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Project-based learning within eHealth, bioengineering and biomedical engineering application areas

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Abstract

This paper presents a short overview of projects conducted at RMIT University in Melbourne, Australia, as a part of the learning and teaching activities in the Science, Technology, Engineering and Mathematics (STEM) College. The focus is on eHealth, bioengineering, biomedical engineering and related application areas. We introduce how these research areas are embedded into the curriculum, as well as, present a number of recent and current projects conducted by our students in collaboration with industrial partners, other academic institutions and medical practitioners.

Keywords: project-based learning, bioengineering, biomedical engineering, eHealth, software engineering

1. Introduction

This paper presents a small fraction of the RMIT University's integrated research and Learning and Teaching (L&T) activities, in the disciplines of eHealth, Engineering, Bioengineering and Biomedical Engineering. It shows comprehensive approach that includes combination of software engineering, computing, electronics, electrical, mechanical and chemical engineering for human wellbeing and medical diagnostics and treatment applications. Generally, application of engineering principles to living structures is known as Bioengineering, while Biomedical engineering covers concepts and design of medical equipment. Research into the development, and application of eHealth for assessment and management of various conditions, are conducted in few University schools. We are presenting here just the activities conducted within only two STEM College schools, School of Engineering and the School of Computing Technologies. Projects' activities include the use of the latest Information Communication Technology (ICT), especially the use of smartphones, various Web applications for tracking health, applications for delivery of therapy and management of health data. Research is conducted through the laboratory activities and industry supported Work Integrated Learning (WIL) capstone projects integrated into Bachelor, Honors, Masters and PhD studies.

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Refereeing to educational context first, in our previous work [1, 2], we presented how the research on autonomous systems engineering is embedded into the study curriculum in the STEM College at the RMIT University. We introduced a general structure of our WIL modules and the core ideas on how the research and development of autonomous systems and robotics is covered within the final-year courses. In our later work [3], we also discussed the core ideas, of our redesign of the Software Engineering (SE) project course, to meet such challenges as management of large cohorts of students, providing a real industrial experience, helping students to identify gaps in their skills and close these gaps based on the project experience, etc. Our goal was to meet the above challenges and to cover the Engagement, Experience and Employability, known as E^3. Because of the COVID pandemic, we have rapidly changed all aspects and methodologies in teaching and learning, as well as the research, but this will be the subject of some of the future publications.

One of the challenges mentioned in [3], was on how to make the project task interesting to students to ensure their engagement. A crucial contribution to solving this challenge is whether the students can relate themselves to the topic, in terms of their previous study, or life experience, as well as, in terms of their future career plans. Thus, the range of the project topics is broad enough to cover the needs and aspirations of the very diverse students' cohort.

In our current work, we went further to cover more research areas, such as eHeath, bioengineering, biomedical engineering and other related domains. We are presenting here how we have evolved our research embedded in teaching within the final year courses that provides the capstone project courses in our two schools within the STEM college. As the final year courses, they provide the finishing and integrative experience of the whole study programs. Finally, we also present some of the WIL projects conducted through Masters and PhD studies and research.

Incorporation of capstone projects into the study curriculum is one of the best solutions to give students real industry experience [4, 5, 6, 7]. The study projects of this type are especially effective if conducted with real industrial clients working on real life problems [8]. Another advantage of having these courses in the study curriculum is that these courses help students to develop their communication and problem-solving skills, as well as exercise teamwork. Moreover, they allow providing a really authentic assessment for the project- and problem-based learning tasks [9, 10].

Referring to the learning outcomes of the projects conducted at the Masters level in engineering study, we have two groups: professional practice outcomes and research outcomes. In the Professional Practice domain, outcomes involve Communication, Responsibility and Management, and Professional Conduct. Students communicate in a variety of ways to collaborate with other people and team members. That is including accurate listening, reading and comprehension, based on dialogue, taking into account knowledge, skills, expectations, requirements, interests, terminology and language of the intended audience. In the Research domain students build capabilities to develop creative and innovative solutions to engineering challenges. They plan and execute substantial research-based projects, with creativity and initiative in new situations in professional practice, with a high level of personal autonomy and accountability. Students assess, acquire and apply the competencies and resources appropriate to engineering activities. Then, they demonstrate professional use and management of information. Finally, students clearly acknowledge their own contributions and the contributions from other team members and distinguish contributions they may have made as a result of discussions or collaboration with other people. Prerequisite for the research capstone course is ResearchMethods course in addition to all other courses in the Masters program of study.

Outline: The rest of the paper is organized as follows. Section 2 introduces the related work from the learning and teaching perspective. Section 3 presents a number of examples i.e. projects conducted in the School of Engineering and the School of Science with the focus on biomedical engineering, bioengineering, eHeath, as well as related research areas. Finally, Section 4 summarizes the paper.

2. Related work

We concluded that project-based learning provides many advantages for students. In the case of industry-oriented courses, project topics either come from industry, or reflect real industrial problems. In the second scenario they are conducted in the University labs that emulate industry environment. Many of the University labs are state of the art facilities at the same level, or even above the industry places. This is the case with RMIT's Centre for Additive Manufacturing incorporated into STEM college. The real problems are used as the stimulus and focus for student activity, see [11, 12, 13]. The idea of Problem-Based Learning (PBL) is often applied for developing of capstone project courses, which students have to take in their final semester, see [14, 15, 16, 17]. One of the advantages of this approach is that students not only learn how to apply the skills they acquired in previous semesters, but also learn how to identify and fill the gaps in their skills to complete the project successfully. This is especially important for the case of SE, as self-study of new technologies and programming languages is a part of every-day life in SE industry due to the dynamically evolving technologies, languages, etc.

Another advantage of project-based learning is providing students a team-work experience, where students learn how to organise their work as a team sharing the tasks and responsibilities. In the case of teaching Agile development, team-work experience becomes even more important. The actual goal is to make the learning collaborative, where the students work jointly and learn from each other's experience, instead of having a simple cooperation, where the students divide the tasks and work as independent contributors rather than as a collaborative team, see [18, 19, 20].

Factors that can contribute to collaborative learning within a team, include the following:

T1: Whether the teams are created based on students' preferences on team members as well as time availabilities, see [21], because
  - working with preferred team members can stimulate collaboration, and
  - working with the team members having similar time availabilities allows to find common time to meet and work jointly.

  However, letting students form complete teams on their own might provide suboptimal results [22]. Thus, a balanced approach is required to take into account the students' skills, attitudes, etc., see [23].

T2: Whether the allocation to the project topics is based on students' preferences, as this increases students' motivation [24].

Thus, having well-composed teams is also a crucial learning factor [25, 26], which we take into account within the redesigned course. As mentioned, many studies demonstrated that making the projects industry-oriented rather than just theoretical/academic, motivates students, see e.g., [1, 27].

3. PBL examples with the focus on the eHealth, bioengineering, biomedical engineering research areas

The capstone courses focus on hands-on practical experience within the related area of study. The work is team-based, which helps students to gain more experience on collaborative aspects of the work, to master their communication and planning skills. RMIT academics provide their expertise on project management and software engineering, especially focusing on requirements' engineering aspects and problem analysis. The domain expertise is also provided by our industrial partners.

Project-based learning ideas presented in this paper were applied in the WIL modules within the following study programs:

- Bachelor of Engineering (Advanced Manufacturing and Mechatronics) (Honours) at the School of Engineering,
- Bachelor of Software Engineering (BSE) and Master of IT (MIT) at the School of Computing Technologies.

The project teams typically have four to six students (in some cases we also accepted more students), assuming that the students already passed the courses on programming, fundamentals of software engineering, software engineering project management, etc. Thus, the emphasis is on

- understanding and working within a corporate environment,
- applying project management and software development methodologies, which were studied in the separate course as the prerequisite,
- integrating all the skills and knowledge acquired from the previous courses into a solid base.

The successful results of the proposed *Research embedded in teaching* initiative are presented in [28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39].

3.1. Examples of the Bioengineering and Biomedical engineering projects

Human motion is initiated by intentions, i.e. thoughts that are creating brain signals. Extensive research in this area was conducted in order to establish classification of left and right knee extension motor imagery using common spatial pattern for Brain Computer Inter- face (BCI) applications [40, 41, 42]. We have performed event-related changes detection in sensorimotor rhythm [43]. Finally, we have developed EEG-Based BCI Control Schemes for Lower-Limb Assistive-Robots [44]. This project activities involved students not just as team members, but as subjects of research. To be able to conduct experiments, all ethics approvals were obtained before the research has started.

b

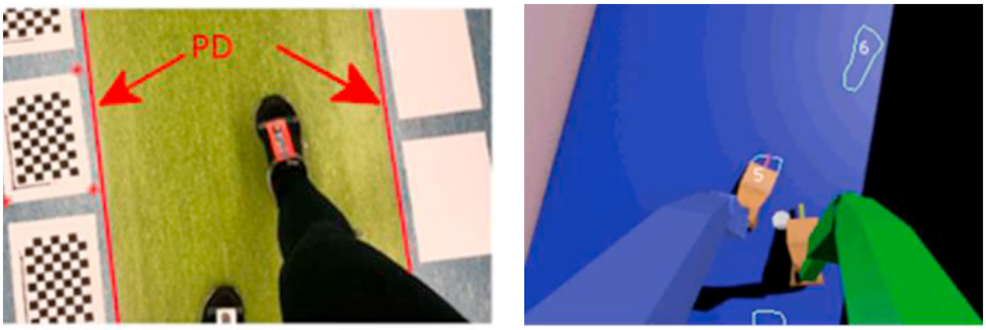


Fig. 1. (a) Captured image of subject's walking in Progression Direction (PD); (b) Simulated 3D image

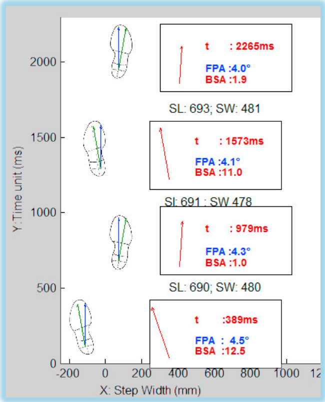
Other compatible research projects are in the area of motion biomarkers monitoring [45, 46]. Our approach is based on vision and image processing, instead of using expensive gait laboratories. As an example, captured and simulated images are shown in the Fig. 1. Smartphone camera was used for data acquisition. In this project students are doing programming in MATLAB to perform digital signal processing. They are developing novel algorithms [46], but they are also subjects of the research. For this project activity, ethics approvals were, also, obtained before the experimental part of the project have started. This project was conducted in the collaboration with the University of Sydney, Australia. Images are collected using mobile phone camera, while processing is performed on laptop running MATLAB program. A segment of demonstration code, used to detect one of the key stages in walking, when the foot is on the ground, is given in Fig. 2. At that moment Foot Progression Angle (FPA) could be measured. Set of numerical results of the measurements is given in Fig. 3(a), while graphical view is presented in Fig. 3(b).

```
while hasFrame(video)

       read_next_frame()
     if found_footarea()

          foot_speed    = measure_foot _v_frame_speed()
          floor_speed   = measure_floor_v_frame_speed()

           if foot_speed = floor_speed()
            %Foot Flat Phase found

                  image_rectification()
                  measure(FPA,step_width,step_length)
                  write_FPAinfo_into_step_array()
              end

        end

end while
```

Fig. 2. (a) MATLAB code of the algorithm developed to detect Flat Foot Phase (FFP)

Left foot			Right foot		
#	t(ms)	FPA(°)	#	t(ms)	FPA(°)
1	389	4.542	2	979	4.34
3	1573	4.132	4	2265	4.095
5	2859	4.401	6	3452	5.267
7	4047	4.876	8	4645	4.74
9	5236	4.412	10	6424	5.026
11	7022	4.378	12	7616	4.218
13	8208	4.881	14	8799	4.616
15	9392	5.019	16	9991	4.213
17	10587	4.47	18	11182	5.086
19	11776	4.943	20	12358	4.497

(a)



(b)

Fig. 3. (a) FPA measurements, Fig. (b), Outputs collected during the video analysis. Y axis corresponds to the Progression Direction (PD). Motion time is expressed in (ms). Axes X and Y together show 2D layout of the experimental place. Time t is the elapsed time from the beginning of the video, while FPA and other quantities, are shown for each step. (#: step number).

After this PBL project, the following one will have the main objective to perform data acquisition and processing using just mobile phone instead of laptop. Finally, that should happen in the real time so that a biofeedback system could be developed and handed over to medical practitioners and the public.

From brain signals, generated by our intention to walk, to the motion and gate events monitoring and corrections, as the treatment for medical conditions, we are going down to the shoes. An AMSI Intern Project was conducted in collaboration with industry. Main objective was to develop software tool, using CATIA, that could be used by medical practitioners to measure patient's foot geometry, length of the legs and then 3D print shoes sole for the people that need adjustment. No one in the world has the same length of the extremities, but if the difference is above acceptable level,usually 2-3 cm, medical solutions, or adjustments are needed.

Another project on dental implants osseointegration was conducted in collaboration with the University of Melbourne. Osseointegration is an artificial implant structural connection with living bone. We could say the it is the formation of a direct interface between an implant and the bone, without affecting soft tissue. One of the main questions that dentist has to answer is if the implant is properly osseointegrated. Currently, dentist surgeons are using devices that implement small force F, to test the motion range of the implant. If the osseointegration is satisfactory well achieved, the movement will be smaller. We know that we have distributed mechanical stiffness, with coefficient k, and friction with coefficient b, around the body of the implant that has the mass m. This is a mechanical system that can be modelled with a simple ordinary differential equation.

$$bv + m\frac{dv}{dt} + k\int vdt = F \tag{1}$$

where F is the excitation force while v is the velocity of induced movement. With the procedure explained here, surgeon is basically establishing mechanical impedance. Application of force is destructive to the process of osseointegration. Practitioners come up with the question, if the nondestructive diagnostics methods could be developed.

Our research hypothesis was that it is possible to use bioimpedance electrical measurements to determine successful osseointegration, and perform testing using nondestructive method, i.e. without application of force. The idea was to develop new test methods to measure the stability and osseointegration of bone anchored endosseous implants. We look at the whole system now as an electrical system. It can, also, be expressed with another ordinary differential equation, analogue to previous one:

$$Ri + L\frac{di}{dt} + \frac{1}{C}\int idt = v \tag{2}$$

where R is the sum of the distributed resistivities, L represents the sum of the distributed inductivities, C represents the sum of the distributed capacities and f is frequency of the excitation signal voltage $v(t)$, given as:

$$v(t) = Vsin(2\pi ft) \tag{3}$$

Accordingly, interface between the bone and the implant can be investigated through electrical impedance expressed as following:

$$Z = R + j2\pi fL + \frac{1}{j2\pi fC} \tag{4}$$

We have developed measurement system consisting of a testing rig with signal generator. As per our hypothesis electrical impedance of the well osseointegrated implant should be different than the impedance of non osseointegrated implants and the difference should be clearly detectable. In order to establish correlation between electrical impedance and adhesion between the bone and the implant we are scanning through the frequencies. Of course, that it is different from patient to patient, it depends on the age and gender as well as other factors. Project is still going on and requires a lot of testing and data analysis.

3.2. CannEpil Project

A team of six students was working within this project in collaboration with domain experts from the MGC Pharmaceuticals Ltd. The result of this project was a Clinical Trial application, elaborated as a part of the International Library of Cannabinoids (ILC) platform. The main objective of the project was to analyse the usability aspects critical for data collection applications within this domain, i.e., collecting the treatment data as well as data on diverse cannabinoids (the major compounds of the Cannabis sativa L. plant) strains. The analysis of cannabinoid treatment gains more and more interest from researchers, e.g. as a potential anti-cancer treatment [47, 48].

Fig. 4 presents some examples of the interfaces of the Clinical Trial application. The system supports several types of users – from doctors, who can work in a number of hospitals, and academic researchers to the patients and caretakers, as well as system administrators and clinical trials coordinators. The Web interface was developed to provide the required functionalities to doctors, academic researchers, administrators and clinical trials, where the mobile interface (iOS and Android) was provided to be used by patients and caretakers. The Web-based application was implemented on the basis of Angular 6, an open-source front-end web application platform. The iOS and Android applications were implemented on the basis of Xamarin, which supports cross-platform compatibility between Android and iOS.

The application elaborated within the capstone project contributed to the CannEpil platform creation, see also [49] for the core implementation details. The core idea of platform is to use the collected data for the efficiency analysis of cannabinoid treatment of various disorders to provide an evidence-based assistance for doctors, researchers and industry to identify the right cannabinoid profiles for various conditions.

3.3. Analysis of the potential correlations among the weather conditions and medicine consumption / purchasing

A team of five students, was working on this project in collaboration with the data analytics experts from *NostraData*. The result of the project was a framework for automated analysis of data from Australian public sources. The goal was to identify fluctuations in medicine consumption/purchasing and the higher risk of a worsening health conditions depending on the weather changes. The research results of this project were presented in [50].

In the elaborated framework, the data management was implemented on the basis of the Hadoop Distributed File System [51, 52]. For the data analytics, we utilized Apache Nifi along with Vertica and MicroStrategy platforms. The core analysis was performed using R Studio, an open source software for R language, and the library Association Rules on the basis of the Apriori algorithm, cf. [53]. For data mining, the framework applies the Weka Apriori Association Analysis Algorithm, cf. [54, 55]. Fig. 5 illustrates the data collection and processing within the elaborated framework: the data are collected from the Apache Nifi and moved within Streaming Processing engines, Hadoop Cluster and the OLAP (Online Analytical Processing) engine.

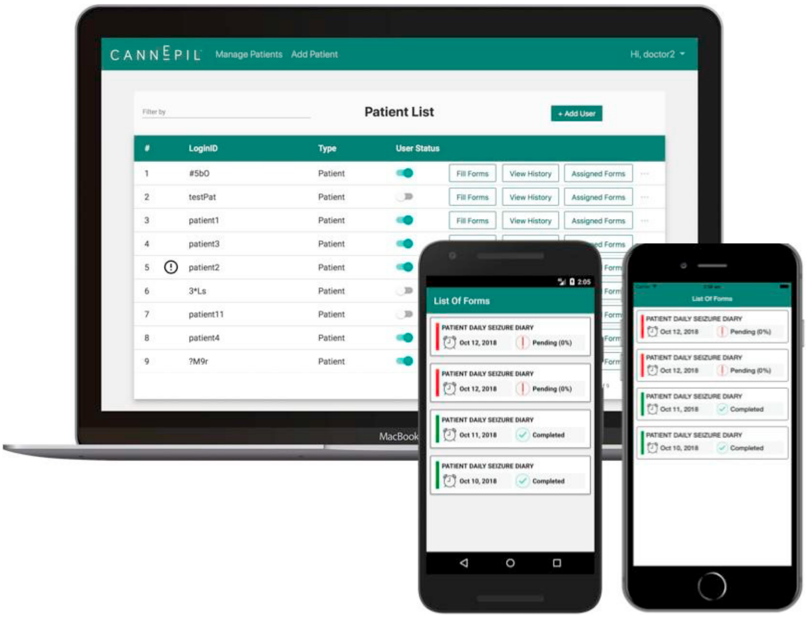


Fig. 4. Clinical Trial application: Web- and smartphone applications

We applied the framework on a number of case studies to analyse correlations among medicine consumption and weather conditions. Experiments were conducted on the selected datasets for specific medicine generic ingredient description codes, where we have focused on the data on the drugs acting against allergic, auto-immune and transplant related diseases, cholesterol, Hepatitis C, and Asthma.

3.4. *Health Delivered*

Two teams, of seven students worked on this project in collaboration with the experts from the digital health company *Health Delivered.* The main objective of is *Health Delivered* is to provide a technology platform for personalized and clinically validated meal plans. The platform aims on providing an unprecedented, scalable nutrition solution without the need to see a dietitian. The scope of the student project was limited to creating a prototype of the cloud-based dietary management platform, which was later created by *Health Delivered*. The core aims of the prototype included

- management of profile information such as first name and surname, gender, date of birth, email, location, pertaining to the client,
- management of notes that affects the client such as stress factor, activity factor, BMI, a pre-consultation questionnaire and daily snapshots
- management of the diet requirements and restrictions for clients, which should provide a basis for the meal planner,
- management the health goals on carbohydrate, protein, fluids etc.

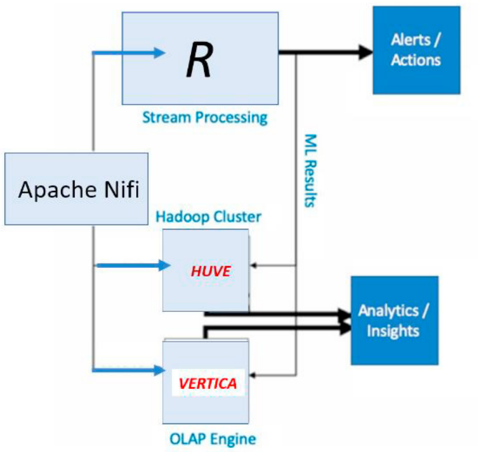


Fig. 5. Data collection and processing within the proposed framework

To implement the prototype, the team used Django REST framework (Python-based framework for business logic and secure API development) and the corresponding Python-based testing suite, as well as React.js and Redux libraries.

4. Conclusions

In this paper we have presented an overview of Work-Integrated Learning projects conducted at the RMIT University as a part of the Learning and Teaching activities in the STEM College with the focus on eHealth, bioengineering, biomedical engineering and related application areas. We have shown how real-life projects are embedded into the curriculum and presented a number of recent projects conducted by our students in collaboration with industrial partners, other academic institutions and medical practitioners.

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References

[1] M. Simic, M. Spichkova, H. Schmidt, I. Peake, Enhancing learning experience by collaborative industrial projects, in: International Conference on Engineering Education and Research (ICEER), 2016, pp. 1–8.
[2] M. Spichkova, M. Simic, Autonomous systems research embedded in teaching, in: Intelligent Interactive Multimedia Systems and Services, Springer, 2017, pp. 268–277.
[3] M. Spichkova, Industry-oriented project-based learning of software engineering, in: 24th International Conference on Engineering of Complex Computer Systems (ICECCS), IEEE, 2019, pp. 51–61.
[4] M. Paasivaara, D. Voda, V. T. Heikkila, J. Vanhanen, C. Lassenius, How does participating in a capstone project with industrial customers affect student attitudes?, in: Software Engineering Education and Training, 2018, pp. 49–57.
[5] M. Balaban, A. Sturm, Software engineering lab: an essential component of a software engineering curriculum, in: Software Engineering Education and Training, ACM, 2018, pp. 21–30.
[6] D. Knudson, S. Kalafatis, C. Kleiner, S. Zahos, B. Seegebarth, J. Detterfelt, I. Avazpour, K. Sandahl, P. Gorder, J. A. Ginige, et al., Global software engineering experience through international capstone project exchanges, in: Global Software Engineering, ACM, 2018, pp. 54–58.

[7] M. C. Bastarrica, D. Perovich, M. M. Samary, What can students get from a software engineering capstone course?, in: Software Engineering Education and Training, IEEE, 2017, pp. 137–145.

[8] B. Bruegge, S. Krusche, L. Alperowitz, Software engineering project courses with industrial clients, Transactions on Computing Education 15 (4) (2015) 17.

[9] C. Redecker, Ø. Johannessen, Changing assessment—towards a new assessment paradigm using ict, European Journal of Education 48 (1) (2013) 79–96.

[10] S. C. Dos Santos, Pbl-see: An authentic assessment model for pbl-based software engineering education, IEEE Transactions on Education 60 (2) (2016) 120–126.

[11] D. Boud, G. Feletti, The challenge of problem-based learning, Routledge, 2013.

[12] J. Savery, Overview of problem-based learning: Definitions and distinctions, Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows 9 (2015) 5–15.

[13] J. Armarego, Advanced software design: A case in problem-based learning, in: Software Engineering Education and Training, CSEET, IEEE, 2002, pp. 44–54.

[14] L. Brodie, H. Zhou, A. Gibbons, Steps in developing an advanced software engineering course using problem based learning, Engineering Education 3 (1) (2008) 1–12.

[15] S. S. Yadav, J. Xiahou, Integrated project based learning in software engineering education, in: Educational and Network Technology, IEEE, 2010, pp. 34–36.

[16] D. Davcev, B. Stojkoska, S. Kalajdziski, K. Trivodaliev, Project based learning of embedded systems, in: ICCSST, WSEAS, 2008, pp. 120–125.

[17] R. Cörvers, A. Wiek, J. de Kraker, D. J. Lang, P. Martens, Problem-based and project-based learning for sustainable development, in: Sustainability Science, Springer, 2016, pp. 349–358.

[18] C. Schoor, S. Narciss, H. Körndle, Regulation during cooperative and collaborative learning: A theory-based review of terms and concepts, Educational Psychologist 50 (2) (2015) 97–119.

[19] O. Gol, A. Nafalski, Collaborative learning in engineering education, Ph.D. thesis, Unesco, Internationa Centre for Engineering Education (2007).

[20] T. Panitz, Collaborative versus cooperative learning: A comparison of the two concepts which will help us understand the underlying nature of interactive learning (1999).

[21] T. J. Scott, J. H. Cross, II, Team selection methods for student programming projects, in: Software Engineering Education, Springer, 1995, pp. 295–303.

[22] S. Fincher, M. Petre, M. Clark, Computer science project work: principles and pragmatics, Springer Science & Business Media, 2001.

[23] S. P. Linder, D. Abbott, M. J. Fromberger, An instructional scaffolding approach to teaching software design, J. Comput. Sci. Coll. 21 (6) (2006) 238–250.

[24] T. Ahtee, T. Poranen, Risks in students' software projects, in: Software Engineering Education and Training, IEEE, 2009, pp. 154–157.

[25] R. Lingard, E. Berry, Teaching teamwork skills in software engineering based on an understanding of factors affecting group performance, in: FIE, IEEE, 2002, pp. 1–6.

[26] D. Dzvonyar, L. Alperowitz, D. Henze, B. Bruegge, Team composition in software engineering project courses, SEEM.

[27] M. Daun, A. Salmon, T. Weyer, K. Pohl, B. Tenbergen, Project-based learning with examples from industry in university courses: an experience report from an undergraduate requirements engineering course, in: Software Engineering Education and Training (CSEET), IEEE, 2016, pp. 184–193.

[28] A. Christianto, P. Chen, O. Walawedura, A. Vuong, J. Feng, D. Wang, M. Spichkova, M. Simic, Enhancing the user experience with vertical transportation solutions, Procedia computer science 126 (2018) 2075–2084.

[29] L. Clunne-Kiely, B. Idicula, L. Payne, E. Ronggowarsito, M. Spichkova, M. Simic, H. Schmidt, Modelling and implementation of humanoid robot behaviour, in: 21st International Conference on Knowledge-Based and Intelligent Information & Engineering Systems, Elsevier Science Publishers BV, 2017, pp. 2249–2258.

[30] M. Spichkova, J. Bartlett, R. Howard, A. Seddon, X. Zhao, Y. Jiang, SMI: Stack Management Interface, in: 23rd International Conference on Engineering of Complex Computer Systems (ICECCS), 2018, pp. 156–159.

[31] M. Spichkova, J. van Zyl, S. Sachdev, A. Bhardwaj, N. Desai, Easy mobile meter reading for non-smart meters: Comparison of aws rekognition and google cloud vision approaches, in: 14th International Conference on Evaluation of Novel Approaches to Software Engineering, 2019, pp. 179–188.

[32] C. Sun, J. Zhang, C. Liu, B. C. B. King, Y. Zhang, M. Galle, M. Spichkova, M. Simic, Software development for autonomous and social robotics systems, in: International Conference on Intelligent Interactive Multimedia Systems and Services, Springer, 2018, pp. 151–160.

[33] P. K. Gaikwad, C. T. Jayakumar, E. Tilve, N. Bohra, W. Yu, M. Spichkova, Voice-activated solutions for agile retrospective sessions, Procedia Computer Science 159 (2019) 2414–2423.

[34] M. Spichkova, J. van Zyl, S. Sachdev, A. Bhardwaj, N. Desai, Comparison of computer vision approaches in application to the electricity and gas meter reading, in: International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE), Springer, 2019, pp. 303–318.

[35] M. Spichkova, J. van Zyl, Application of computer vision technologies for automated utility meters reading, in: International Conference on Software Technologies, SciTePress, 2020, p. (to appear).

[36] L. C. George, Y. Guo, D. Stepanov, V. K. R. Peri, R. L. Elvitigala, M. Spichkova, Usage visualisation for the aws services, Procedia Computer Science 176 (2020) 3710–3717.

[37] M. Spichkova, B. Li, L. Porter, L. Mason, Y. Lyu, Y. Weng, VM2: automated security configuration and testing of virtual machine images, Procedia Computer Science 176 (2020) 3610–3617.

[38] M. Spichkova, A. Vaish, D. C. Highet, I. Irfan, K. Kesley, P. D. Kumar, Gosecure: Securing projects with go., in: ENASE, 2020, pp. 587–594.

[39] M. Spichkova, J. van Zyl, S. Sachdev, A. Bhardwaj, N. Desai, Easy mobile meter reading for non-smart meters: Comparison of aws rekognition and google cloud vision approaches, in: Proceedings of the 14th International Conference on Evaluation of Novel Approaches to Software Engineering, 2019, pp. 179–188.

[40] M. Tariq, P. M. Trivailo, M. Simic, Mu-beta event-related (de) synchronization and eeg classification of left-right foot dorsiflexion kinaesthetic motor imagery for bci, Plos one 15 (3) (2020) e0230184.

[41] M. Tariq, P. M. Trivailo, M. Simic, Classification of left and right knee extension motor imagery using common spatial pattern for bci applications, Procedia Computer Science 159 (2019) 2598–2606.

[42] M. Tariq, P. M. Trivailo, Y. Shoji, M. Simic, Comparison of event-related changes in oscillatory activity during different cognitive imaginary

movements within same lower-limb, Acta Polytechnica Hungarica 16 (2) (2019) 77–92.

[43] M. Tariq, P. M. Trivailo, M. Simic, Event-related changes detection in sensorimotor rhythm, International Robotics & Automation Journal 4 (2) (2018) 119–120.

[44] M. Tariq, P. M. Trivailo, M. Simic, Eeg-based bci control schemes for lower-limb assistive-robots, Frontiers in human neuroscience 12 (2018) 312.

[45] J. Young, M. Simic, M. Simic, Monitoring gait events by image processing, Procedia Computer Science 176 (2020) 3601–3609.

[46] J. Young, M. Simic, M. Simic, A novel foot progression angle detection method, in: Computer Vision in Control Systems-4, Springer, 2018, pp. 299–317.

[47] A. Bachari, T. J. Piva, S. A. Salami, N. Jamshidi, N. Mantri, Roles of cannabinoids in melanoma: Evidence from in vivo studies, International Journal of Molecular Sciences 21 (17) (2020) 6040.

[48] K. Singh, N. Jamshidi, R. Zomer, T. J. Piva, N. Mantri, Cannabinoids and prostate cancer: A systematic review of animal studies, International journal of molecular sciences 21 (17) (2020) 6265.

[49] R. Chugh, N. Chawla, R. M. Gracias, J. S. Padda, S. Li, M. T. Nguyen, M. Spichkova, N. Mantri, Automated gathering and analysis of cannabinoids treatment data, Procedia Computer Science 159 (2019) 2570–2579.

[50] M. Spichkova, Automated analysis of the impact of weather conditions on medicine consumption, in: 2018 25th Australasian Software Engineering Conference (ASWEC), IEEE, 2018, pp. 166–170.

[51] K. Shvachko, H. Kuang, S. Radia, R. Chansler, The hadoop distributed file system, in: 26th symposium on Mass storage systems and technolo- gies (MSST), IEEE, 2010, pp. 1–10.

[52] T. White, Hadoop: The definitive guide, O'Reilly Media, Inc., 2012.

[53] M. Kantardzic, Data mining: concepts, models, methods, and algorithms, John Wiley & Sons, 2011.

[54] M. Hall, E. Frank, G. Holmes, B. Pfahringer, P. Reutemann, I. H. Witten, The weka data mining software: an update, ACM SIGKDD explorations newsletter 11 (1) (2009) 10–18.

[55] K. Hornik, C. Buchta, A. Zeileis, Open-source machine learning: R meets weka, Computational Statistics 24 (2) (2009) 225–232.