Interdisciplinary Learning in Undergraduate and Graduate Education: Conceptualizations and Empirical Accounts

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Abstract: The purpose of this symposium is to bring together several research programs that aim to advance the conceptual and methodological foundations for studying interdisciplinary learning and to provide empirical evidence for further development of this, currently undertheorized and understudied, field. The first paper embraces a sociological concept of academic hospitality to look at how different modes of interdisciplinarity are adopted in university courses. The second paper adopts an activity-centered framework to investigate the development of students' competence during interdisciplinary learning. The third paper takes a linguistic perspective and examines connectedness as a measure of interdisciplinarity in students' produced artifacts. The last paper adopts a multimodal blending lens to look at how students integrate their ideas and construct shared knowledge artifacts during interdisciplinary innovation meetings. Collectively, the contributions provide a broad conceptual and methodological 'toolkit' for studying interdisciplinary learning from different analytical perspectives and at different levels of granularity.

Introduction

The focus of the symposium and the major issues addressed

Solving critical challenges that society encounters today, such as sustainability, healthcare and equity, are increasingly seen as primarily interdisciplinary (ID) endeavors (National Academy of Sciences, 2018). Therefore, competencies for working in interdisciplinary teams and creating joint knowledge products are increasingly seen as essential (Cooke & Hilton, 2015). However, struggles and even failures of ID teams have been common, surfacing a fundamental learning issue: many people lack competencies that are needed to work productively in ID teams. (Frickel, Albert, & Prainsack, 2017; Ledford, 2015; MacLeod, 2018).

In response, higher education institutions have been increasingly expanding their ID offerings; creating ID programs and courses or introducing ID tasks into existing subjects (de Zure, 2017; Lyall et al., 2016). Many proposed approaches view ID competencies primarily as a matter of certain generic 'T-shaped' competencies that need to be added on top of disciplinary knowledge and skills and propose generic models for developing such competencies (Bammer, 2017). However, the conceptual foundations that underpin pedagogical designs of ID offerings have been underdeveloped. As the UK Higher Education Academy's review of interdisciplinary provisions concludes, ID teaching and learning are one of the most seriously undertheorized and underthought concepts in modern universities (Lyall et al., 2016). Evidence for the principles and other ideas that underpin ID education is largely missing: "theory has not yet caught up with practice in this field" (Lyall et al., 2016, p. 68). It is not even clear what ID competencies are. Questionable conceptual foundations of ID courses and research approaches and, consequently, of students' learning experiences and outcomes have become important matters.

In the learning sciences field, researchers have been studying diverse collaborative learning practices and advancing a range of conceptual and analytical frameworks for conceptualizing and investigating collaborative

knowledge work, such as knowledge building and knowledge creation (Scardamalia & Bereiter, 2014). However, this work has usually focused either on productive disciplinary engagement or general issues of collaborative learning. Key challenges that are encountered when students learn and work across disciplinary boundaries need further investigation.

In cognate fields of science and technology studies (STS), organizational science, cognitive science, linguistics and others, researchers have developed a number of frameworks and methods for conceptualizing and studying knowledge work and learning across the established disciplinary boundaries, such as knowledge integration (Pennington, 2016), academic hospitality (Phipps & Barnett, 2007), conceptual blending (Fauconnier & Turner, 1998) and others (Derry, Schunn, & Gernsbacher, 2005; Frickel et al., 2017). However, these ideas have rarely been applied to theorizing and investigating ID learning in higher education. Research in the learning sciences that specifically focuses on the issues distinct to ID knowledge work and learning is just emerging (Herrenkohl et al., 2018; Shen, Sung, & Zhang, 2015).

This symposium brings into the dialogue four projects that investigate ID learning in higher education. In doing so, it aims to present and discuss the approaches created by the project teams to conceptualize and empirically study this phenomenon. In line with the conference theme, it explores how conceptual approaches and methods from the learning sciences can be blended with approaches and methods from other cognate fields to enhance our understanding of ID learning.

Organization of the symposium and significance of the contributions

The introduction to the symposium will be followed by presentation of four complementary studies, the discussant's response and discussion with the audience. Each presented study conceptualizes ID learning from a different perspective and provides a deep insight into a particular aspect of ID knowledge work and learning. They investigate the phenomenon across different levels (from institutions to individuals) and use different units of analysis (from an entire course to a specific phase of ID problem-solving).

Damsa and colleagues examine academic hospitality and how it makes the materialization of ID teaching and learning possible. Data are examined through a three-modes framework of ID to uncover the nature of processes involved at institutional, curricular and student learning levels.

Muukkonen and Celik combine the approaches and methods of knowledge creation, activity-centered design and collaborative knowledge practices to investigate students' situated learning activities. The study examines how these activities were related to the developed competence in a course that uses organization simulation and personal learning diaries to develop students' ID competencies.

Thompson and colleagues use connectedness as a measure of interdisciplinarity. Drawing on research into ID collaboration, they apply a linguistic lens to analyze individual student reflections and their final group product (a research proposal) to discover the connections students make between knowledge gained from stakeholders, presenters, and each other, and use a rubric to assess their final group product.

Arthars and Markauskaite focus on how ID postgraduate student teams working on innovation projects combine their individual ideas at different phases of innovation projects. They use an analytical framework that originates in the theories of conceptual blending from cognitive linguistics but extend it to the distributed ecological view of cognition and look at ID knowledge work from the multimodal perspective.

Kali will provide an integrative overview of the contributions and pose questions for further discussion.

Collective contributions towards the issues raised

Collectively, the symposium papers evidence that producing a better understanding of how students learn to work across disciplinary boundaries and how to facilitate formation of their ID capabilities is not just a matter of deploying existing research approaches. Neither cognitively oriented frameworks for studying how students learn disciplinary concepts, nor socio-culturally oriented approaches for investigating how they become enculturated into existing disciplinary practices can provide a satisfactory explanation of how students learn to make new connections across multiple disciplines and participate in hybrid interdisciplinary knowledge practices. Research in this domain requires development of more integrative conceptual approaches and methods that enable holistic investigation of this phenomenon across disciplines, across scales and across modalities. This conceptual and methodological challenge is itself interdisciplinary. In short, ID learning disrupts not only disciplinary frameworks and identities that students bring to the ID learning space, it also disrupts research frameworks that have been constructed to study productive disciplinary engagement.

Academic hospitality as a frame for interdisciplinary learning

Crina Damsa, Molly Sutphen, Rachelle Esterhazy, Tone Dyrdal Solbrekke, Ciaran Sugrue, and Velda McCune

Background and aim

This contribution presents a study on interdisciplinary learning in a higher education context that is the conceptual perspective of academic hospitality (AH). The study takes as a departure point that teaching and learning in the university is understood as taking place within disciplinary boundaries, unless labelled otherwise. The causes for labelling and often celebrating ID learning are several, starting with universities being asked to (or touting themselves as able to) meet the challenges of preparing their students to address complex, ill-structured problems our society and environment face, many of which require an ID approach. The challenges for learning include insufficient knowledge about: 1) how higher education institutions frame interdisciplinarity; 2) how academics view and enact interdisciplinarity; and 3) how students engage and experience ID learning designs and projects. This study aims to advance understanding and conceptualization of ID learning by building on the framework of AH and empirical data collected in an initial exploratory study that addressed these three analytical levels, and which sets the basis for a more comprehensive project.

We conceptualize *interdisciplinarity* broadly and define it as a particular way of combining concepts, practices, approaches, instruments, assumptions, methods, or expertise by those from different disciplines. We employ a framework proposed by Barry and Born (2013) to examine the empirical material. They propose that ID takes three distinct modes: 1) *a synthetic-integrative* mode, where through negotiation on or integration of different disciplinary approaches a process of synthesis occurs and is most often sanctioned by institutions and may produce epistemic transformations; 2) *a subordination and service mode*, where one or more disciplines serve other disciplines; and 3) *an agonistic-antagonistic mode*, where disciplinary ontology and epistemology are 'in play' through contest or transcendence of epistemologies and/or ontologies; the deliberative communication as 'having the better argument' rather than seeking 'legitimate compromise' applies in this case. During the last two decades, the concept of hospitality has reentered the work of anthropologists (e.g., Candea, 2012; Selwyn, 2001) and entered research on higher education (Phipps & Barnett, 2007). *Academic hospitality* is a notion that depicts academics' and students' ways of engaging with ID work, and is framed as the material, linguistic, epistemological, and touristic (e.g., academic visits) forms or interactions (Phipps & Barnett, 2007). For example, how open-minded are students and academics to using knowledge or skilled know-how in new ways, or how do students learn to be receptive to using concepts or methods they learn from one field in another? (i.e., epistemological hospitality). Studies have explored AH in student mobility (Kenway & Fahey, 2009; Ploner, 2018), ID collaboration (Harvey, 2018) and other domains (Phipps & Barnett, 2007). We adopted this approach for exploring challenges encountered by learners, teachers and institutions when attempting to work interdisciplinary.

Methods

The empirical context of this study is a large research university in Norway, where we have been exploring and mapping the ways in which AH comes into play and fosters ID learning. Three programs designated formally as ID by the university, representing various topical orientations, and three programs not identified formally as ID by the university have been selected also to explore contrasting characteristics. We have been exploring at three levels (institutional, curricular, and students' learning) by collecting various types of data. We started with the *institutional level* to determine how the university designates interdisciplinarity, and we looked for examples of ID learning. We used the following types of data: 1) digital documents, collected through surveying the way ID programs are presented through public and official channels (webpages, institutional documents); and 2) interviews with institutional/program leaders. On the *curricular level,* we investigated the structures and teaching practices, in which AH is or is not enacted for ID teaching. Data sources included: 3) course documents and 4) interviews with teachers. Finally, at the *students' learning level,* we investigated the processes and function(s) of AH in teaching and learning. Data included: 5) focus group interviews with students, and 6) student grades. During the interviews, we examined different approaches to foster AH, by asking participants to reflect on the ID approaches identified in the three-modes framework by Barry and Born (2013). The documents were analyzed through document analysis, interviews were analyzed through thematic analysis.

Findings and conclusions

Preliminary findings show that AH takes different forms, whether the program is advertised as interdisciplinary or not and depends on institutional support that varies widely. We also found AH easy to aspire to at an institutional level but hard to put into teaching practice by academics. The synthetic-integrative mode is conceived as an ideal form of interdisciplinarity, but difficult to realize. The most common realization is the subordination and service mode. Importantly, the findings show that each of the three modes have a function in framing

interdisciplinarity and the efforts undergo different phases. For example, in the time of transformation, the agonistic-antagonistic mode is also represented. The institutional level encounters the most difficulties to enter a synthetic-integrative mode, while students enter this mode more fluidly. The findings generate implications related to awareness creation and the building of infrastructure conducive to as well as foster ID learning, where AH mechanisms are activated at different levels and for different stakeholders.

Organization simulation: Situated activities and competence development in interdisciplinary teamwork

Hanni Muukkonen and Ismail Celik

Background and aim

Professional work has taken a major shift from disciplinary to interdisciplinary teamwork to respond to the growing complexity of tasks and dynamic nature of problems that society needs to solve (Benoliel & Somech, 2015). Higher education faces a challenge preparing students for these changes and helping them develop related competences. The most commonly adopted pedagogical approach is to involve students in ID project-based teamwork during courses. However, a much better understanding is needed of how course design decisions interact with students' engagement in collaboration and epistemic activities, and the learning outcomes. We investigated an organization simulation course to study the enacted design from the students' perspective. We analyzed the situated learning activities, and how these activities related to developed competence.

In this paper, we look at ID learning as situated activity aimed at collaborative knowledge creation. Su and Goodyear (2019) have described situated learning activity as a 'meshwork' of people and things, brought together in processes of co-configuration. Such learning activity can be unpacked by analyzing three interacting processes: activity as physically, socially, and epistemically situated. This provides a fruitful framework to analyze aspects of ID teamwork during learning. Further, learning can be designed as a process of knowledge creation, through interactive practices that contribute to ideas being materialized into shared knowledge objects, such as reports, designs or other products (Paavola et al., 2011). This entails that students are expected not only to process and assess knowledge but also generate knowledge solutions to complex problems (Damsa & Muukkonen, 2019; Shaw, Holbrooke, & Burke, 2011). However, the development of competence for such ID work is intricate to operationalize.

The research questions addressed in this study were: 1) How did students describe their learning activities as individual and collaborative situated activities in ID teamwork? 2) How was engagement in situated learning activities related to competence development and final grade at the team level?

Methods

Data were collected over four consecutive years in an Organizational Psychology course for Masters students at the [university]. Students (N=106) were from educational psychology, education, engineering, economics, and humanities. Students took part in an organization simulation, where they worked in teams to set up an expertise profile for their organization and to create a response to a customer's call for bids for a new human resources development initiative. Individually, students had a weekly task that required them to read a research paper and write a reaction, and to compile a learning diary (integrating reflection of individual and team learning activities and conceptual knowledge). These diaries were qualitatively analyzed to capture a description of the physically, socially, and epistemically situated activities in ID teams. The analysis focused on the types of activities, engagement, and challenges relating to students' individual and collaborative efforts.

Further, students responded to the Collaborative Knowledge Practices (CKP) questionnaire after the course. This questionnaire provides information on how the course helped students to develop knowledge work competence related to seven aspects: 1) object-oriented collaboration, 2) integration of personal and collective agency, 3) development through feedback, 4) persistent development of knowledge objects, 5) understanding of different disciplines and related expertise, 6) interdisciplinary collaboration, and 7) using digital technology (Karlgren et al., 2019; Muukkonen at al., 2019). Also, students provided a brief pre-post evaluation on their personal knowledge work competence, consisting of six items (Cronbach's alpha pre and post evaluations were .80 and .85, respectively). A final grade based on the diaries, provided by the teachers on a scale from 1 (lowest) to 5 (highest), was also included in the analysis.

Findings and conclusions

The analysis of the learning diaries showed variation in the initial and later stages of engagement in teamwork. This variation was partially related to the disciplinary background: Students in education and humanities

experienced more challenges with taking an expert role in the team. Further, the analysis revealed students' challenges related to recognizing the expertise needed to produce the bid and finding suitable ways to contribute to ID interaction. Eventually, students with higher final grades also evaluated their learning on integration of personal and collective agency and ID collaboration higher than students with lower final grades. Overall, the analysis shows that students' learning diaries and their self-evaluations give a rich description of how students engage with the tasks and develop necessary competence. It reveals that the design of organization simulation and learning diary task made both their growth in disciplinary expertise and the requirements for competence in ID teamwork visible for students. This helps them prepare for their future professional life.

Identifying connectedness in individual and group artifacts during a graduate summer school in interdisciplinary research

Kate Thompson, Penny Wheeler, and Daniela Vasco

Background and aim

In the last fifteen years, there has been a focus on finding ways to facilitate interdisciplinary collaboration between social scientists, engineers and environmental scientists to solve socio-environmental problems (Kemp & Boynton, 2012; Lélé & Norgaard, 2005). There is, therefore, a need to prepare graduate and undergraduate students to be leaders of ID research. To meet this need, the Employing Model Based Reasoning in Socio-Environmental Synthesis (EMBeRS) approach was developed, building on an extensive review of the literature (Pennington et al., 2016). This approach was implemented at two Summer Schools for graduate students from multiple disciplines and universities (Thompson et al., 2017). The work of ID teams is often assessed at the completion of a project. What is lacking in the literature is, as Callard, Fitzgerald and Woods (2015) express it, "the mundane detail of what it looks and feels like to labor in an interdisciplinary setting" (p. 4). In this paper we present an approach to identifying evidence of student ID reflection. Using a linguistic lens, we identify and follow connectedness through student artifacts, and assess the final submission made by their group. The aim of the research is to examine the connectedness of different sources of knowledge (from disciplinary backgrounds, group members, presenters, and other stakeholders) and its importance to the assessment of interdisciplinarity, in individuals and groups.

Methods

Training activities were implemented during two two-week EMBeRS Summer Schools (Thompson et al., 2017). In this paper, we focus on the thirteen graduate students (3 groups) who attended the second Summer School. The design of the EMBeRS Summer School guided participants through lightly structured activities that employed the key phases of interdisciplinary problem-solving including field trips, concept mapping, stakeholder identification, and systems thinking. At the end of each day, the group had dedicated time for reflection on these activities to guide student understanding of design choices, learner activity and learning outcomes, and each evening they were asked to engage in individual reflections about their learning. In addition to the collaborative discursive synthesis tasks, students were also given an individual written synthesis task (Thompson et al., 2017).

Multiple types of data were collected, including audio and video recorded observations, paper and digital artifacts produced by students individually and together, and student reflections. Three sets of these artifacts were compared for individual and group performance. The type of artefact selected from the available items was motivated by measures for interdisciplinarity listed by Huutoniemi et al. (2010). These include explicit description of the epistemic challenge, the distance between the fields being combined, and a focus on new knowledge resulting from combining or integrating one discipline with another and framing the research problem.

Methods that allowed a close textual analysis and comparison were adopted to examine these artifacts. Linguistic and discourse analytics were used at different scales, with Halliday's systemic functional grammar (Halliday & Matthiessen, 1999) providing the general framework for analysis. The evaluation of 'integration', as an overarching feature of interdisciplinarity, as represented by connection and conjunction, was central in each analysis. Segments of interest were derived using natural language processing for two sets of terms: 1) where 'connection' is the focus of the discourse; and 2) where conjunctions in the text construe different kinds of connections. A rubric was used by the researchers to evaluate the interdisciplinarity of the final group products. The criteria were adapted from the measures proposed by Pohl et al. (2010) to "assess the quality of integration in inter- and transdisciplinary research proposals" (p. 3).

Findings and conclusion

During the workshop, students described events or experiences of connection. For the students in the three groups,

an occurrence of 'connect' or its synonyms was identified 77 times. The number of connections identified was very similar when compared across groups. Within each group, there was one individual who described more connections than the others in the group in their individual reflections. The focus of these was different in each group, to include task connections (making connections related to elements of the task), and personal and research connections (making connections between people and the research that they do).

Two groups' proposals were assessed as interdisciplinary, each with different strengths, and examination of the student reflections confirmed these strengths. One group's proposal was assessed as multidisciplinary mostly due to the low diversity in methods, scales and social actors. Students expressed frustration at the final product and processes in this group. These findings were also supported by the linguistic analysis of coordinating conjunctions in the proposal. Overall, ID connections were primarily found in the connections made within artifacts produced by groups, rather than by individuals.

This study provides conceptual and methodological foundations for further research that uses corpus and systemic functional linguistics and integrates additional methods (e.g., scoring rubrics) and data sources (e.g., visual representations constructed by groups). The results from the complementary analysis of individual and group artifacts provide new indicators for recognizing development of an individual ID perspective, and criteria for success of ID groups. The results of this research have already informed the design of ID research education in other settings and show that the provision of multiple opportunities for connecting knowledge is essential for the success of such programs.

How interdisciplinary student teams combine heterogeneous ideas: A multimodal blending approach for analyzing knowledge integration

Natasha Arthars and Lina Markauskaite

Background and aim

Interdisciplinary project-based learning often involves multiple phases, during which teams work on specific aspects of the problem, such as problem exploration, idea formulation and consolidation of ideas into a final knowledge artifact (Ness, 2014). Various representations of knowledge inscribed in external media, expressed in language and other modes play critical roles in this process (Markauskaite & Goodyear, 2017). When people work in disciplinary or other established teams, they often draw on their mastery of already existing and well familiar for all team members joint representational infrastructures (Goodwin, 2018). These infrastructures allow them to share their ideas, bring them together and construct joint knowledge artifacts. However, ID student teams do not have shared infrastructures and must find their own ways to share and integrate heterogeneous ideas. How ID students' teams combine individual knowledge into joint knowledge artifacts and how, through this process, they create a shared understanding are little understood. The complexity of this process is a key methodological issue. It draws on knowledge distributed across people and media, and involves complex conceptual work, interaction and inscriptional work simultaneously (Goodwin, 2018; Markauskaite & Goodyear, 2017).

In this study, we aimed to develop a multimodal analytical approach for investigating how ID student teams integrate ideas to construct joint knowledge artifacts representing their shared understanding at different phases of innovation-oriented ID project-based work. We drew on the analytical approaches of conceptual integration (Fauconnier & Turner, 1998) and material blending (Hutchins, 2005), and extended them to the analysis of multimodal human interaction during the *blending process* (e.g., movement, gestures).

Methods

Our data came from two ethnographic cases in a 13-week postgraduate project-based ID course. Two student teams explored and designed innovative solutions to address one of two complex problems: poor air quality for cyclists and trust in online lending. Data included video-recorded observations of team meetings (52 hours in total), online group interactions (e.g., Trello), copies of produced artifacts (e.g., notes, drawings), and interviews. We analyzed episodes and artifacts from team meetings that represented two critical phases of problem solving where teams worked intensively with heterogenous ideas: 1) exploration of the *problem*, where teams blended individual research outcomes and ideas to construct a joint conceptualization of the problem, and 2) exploration of the *user*, where teams blended individual ideas and research to construct a joint conceptualization of user needs.

We adapted, extended and applied conceptual integration (Fauconnier & Turner, 1998) as an analytical approach for investigating students' work constructing joint knowledge artifacts. Conceptual integration theory originates in cognitive linguistics and aims to explain how people create new meanings by blending several separately encountered arrays of ideas, called 'mental spaces' or 'inputs'. During blending, structures and elements from several input spaces are selected and projected into a new, compressed, composite space, called a

'blend'. This blend has an emergent structure that allows performing further cognitive work in it, i.e. manipulating elements according to an emergent structure and creating new meanings.

In conceptual integration theory, 'inputs' and 'blends' are seen as mental spaces and blending is seen as a cognitive process performed on abstract structures in the mind. However, recent research shows that similar blending processes can be observed when cognition is distributed across humans and nonhumans, and inputs are not only mental arrays, but also material objects (Hutchins, 2005), inscriptions (Markauskaite & Goodyear, 2017), physical and virtual spaces and other arrangements (Enyedy, Danish, & DeLiema, 2015). In our analysis, we focused on investigating what sorts of inputs students bring to the joint space and moves involved in integrative knowledge work constructing joint knowledge artifacts: 1) a system map, 2) a problem statement and 3) user personas. Video recordings of teamwork together with artifacts produced by the teams were analyzed by identifying inputs together with structures and elements in the blended space and exploring blending moves.

Findings and conclusions

The process of creating the final joint knowledge artifacts involved a series of blends with each becoming more compressed and refined. We identified that when students engaged in blending as a team, they 1) made their ideas visible by sharing their knowledge and initial individually produced artifacts, 2) explored the space by connecting similar ideas together, 3) selected, adapted or created an organizing frame through which to blend (e.g., a persona template), 4) negotiated how to compress and project input spaces into the blend, and 5) projected elements from the input spaces into the blend to create a new, shared knowledge artifact.

This process often involved the construction of a shared representational infrastructure that allowed the re-representation of individual ideas to form relationships among them in a joint space. It included such aspects as construction of joint inscriptional scheme through negotiation of meanings assigned to colors, spatial layout, and connecting lines that gave key structure for the further joint work in the saturated space. Almost all blends involved not only expression of ideas in symbolic artifacts, but also multimodal interaction that combined dialogue, gesturing, writing, drawing and mirroring of bodily action.

Overall, our analysis shows that constructed artifacts are the result of blending; however, they often act as inputs in subsequent blends. The blending process alone does not convey the representational infrastructure that is created simultaneously and serves as a joint meaning-making frame during ID work. The results point to the importance of developing students' competencies not only to work with conceptual ideas from different disciplines, but also to develop their epistemic competencies to co-construct, what Knorr Cetina (1999) called, 'machineries' for joint knowledge construction.

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