tested on 2 classes of 2016 and 2017  - Both classes developed mobile applications for the Android platform.  - An expert committee performs the project evaluation.  - Final project must be submitted to an entrepreneurship competition  **Software, development approaches, technologies used:**  **-**Structuring software development projects, SCRUM agile development process, user-centered design (personas), entrepreneurship, Mobile App Development with Android.  **Programme:** BSc. Computer Science | **Findings:**  **-** The study proposes a detailed approach, techniques and operation of a capstone course with an estimated hr load of 72h over a semester.  - The study verifies that the courses presents challenges considered significant for the students  -The study allowed students to practice concepts that they believe to be very important about software development.  -The use of entrepreneurship in software development motivates students to develop business-oriented skills.  **Researcher(s) Contribution:**  - The study developed and proposed an approach that can be a successful and desirable educational practice for a computer science course. The model developed allows to integrate and practice technical skills as well as to develop other desirable soft skills among students.  **Gaps/Future work:**  This paper is an initial step towards to business and practice approaches of teaching software engineering. However, more research is needed in the application of this approach in order to compare students’ performance, and to improve the proposed approach.  **Commercialisation Possibility**: Not commercialised. No mention. |

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| 84. | Heymann & Greef (2018)  Google Scholar  2018 IEEE Global Engineering Education Conference  University of Johansburg, South Africa | **Problem Statement**:  Creating a capstone topic for can be quite challenging for academic staff and students, since projects are expected to fulfil all requirements that are tested but also be interesting enough to attract the attention of the final year students. Interactive electronic games are an idea that can help students develop practical problem solving skills.  **Research Objectives**:  To describe experiences of study leaders and students in developing an interactive game and therapeutic game for students.  **Conceptual framework**: Not included | **Research Design:**  Design Science  **Research Type:**  Solution Proposal  **Methodologies:**  Qualitative Methods  **Data Collection:** Interviews and software observations  **Population/ Sample:**  3 students  **Data Analysis:**  Qualitative analysis | **Curriculum Structure**:  - Students begin by studying about problem definition, literature review and preliminary project analysis  -Students are introduced to research skills and problem analysis.  **Capstone Project**:  - Academic staff define a number of available capstone project titles  - Some students propose their own topics which are vetted by a special faculty committee  - Students consult academic staff and do preliminary studies on the various topics  -Students submit tenders for topics they are interested in  - Tenders are made anonymous and made public  -Students and staff vote on the best tenders/ ideas  -These votes are used to determine which student is allocated to which project.  -Each student is allocated a staff member as a study leader  -Students work on projects individually over two semesters  - Work in the first semester focuses on defining the problem, conducting an in-depth literature study and doing a preliminary design.  -Students design, implement project, test it in the second semester  -At the end of the project, 3 serious games for children were created by students.  - At the end of the academic year, students submit a mini-dissertation documenting their work, and a conference paper on the work.  **Software, development approaches, technologies used:**  Accelerometers, Sensor, batteries, Arduino platform.  **Programme:** BSc. Electrical Engineering. | **Findings:**  - Projects improved students engineering design skills, enabled independent learning, community engagement, and professional written communication skills among participants.  -Since the participants were developing health related games for children, they were confronted with ethical dilemmas and learned how to apply ethical principles in HCI game development.  -The project was multidisciplinary and therefore very educative for both participants and project leaders.  **Researcher(s) Contribution:**  -The project led to the design of an interactive game for children by electrical and electronic engineering final year students.  -Students created an electronic device that would be attached to a child, record motion and then transmit that data to a computer game where the motion gets transformed into appropriate game interaction. The child thus plays the game by moving around.  -The aim of the game was to encourage children to be an active participant and, also provide therapeutic interventions.  **Gaps/Future work:**  The paper only reported results of three capstone projects of 3 students. This sample was too small and not scientifically determined. More research should be conducted on a larger sample size in an African context.  **Commercialisation Possibility**:  The games were piloted but not commercialised. |

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| 85. | Swart, (2016) Ieee lirary, t  IEEE Transactions on Education, VOL. 59, NO. 2, MAY 2016  University of South Africa (UNISA)  South Africa | **Problem Statement**:  There is an apparent shortage of practical skills and qualified professionals, especially  engineers, technologists, and technicians in South.  **Research Objective**:  To analyse the most effective pedagogies that  produces the best student academic results for practical  instruction in SA.  **Conceptual Framework**:  Not included | **Research Design**:  Longitudinal & Design Science  **Type:** Solution Proposal  **Methods**  -Descriptive Case study  - Quantitative  **Population**:  680 students | **Curriculum**:  Students are introduced to skills research and investigation, problem analysis, and application of knowledge;  -All earlier modules studied have a combination of theoretical ad practical skills  **Capstone**:  - course delivered through problem based learning ad project based learning  - Students are expected to practically design an electronic project based on various radio frequency (RF) circuits.  -students design a specific antenna gain required for a given meteor-based communication system  -students use simulation ad modelling to develop solution and are not required to physically build the antenna;  -Development of electronic circuits (LC oscillators, crystal oscillators, and brute-force synthesizers)  -simulation results are detailed in a written assignment that must be submitted to the university;  -The final product (the electronic circuits) must be fully operational, and an academic tests them with an oscilloscope and award marks to the students.  **Software used:**  PRBL, Project based learning, Radio Frequency, electronic circuits, satellite systems.  **Design Approaches Used in projects studied**: Project-based Learning, case studies, practical case studies,  **Academic programme studied**:  Baccalaureus Technologiae (B.Tech.)  in Electrical Engineering (EE) | **Findings**  - Distance learning engineering students do very well in practical work,  -Cooperative learning and face-to-face academic facilitation improve students learning  - Internet availability improves project design  - Students faced significant challenges in PBL assignments, including the difficulty in sourcing the components, constructing a working circuit, and packaging the circuit correctly for postal delivery.  -The results show that distance learning engineering students languish under project-based  learning, while they thrive in case studies and practical workshops.  **Contribution**: This study highlighted student academic results of practical work done in an electrical engineering qualification that includes three pedagogical approaches.  **Gaps/limitations**:  The solutions developed were only simulations ad not real systems. The ability to solve problems with specific reference to designing and constructing a working electronic circuit remains a large challenge which academics need to address.  **Possibility of Commercialising and up-scaling results of Projects**: products developed were only simulations ad not actual physical designs. They could not be commercialised. |

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| 86. | Greeff, et al., (2018).  2018 IEEE Global Engineering Education Conference (EDUCON),  IEEE Xplore, University of Johannesburg,  South Africa | **Problem Statement**:  Capstone projects are difficult to coordinate because students make less input during project allocations, there is lack of transparency on the assignment mechanism among other issues.  **Research Objective**:  To describe the design and implementation of the tender game.  **Conceptual Framework**:  Self-determination theory, Authentic Learning Approach, Gale-Shapley algorithm | **Research Design**:  Design Science  **Type:** Solution Proposal  **Methods**  -Descriptive Case study  - Quantitative  **Population**:  97 students | **Curriculum**:  Not included  **Capstone**:  - project involved the creation of a learning game for students  - The game forms part of a larger and on-going project to gamify the whole of the final year experience for Electrical Engineering students at UJ.  -The project started in 2016 and comprises of a number of subsystems that attempt  to support students in different aspects of the conceptualisation, creation and presentation of their capstone project.  -The developed full system consists of:  • The project day location-based alternate reality game  (ARG),  • The Tender Game,  • The Research Question Battle, and  •The challenge-based gamification system.  The main loop of the game is as follows:  1) Study leaders post projects they wish to supervise in the year,  2) Students competitively tender for the projects using their gained points in the gamified system and completion of  challenges to strengthen their tender,  3) Once all tenders have been loaded, everything gets anonymised and students now change hats to act in the role of tender evaluators, allowing them to practice  their skills as engineers and measuring which tenders put forward the best solutions to the problems posed,  4) Once all inputs have been taken, the automated process  is run to do the final allocations based on votes that were allocated by the tender boards.  **Software used:**  Game development,  **Design Approaches Used in projects studied**: Project-based Learning, case studies, practical case studies,  **Academic programme studied**:  BSC. Electrical Engineering | **Findings**  -Student engagement was a big factor in reaching an idealised matching of students to projects,  -Automated assignment of projects is still highly beneficial to the course coordinator in terms of lowering the administrative burden.  **Contribution**: This study presented a method of matching algorithm and the results obtained by the implementation of game play loop students.  **Gaps/limitations**:  The study focused on only students and not coordinators. There is need to do a follow up study analysing the include of the pedagogical methods on instructors ad team leaders.  The game developed was only a simulation. Further research is required to see how real-life, industrial gamification can be achieved.  **Possibility of Commercialising and up-scaling results of Projects**:  The game play loop presented in the paper was still under development, and could not e commercialised at that time. |

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| 88. | Buchele, & Dafla (2015)  IEEE Xplore,.  E4S Conference Leuven (6) June 18&19, 2015  Ashesi University College,Ghana | **Problem Statement**:  Ashesi university offers only 3 degree programmes, with  two majors, Business Administration and Computer Science,  and Management Information Systems  major a few years later. There is a increasing need for a well-designed engineering degree to fill the gap of a few engineers in Ghana.  **Research Objective**:  To describe the development  process of a unique engineering programme, and provide a summary of its curriculum.  **Conceptual Framework**:  Not included. | **Research Design**:  Design Science  **Type:** case study  **Methods**  -Descriptive Case study  - Qualitative  **Population**:  Not included. | **Curriculum**:  The university introduced new skills, like transformative and innovative thinking, & entrepreneurial skills.  -Economics, Business Administration-Finance, and International Relations, and Business Administration, Agriculture,  -Design thinking, Communication, Integrity / ethics, Systems thinking, Real world projects in a local context, Teamwork, Continuous assessment of graded work, Strong general engineering coursework, Computer programming, & Fluency in the French language  **Capstone**:  - A two semester project capstone.  -Aims to further students' expertise in project planning, system level design, application, and the practice of the profession in a local context.  -Capstone projects are either individual or small  group projects that students select  -overseen by a faculty mentor.  - to ensure competence of all members in a group project, group projects are expected to cut across  engineering disciplines and be more substantial in scope and effort than individual projects  - Individuals are evaluated separately.  - A different option for capstone projects are Ashesi Corporate Projects, in which small groups of students work directly with a mentor from a corporate partner on a real-world engineering design and application project of the corporate partner's choosing.  -The capstone is supported by another course called project management.  - students get weekly seminars ad guest lectures from industry experts to support the capstone project  Projects developed include: networking and distributed computing systems, data structure systems, communication systems, operating system related tools, working with electrical and electronic machines, thermal system technologies, mechanical machine design, etc.  **Design Approaches Used in projects studied**: Project-based Learning, Robotics, engineering and Design Science  **Academic programme studied**: BSc. Computer Engineering  BSc. Electronic Engineering  BSc. Mechanical Engineering | **Findings**  -Practical work, critical thinking, ethical conduct is emphasized throughout university’s engineering curriculum.  **Contribution**: the study shed light on the new world-class engineering programme was created. The curriculum was adapted to the Sub-Saharan context, and grounded in a liberal arts and sciences, with a strong leadership and ethics focus.  **Gaps/limitations**:  The is only a descriptive case study that gives no details about the impact of the new engineering programme on leaners and tutors.  **Possibility of Commercialising and up-scaling results of Projects**:  The paper only reviews a programme curriculum and does not detail the capstone projects that students engage in. |

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| 89. | Omeleze, S., Pieterse, V., & Solms. F. (2015)  Google Scholar, Proceedings for the 6th Annual International Conference on Computer Science Education:  Innovation & Technology, University of Pretoria  South Africa | **Problem Statement**:  - Many of SE practices are not taught in the CS curriculum.  - Consequently, graduate professional software developers  do not have skills required to be productive developers.  - The traditional capstone project which would address this gap is usually characterised by teamwork, poor planning, mismanagement of requirements,  poor design and documentation, excessive code bulk, late integration and poor testing.  **Research Objective**:  To article discusses the  SE challenges and the presentation of a module to teach CS students how to overcome these challenges.  **Conceptual Framework**:  Design the mini-project as a modular project. | **Research Design**:  Design Science  **Type:** case study  **Methods**  -Mixed methods  **Population**:  100 students and 8 development teams | **Curriculum**:  - Software Engineering (SE) module is offered I 3rd year  -course helps in consolidating skills learned in earlier courses.  **Capstone**:  -The aim of the capstone is to design and implement a medium-sized software system.  - Students undergo the complete SE life cycle  -Starts with the mini- project, working in lecturer -assigned teams.  -mini-project takes 6 weeks  - The they develop the main project in 22 weeks  -Students work on the main project in teams.  -All teams work on the same project  -students document requirements,  the design of the entire system  -Students then implement the system.  - students then document reporting the testing and  assessment of the implementations produced  -agile development is followed  -Development is done in rounds  - iterative process until a good system is designed  -Teams then put together modules to complete system.  **Design Approaches Used in projects studied**:  Agile development/ Scrum  Iterative design   * Java-EE technologies, * Node.js framework * Project repositories on * GitHub * Gradle, Apache Maven, * Apache Ant with Ivy, npm * Object-Relational Mappers (ORMs), NOSQL databases. * Standard unit- testing tools such as JUnit, unit.js, Boost.Test and Google Test were used for both the unit and integration testing. * Communication tools: scrum meetings, WhatsApp, phone calls, chat-walk-chat, and email.   **Academic programme studied**: BSc. Computer Science | **Findings**  -Personal involvement has been proven to  enhance the SE presentation to students.  -The study found that computer science academic staff as well as project clients assessed the capstone projects as having a higher quality.  -Students indicated that the capstone is a good experience  -Students learned more communication skills, team work, dealing with free-riders.  -System integration is a lot more work and takes a lot longer than a person might think.  **Contribution**:  -The project enhanced lecturers’ personal involvement with the students and motivated learners to achieve effective performance.  -Students’ became more aware of technologies and soft skills needed to implement large systems.  **Gaps/limitations**: Although the projects were meat to improve SE practices among students, a number of SE pedagogical approaches were not explored in this study. These include methods like peer code-reviews, test-first approach, ad project management approaches. More research is needed in these approaches.  **Possibility of Commercialising and up-scaling results of Projects**:  The paper led to the development of 2 class projects per student team, one mii project and a final large project. But none of these were commercialised. |

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| Annotated Review table | | | | | |
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| 90. | Pieterse, &Van-Eekelen, (2018)  Google Scholar, Proceedings of the 47th Annual Conference of the  Southern African Computer Lectures’ Association (SACLA 2018)  University of Pretoria, South Africa | **Problem Statement**:  - Students enrolling for a Computer Science degree at the University of Pretoria are culturally diverse. They have different backgrounds, beliefs and morals. This affects their performance in capstone projects.  **Objectives:**  **-** To assess whether culturally diverse software development teams produce better work than culturally homogeneous teams.  -To assess whether culturally diverse software development teams produce better work than culturally homogeneous teams.  **Conceptual Framework**:  Design the mini-project as a modular project. | **Research Design**:  Longitudinal design  **Type:** Case study  **Methods**  -Quantitative methods  **Population**:  434 students, assigned to a total of 246 differently composed teams | **Curriculum**:  - Not included.  **Capstone**:  - Teams are created in the class  - Each team is assigned a micro project.  - The different micro projects build on each other to constitute the design, implementation and testing of a single, fairly large, software product comparable to a real-world software product.  -Students undertook projects in teams  -Teams were an average of 7 people  -Each team was ethnically diverse  - Each team communicated in different languages  -Projects were assessed assigned work quality, team cohesion  -Teams were assigned a lecturer  - Projects were relatively small and well-defined (teaching assignment vs. real-world projects).  **Design Approaches Used in projects studied**:  Project based learning  **Academic programme studied**:  BSc. Computer Science | **Findings**  -Majority of participants were males  - majority of students were white  -most students spoke either Afrikaans or English or both.  - Ethic diversity in a team has a positive impact on how well the individuals in the team work together,  -Team cohesion increases as the team’s ethnic diversity increases.  - Language diversity negatively affects team cohesion.  **Contribution**:  - The study summarises the advantages and disadvantages of having culturally diverse capstone project teams. Educators can use cultural diversity to influence the classroom situation when students are required to work in teams, and enable the implementation of real-world software products.  **Gaps/limitations**:  -The study did not consider real-world criteria for project success, like cost and time to market. There is need for future studies considering these two aspects and other elements of the triple constraints for projects.  -The study did not corroborate findings of other researchers who have highlighted the benefits and drawbacks of having culturally diverse teams.  **Possibility of Commercialising and up-scaling results of Projects**:  The paper led to the development of 2 class projects per student team, one mii project and a final large project. But none of these were commercialised. |

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| Annotated Review table | | | | | |
| Author, Journal, Year, Country | **Problem Investigated/ Research Objectives; Theoretical/ Conceptual Frame** | **Methodology** | **Findings** | **Findings, Gaps/ Limitations/ Areas of further study, & Entrepreneurial Value/ Commercialisation of Project** |
| Boucher, & Piderit, (2017)  Google Scholar, Proceedings of the 46th Annual Conference of the  Southern African Computer Lecturers’ Association (SACLA 2017),  University of Fort Hare, South Africa | **Problem Statement**:  - The development &  management of the capstone software projects by students is quite overwhelming. More appropriate instructional tools are necessary to ensure quality of developed systems.  **Objectives:**  **-** To examine the impact that the Agile methodology with scrum instructional tools had on the quality of the software development projects.  **Conceptual Framework**:  Action Research Model | **Research Design**:  Action research  **Type:** Solution Proposal  **Methods**  -Qualitative methods  - Qualitative data in the form of project deliverables, project group feedback, tutor reports and lecturer class notes were collected throughout the academic year.  **Population**:  434 students, assigned to a total of 246 differently composed teams | **Curriculum**:  - Instructional model focussed on: documentation, methodologies, business ethos, teamwork, programming, or some  hybrids.  **Capstone**:  -The project is designed to provide students with an opportunity to put their foundational knowledge and skills learned during their undergraduate studies into practice in a controlled environment  -5 project classes  -3-5 members per team  - Project undertaken in cycles  -First cycle followed a waterfall approach  -Last cycle followed agile development  - Project done for 14 weeks in 3rd year, but has been improved to take one academic year  -Traditionally used waterfall, but has moved to scrum  - Students work with either real clients from the industry or pseudo clients in academia (the lecturers/mentors)  -Students are encouraged to choose their own clients  - The facilitated interaction with an industry client further assists in developing the soft skills  -Students used scrum meetings /sprits to divide the work  - The sprint sessions were scheduled to last from 15-30 minutes  -The students did testing and code review sessions  - Weekly scrum presentations were undertaken by groups  -The project follows a software development methodology and project management principles to manage their project deliverables for the duration of the course  -A final product and database prototype are delivered at the end of the project  -Documentation is done by students  **Design Approaches Used in projects studied**:  Project management approaches, Agile Methodology with Scrum instructional tools, prototyping, Student-centred learning, Fishbone Diagrams for Cause-Effect Diagnosis  **Academic programme studied**:  BSc. Information Systems | **Findings**  - Agile Methodology with Scrum instructional tool had on the quality of the software development projects. It was determined that the intervention had a positive impact on the quality of the group projects compared to previous years.  - Providing a suitable methodology for  students to follow improves requirements identification  - Providing team-building training improves team dynamics  - Making the scheduling of meetings, venues and deliverables visible and known by students improves projects  -Case studies improve problem students’ solving skills  - System testing improves project implementation  -IS literacy improves project implementation  -User interface design logic can be improved by providing students with additional resources and training on best practices.  - Coding practices of teams can be enhanced by providing them with a set of best practices.  **Contribution**:  - The researches identifies and discusses 8 lessons learned related to scrum tools, and  Their impact on the software quality of the student projects.  -The researchers note that the transformation from traditional waterfall methodologies to an agile with scrum methodology leads to the success of capstone projects.  **Gaps/limitations**:  -The scrum intervention studied did not adequately address all the factors that affect quality of students’ software projects and therefore more research is necessary to ascertain these factors.  **Possibility of Commercialising and up-scaling results of Projects**:  Deliverables were only prototypes which could not be commercialised. |

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