Challenges for engineering students working with authentic complex problems

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ABSTRACT

Engineers are important participants in solving societal, environmental and technical problems. However, due to an increasing complexity in relation to these problems new interdisciplinary competences are needed in engineering. Instead of students working with monodisciplinary problems, a situation where students work with authentic complex problems in interdisciplinary teams together with a company may scaffold development of new competences. The question is: What are the challenges for students structuring the work on authentic interdisciplinary problems? This study explores a three-day event where 7 students from Aalborg University (AAU) from four different faculties and one student from University College North Denmark (UCN), (6th-10th semester), worked in two groups at a large Danish company, solving authentic complex problems. The event was structured as a Hackathon where the students for three days worked with problem identification, problem analysis and finalizing with a pitch competition presenting their findings. During the event the students had workshops to support the work and they had the opportunity to use employees from the company as facilitators. It was an extracurricular activity during the summer holiday season. The methodology used for data collection was qualitative both in terms of observations and participants' reflection reports. The students were observed during the whole event. Findings from this part of a larger study indicated, that students experience inability to transfer and transform project competences from their previous disciplinary experiences to an interdisciplinary setting.

1 INTRODUCTION

1.1 Section 1

Engineers are expected to be important participants in solving the grand societal challenges [1]. These aspects create new demands for engineering education in the future [1,2] and new ways of students' collaboration in more interdisciplinary situations across disciplines and faculties [3]. This paper describes the experience from a 3-days Hackathon event that took place at a large Danish company where 7 students from AAU (Aalborg University) and one student from UCN (University College North Jutland) worked in two project groups solving authentic complex problems. Students from AAU are used to project work on problems in teams with participants from their own discipline. At the Hackathon event students work with complex problems in an interdisciplinary group. Research shows that students have difficulties with collaboration on complex interdisciplinary problems [4,5]. The aim of this research is to answer the question: What are the challenges for students structuring the work on authentic interdisciplinary problems? Initially the paper introduces the theoretical framework used to interpret the data collected, then presents the methodology and finally describe and discuss the results.

1.2 Theoretical framework

There are different interpretations of the concept interdisciplinarity. However, this study uses the definition by Keestra & Menken [6] where interdisciplinarity is defined as a range of degrees from multidisciplinarity to transdisciplinarity. Multidisciplinarity is defined as a situation where disciplines work together in parallel. Interdisciplinarity is a situation where disciplines are integrated and finally transdisciplinarity is a situation where interdisciplinarity is integrated with non-academic domains. To extend the definition of interdisciplinarity the typologies described by Klein [7] are used. Klein [7] distinguishes between narrow and broad interdisciplinarity. Broad interdisciplinary collaboration teams are teams working together with very different understandings of ontologies, epistemologies and methodological approaches, whereas narrow interdisciplinary teams are teams that are closer aligned in relation to ontology, epistemology, methods and understandings. In relation to interdisciplinarity, boundaries and boundary crossings are very important. Carlile [8] defines three levels of managing knowledge across boundaries in relation to the differences, dependencies and novelty, see figure 1.

The first level – Syntactic transfer: When novelty is minor the knowledge between Actor A and Actor B can be transferred without problems and the category of the boundary object can be represented by a repository [9]. **The second level – Semantic translation**: With increasing novelty, the differences and dependencies can become unclear or there can be different interpretations of meanings. At this level, transformation of knowledge is not enough but translation of meanings or negotiations may be needed and the boundary objects can be categorized as

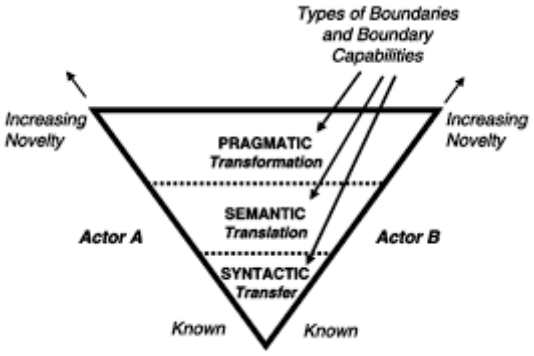

Fig. 1. An integrated framework for managing knowledge across boundaries [8, p.558]. Actor A and Actor B represent actors from different disciplines with differences and mutual dependencies. Increasing novelty entails increasing effort to manage the boundary.

standardized forms and methods. **The third level – Pragmatic transformation**: When novelty increases to a level where it affects the interests of the actors a transition to the pragmatic level occurs. The pragmatic level needs knowledge to be transformed from domain specific knowledge to a mixture of knowledge domains and the boundary object can be categorized as objects, models or maps [9].

2 METHODOLOGY

2.1 Research context

This study, which is part of a larger study, is based on a 3-days extracurricular event arranged by AAU in cooperation with a large Danish company. 7 students from four different faculties at AAU and one student from UCN participated in the event that was structured like a Hackathon. The students came from four different countries. The event took place at the premises of the Danish company, where the students stayed during the whole event together with three employees from the company and three researchers from AAU. The content of the Hackathon was a combination of round tours at the company, supporting workshops and group work. The group work was divided in four sprints with inspiration from a guide concerning PBL and Entrepreneurship [10]. Each sprint finalized with a pitch from the two groups. The overview of the Hackathon is shown in figure 2.

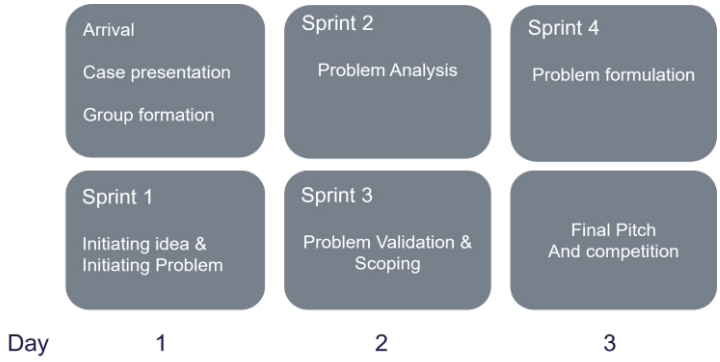

Fig. 2. Overview of the Hackathon event divided in four sprints finalizing with a pitch.

After students' arrival and accommodation at the company, employees from the company presented two different cases for the students. The first case - Case #1 belonged to a problem area familiar for the company whereas Case #2 was regarded as a new problem area. After lunch two groups were formed based on student competences and interest in the two cases. After group formation the students worked in four sprints finalizing with a pitch competition on day 3. The jury for the competition consisted of one jury member from the company and two jury members from AAU. The winning group was awarded with a cash prize.

2.2 Empirical data

The methodology used for data collection was a qualitative research design. Three researchers from AAU participated in the event. Two of the researchers conducted the workshops and structured the event. The third researcher was assigned the role as an observer during the whole event, without participation in the workshops. This researcher used an observation protocol [11, p.190] for recording the observations during the whole event. The observation protocol was divided in a descriptive part, supplemented with columns for details concerning participants, objectives, means and tools, messages and findings and a reflexive part with room for observers own thoughts and comments. The header of the observation protocol contained information about the current project phase. At the registration to the Hackathon

event, the students were asked to give a short-written justification for participation and at the beginning of the event the students were asked to make a competence profile. The competences were parted in two: the professional competences and the PBL competences which worked as baseline for the final reflections and edition of competences gained at this event. After the Hackathon the students were asked to reflect about their experiences with the Hackathon event and give inputs to improvements for the future.

3 RESULTS

3.1 Students justifications for participate

From the students' justifications for participation, it is clear that it is very motivating for the students to participate in an event like this, especially when it is possible to relate the themes to their own studies and backgrounds. *"I would like to join this event because I think that the challenges sound really exciting and the themes fit very well together with my studies".*

Two of the students directly mentioned one of the themes as very important for their participation. The students also mentioned their own backgrounds as important and the experience of how they could contribute*: "With excitement I look forward to see what I can contribute in the context of Your enlightened themes and in the collaboration with other professional groups during the teamwork sessions…..".*

"Additionally, with my knowledge of [……..] together with a background in [……..] and experience in problem solving in a group, I feel I would be able to really make a difference and contribute to the workshop".

Collaboration and problem solving in groups was mentioned too. *"I want to participate because I see it as a great opportunity to work creative and innovative with other students on solving problems"*.

Moreover, reflections about the future about own career and their own role was mentioned: *"Events like this allow me to establish my professional qualities as I have to be a specialist in my area, aware of the fact that my input really matters".* And: *"The possibility to broaden my horizons and challenge my creativity is the reason for my participation"*. At a more meta level a student wrote: *"Furthermore, I am interested in design processes, innovation and the human consequences from implementting smart technologies"*. Finally making new relations also mattered: *"And most importantly, challenging events are the place where amazing friendships start :)".*

3.2 Interdisciplinary team formation

After the presentation of the two cases the students were asked to write down their professional and PBL competences on post-it notes. Subsequently the students shared all the post-it notes on a large white board and presented their personal competences to the other students. With support from the researchers the students formed two groups, based on individual interests in the cases and based on the knowledge from the competence clarification. Group #1 working on Case #1 consisted of four students from four different faculties at AAU (Technical Faculty of

IT and Design (TECH), Faculty of Engineering and Science (ENG), Faculty of Social Sciences and Faculty of Humanities). This case was familiar to the company and the students were able to get information from employees from the company. Group #2 working on Case #2 consisted of three students from AAU (two from ENG, one from TECH) and one from UCN – (Energy management). Case #2 was a case the company had no experience with.

3.3 Working process

The analysis of the working processes for the two groups is based on the information from the observation protocol.

Group #1: The group used written material from the company as basis for communication and for developing the idea together. Trying to decide an idea – discussing pros and cons. They also were inspired by the round tour at the company. They had difficulties with a common platform for communication, but after some time they began to use a white board. The first pitch was not well organized – they had no plan for speaker and content and no agreement on idea and no project management. After the pitch, the group began to work individually to find a problem. They chose an idea and discovered it was already realized. Then changed the idea and discussed who the customer is. In the first sprint retrospective they agreed that they lost their focus and talked past each other. However, they have developed a concept that help them communicate. An employee from the company gave input to the group concerning the problem context, which made it easier for the group to clarify the problem. During the problem analysis the group was still unsure about the problem. This situation changed in the problem validation sprint, where the group used the Business Model Canvas (BMC), they were introduced to in a workshop. The BMC created a structure for the work and became a steering tool for the group. The group created a good understanding of the customer. Still there were no project manager in the group. The group used the white board to define the hypothesis and used a drawing as focal point, however they had problems concerning consensus for the work. In the preparation for the final sprint one student took the lead. The time pressure was evident, however, there was a consensus concerning the result. The final pitch presentation showed good understanding of the customer, the problem, market potential and the opportunities for the company.

Group #2: They started with expectation clarification and worked individual on own ideas. They used the white board to present many ideas to each other and discussed limitations. They had no specific project manager. The time pressure was very clear. They were ready for the pitch, but the problem was still open – they needed to narrow it down. After the first pitch the group used the white board, writing down what they agreed on. Despite disagreements they acknowledged their differences. In the sprint retrospective they agreed that they often end in circular discussions, that they need to be better to ask for help and to realize when they are agreeing. In the problem analysis sprint, it was clear for the group what the essential problem was. However, the group had difficulties delimiting and clarify the problem.

They struggled with identifying the customer. In the problem validation sprint, they started out with individual drawings, but joined using the drawings as focal points. One member of the group stood out as leader. The group rejected to use BMC, instead they used many different methods mixed together. Language was observed as a barrier sometimes. The group worked individual within own discipline, calculating system performance or sketching the solution, resulting in many drawings and calculations. Working systematically, two by two or individually. The time pressure was evident, however, there seemed to be a consensus concerning the result. The final pitch presentation showed a well-structured and well-designed presentation with technical details and a systemic approach. However, there was less determination concerning the customer and hence the problem understanding and possible opportunities for the company.

3.4 PBL competences

Before the group formation the students were asked to reflect on their professional competences and PBL competences. Some of the PBL competences mentioned before the group formation were: *Team collaboration, planning of the process, task delegation, project management, time management, work structuration, conflict management, problem identification and problem analysis.*

After the final pitch, the students were asked to reflect on their new competences acquired during the event: “Shorter time for handling selection [decisions]”, “Awareness of incorporation of “in-house” knowledge that is outside the group”, “Not being blind to externals”. “Acceptance of concepts from all of us”. “See the value in my collaboration skills in ‘the real world’ not tacit”. “Agreements in the group”, “Good team player”, “Value oriented”, “managing time”, “reflective”, “focus on finishing task”, “solution oriented”, “make room for every one to be heard”, “change management”, “giving presentation”, “take responsibility for initiating tasks”.

3.5 Students’ reflections

The students were asked to reflect on the Hackathon event. Some of the observations are described for the two groups below.

Group #1 reflections: Were not used to use all the technical resources present at the company. There is a lot of new tacit knowledge, which mean they need to be more explicit. The communication was a barrier, they used a lot of time because they talked past each other and needed to repeat the information to identify and set a common scene. Commented that it is important to identify the main problem and know the core problem to solve.

Group #2 reflections: Need to be more critical and to say “No”, especially when narrowing down the problem. Identify more soft skills and be able to reflect and identify on the process. The setting was familiar for one of the group members, however, the domain specific competences came only to a little extent into play. Learned new business skills and how to apply it in a company.

Besides the students own reflections, they were asked a question about their expectation to the event. One student answered: "*Learning the new form "Hackathon", "Getting to know [company name] better", and "Getting experience in the processes and in presenting new stuff".* Another student answered, "*Challenge myself with innovation and new concepts"* and a student answered, "*To use my competences, to work interdisciplinary and to hopefully find a solution to the problem".* Furthermore, the students were asked to elaborate on the experience from the Hackathon. One student answered: *"The Hackathon was a great event. The 'lectures' facilitated the development of the project, however I felt the introduction of the topics was not specific enough and left me wondering what we are actually supposed to do. The teamwork was very easy due to everyone being so open to forming new work relationships."* Another student answered *"The social aspect only benefited the teamwork, and I felt that it was very important"* and a student answered *"I think it was great, everything happened at [company name], and we were able to ask them questions. I think it was an experience both socially and professional. And I think it was good motivation".*

Concerning outcome of the event some of the student answers were: *"Knowing new things about myself, found my good presentation skills. getting better at listening".*

"It showed me how I work in interdisciplinary teams, where none actually knows each other beforehand. I also learned the importance of questioning my choices and not agreeing to everything that is brought up in the discussion."

"I experienced a new environment, where I found a new professional part of me. I have learned a lot about myself, and working together with people I don't know".

Students' ideas to improve the Hackathon were: *"Less time in pitching. Let people know a little time earlier that you had to present your own skills, I missed a lot."*

"A more thorough presentation of what the topics are and what is expected would be beneficial. Specifying whether the end result should be a business concept, a product or what would guide the groups in a good direction. Overall, loved it, so thank you for organizing it :) hope to take part in it again"

"Shorter pitches. Maybe we from the beginning could limit our pitches to 10 min. And maybe present, what it a good pitch?". "It was a great experience, and something I will recommend to others"

3.6 Discussion

The two groups performed differently. Group #1 was a broad interdisciplinary group working on a case the company had worked with before and where an expert was available for further in-dept knowledge. The group had a solution early in the process. The group had troubles with finding an agreement, structuring, managing, communicating and understanding each other. However, when they were introduced to Business Model Canvas, they used this model as a boundary object to structure the process and the project. They created a good understanding of the customer in relation to the case and used the guided company round tour to get inspiration for

their solution. Group #2 was a narrow interdisciplinary group working on a case unfamiliar to the company, therefore they could not get any expert knowledge. They were all used to work with technical problems and they had many ideas to solve the technical challenges. Each group member worked in a structured way and they used the white board intensively in the whole process. Communication was difficult and they disagreed about scope. They had troubles identifying the customer and the real problem, but very early focused on the technical part, from different angles, making calculations and drawings. The drawings were this groups boundary objects, as they did not want to use the Business Model Canvas. Referring to Carlile [8] the novelty for both groups were high. The problem areas were new for the students, the time frame very short and the team composition different from what they are used to. Both groups had difficulties with transferring their previous experience and knowledge concerning project work to the new situation. The participants forgot about their experience of how they used to do and needed more support and steering from the facilitators. The general lack of management affected their process and management of time. It was difficult to use knowledge developed in a monodisciplinary setup in the interdisciplinary setup and decide how to work together in the new situation. More time to strengthen their relations could help the process. It was difficult to keep the time in the pitch presentations, more training could help. Moreover, it is difficult for students to express their competences without preparation. They may need more time for that and for creating the necessary relations in the groups. The winning group of the Hackathon event was Group #1, basically because this group had the best understanding of the problem and the customer. Group #2 was more focused on the technical aspects and on a technical solution. At this event the two groups worked with two different cases – the broad interdisciplinary group with the most familiar problem area and the narrow interdisciplinary group with the less familiar problem area. In future Hackathons it will be preferred to present only one case for the students in order to create more even criteria for the competition.

This Hackathon, which is part of a larger study, shows difficulties for students to transfer their monodisciplinary knowledge and experience to an interdisciplinary situation, without guidance and preparation. However, the students' reflections and comments after the Hackathon show that the step from monodisciplinary project work to interdisciplinary project work is difficult, but events like this Hackathon in Engineering Education can help students to experience the challenge of interdisciplinary boundary work and experiment with coping strategies. One step may not be enough but events like this used in different contexts can scaffold the students' interdisciplinary competence development.

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