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The creative and transdisciplinary design process
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ABSTRACT

In higher education, transdisciplinary master programs have been developed to afford students to combine knowledge and methodologies from different fields and thereby develop an understanding of how to create new innovative solutions. An international and transdisciplinary science and engineering master programme in Lighting Design (LiD) at Aalborg University (AAU) in Copenhagen, bases its teaching on problem-based learning (PBL) and a process model “The Lighting Design Experiment” (LDE), which integrates innovation processes and design research methodologies [1] [2]. Knowledge and methods from the fields of architecture, media technology and lighting engineering are to be synthesized and applied into a problem-based semester project. To investigate to which degree students do consider creativity and innovation as integrated parts of their semester projects, a survey was carried out with 20 students from seven semester project groups, looking for aspects within two creativity components; domain relevant skills and creativity relevant processes [3] [4]. The survey indicates that the transdisciplinary approach seems to create the desired synthesis of knowledge and skills, from each academic field into the semester project despite the different knowledge areas and methodologies represented in the courses of the semester. Whereas the investigation of the creative processes points out three areas of attention for improvement; the framing of the project, the group dynamics, and tools for idea generation. The outcome has provided a better understanding of the inherent potential and barriers for creativity in the transdisciplinary design process, and how to possibly improve these in this PBL project-based design approach.

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1 BACKGROUND

In Engineering and science educations, as well as on an overall level in many educational systems, there is a growing emphasis on providing students with skills and competences within innovation and entrepreneurship [5]. This emphasis comes from an a) identified need for establishment of new enterprises, b) creation of new products, and c) being able to contribute to enhanced growth [6]. Graduates combining technical and innovative backgrounds are considered to be an important key in this development, which calls for novel solutions [7]. Creativity is a prerequisite for the ability to combine present knowledge into new solutions, and widely accepted as prerequisite condition for innovation [3] [8]. Creativity and innovation are thus key components in science and engineering educations, including how collaboration and a transdisciplinary view on real life complex problems is necessary, and how it is important to focus on innovative design competences in those educations [5]. However, it is a challenge for educations, that creativity is disregarded (or killed) more often than it is supported [8] [10]. Working pedagogically with PBL and project-based group work, a challenge for both teachers and students, is to focus on the practical application of creative processes [11].

1.1 Problem-solving for innovative LiD projects; the LDE Model

In 2014, the transdisciplinary science and engineering master programme in Lighting Design (LiD) was launched at Aalborg University (AAU) in Copenhagen, as a combination of architecture, media technology and lighting engineering. The '*AAU model for problem-based learning* [9] (AAU Model) shows a strong organizational and didactic support for PBL, which for students, partly materializes through a combination of courses (for basic knowledge acquisition) and a semester project (for the application of said knowledge). The didactic method for LiD divides its three academic fields into three 5 ECTS courses, running in parallel with a 15 ECTS problem-based semester project (in which knowledge and methodologies from the courses are synthesized and expected to be applied). The AAU semester projects include a PBL process from idea generation, problem analysis, problem statement, problem solving, design, and implementing solutions [9]. These stages of the AAU PBL pedagogy are reinterpreted into a five-step, process model for LiD, called the *Lighting Design Experiment* (LDE) (see Figure 1). The LDE model was developed with reference to the innovative process model by Carlile [19], to allow the transfer of knowledge from several domains into a project, translating them into a common (shared) language, and transforming that into innovative solutions and new explicit knowledge, to be shared in new experiments [18]. The aims are to include the didactics of the AAU Model, while also synthesizing knowledge from the three LiD disciplines represented in three criteria into five design steps. Those creative processes should motivate innovative, as well as academically validated solutions in students' design projects [1].

In Figure 1, the five design steps are shown. Idea generation is formed in Step 1 (‘*imagine & ask’*), including an *imaginative research question* (IRQ). The IRQ is conventionally referred to as an *initial problem statement* in most models, but within the LDE, an emphasis is placed on imagination, to encourage a visionary and innovative project approach. The problem analysis and solution direction in Step 2 (*‘analyse & propose’*), performs the transdisciplinary translation of topic combinations for knowledge and skills, from the three fields, into a coherent framework. It is the joined understanding of these knowledge areas, which forms the foundation for creating new combinations of existing knowledge. The process includes

both literature reviews, practical trials and experiments, which ultimately leads to hypothesis-formation within each of the criteria, representing the different academic fields (conventionally often framed as a final research question, or final problem statement). In step 3 (*'link & construct'*), the design is created and students are encouraged to integrate and link tools, methods and approached from the three academic fields. In step 4 (*'test & explain'*) the design is applied and hypotheses are tested, which informs a next iteration of the whole design development [1] [2]. An essential point in innovation [19] is to return new knowledge, gained in the experimental projects, back to the different discipline domains. Step 5 (*'share & learn')* puts explicit knowledge back, as a new point of initiation, whether it be feeding another iteration of the existing project, or to future projects.

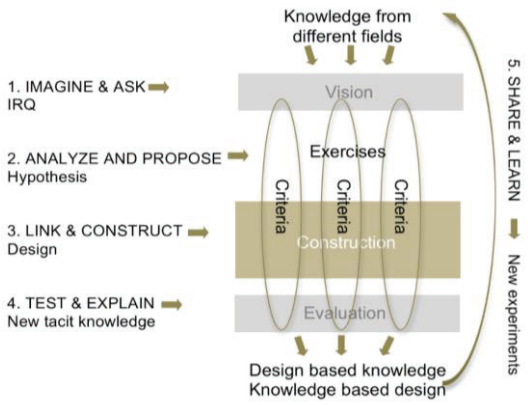

Figure 1. Model of the Lighting Design Experiment [1]

To ensure a transdisciplinary approach to combining the scientific fields, the theory of Koskinen et al. [21] is used to define how different research methods and fields can be integrated, in parallel, in the process. The three different fields in the educational programme represent tools and methodologies referring to natural science, humanities and art. These skills can be defined within the three different criteria in the process model, representing the lab, the field and the showroom - referring to Koskinen at all and their design research methodologies [21]. The iterative nature of the LDE process model is meant to encourage students to actively consider how their knowledge, expertise and technical skills from the three LiD fields, can be applied and integrated into the semester project. The question is, however; do the students experience this process as innovative and creative?

1.2 Creativity as components

The relationship between creativity and learning has been widely recognized [10] [11] [12], and a substantial amount of research in how to promote creativity in technical educations is available [13]. Some studies point out that a creative process is individual, and will often suffer in a group process [15]. Meanwhile, we also see that creative processes in groups can be very effective [11]. The componential theory of creativity Amabile states that creative influence includes three within-individual components (domain relevant skills, creativity relevant processes, and task motivation) and one outside-individual component (the surrounding environment) [3] [4]. *Domain relevant skills*, which include knowledge, expertise, technical skills, and talent, are particular domains that are represented in problem-solving work of AAU student projects. These skills are the basis upon which the individual can combine to create, during a creative process. *Creativity relevant processes* [3] include cognitive and personality processes, which according to Amabile are 'conductive' for novel thinking. Amabile highlights the most important characteristics as risk-taking, seeing new perspectives on problems, a disciplined work-style and skills in generating ideas. The personality processes include self-discipline, and a tolerance for ambiguity [4]. *Task motivation* centers especially around intrinsic motivation; from engagement in an activity purely out of interest in its process, enjoyment, or a personal sense of challenge. *The surrounding environment* (especially the social environment) includes factors which

stimulate creativity, such as collaboration in groups with diverse skilled and idea focused members. Referring specifically to Amabile's *creativity-relevant processes* and *domain-relevant skills*, we have asked our students how they experience the creative and transdisciplinary process within the LDE approach, for the LiD semester project. Based on this initial case study, we will be able to contribute to the discussion of the relation between knowledge, skills and creativity, in transdisciplinary problem-based projects.

2 METHODS

Our approach is based on how 2nd semester LiD students experience *creativity relevant processes,* as part of their project work during their 1st semester, based on Amabile's first two components; *domain relevant skills* and *creativity relevant processes*. Specifically, students are asked into their experience of the previous (1st) semester's project, to make sure they refer to the holistic experience from an entire semester, including courses, project and the relations and dynamics between these. In this study, we excluded empirical focus on *task motivation* and *social environments,* to focus on students' relation to creativity relevant processes in the project. The study was a two-stage approach, as investigating creativity relevant processes requires a baseline; namely, that *domain-relevant skills* are acquired and available to the participating students.

In stage one, we therefore needed to know to what extend the students believed to have acquired the *domain-relevant skills,* provided to them through their three courses, representing the three LiD fields (lighting engineering, media technology and architecture). According to Amabile, *domain relevant skills* include factors such as 'basic knowledge' and 'technical skills'. The first part of the questionnaire asked students to rate their *domain relevant skills* for each of the individual courses, by subjective ratings of their own 'basic knowledge' (for example 'theory, subject information, etc.') as well as their opinion on how easy this was to transfer to the project. If students found the course knowledge to be useless for the project, it would not qualify as 'domain-relevant', and thus be useless in context of the study. Students were asked to rate these on scales from 0 to 6, in which 'basic knowledge' had 0 exemplified as 'not good' and 6 as 'very good'. Students were also asked to rate their technical skills (for example, methods, approaches, usage of tools, etc.), and how well they believed these transferred into the project. These were rated on scales from 0 to 6 as well, with the four ratings approaches- and questionnaire layouts being similar.

In stage two, we looked into the *creativity relevant processes,* asking students to rate Amabile's four main characteristics of the component, in relation to the semester project, using a similar scale from 0 to 6. The four main characteristics were; a) *students' willingness for risk-taking*, (for instance, in order to explore an idea, reach an academic goal or chase personal ambition), b) *the project's ability to push for novel ideas* (for instance, focusing on seeing/finding new perspectives on existing problems), c) *the degree to which the project inspires a disciplined work-style* (for instance, concentrating effort for long periods of time, not being distracted from the task), and d) *degree to which the project supports skills for generating ideas* (for instance techniques, approaches or methods). For these, we introduced an additional sub-item to each rating, where students were requested to 'place a few words on the background for the rating'. Finally, outside the scope of rating Amabile's components, the questionnaire concluded asking students to rate the education of Lighting Design, in term of being an education using/inspiring creativity, on a similar scale from 0 to

6. The analysis of students' ratings used descriptive (non-parametric) statistics, for measures on central tendencies for each question. The written responses were used for qualitative depth, supporting the quantitative ratings, and possibly allow discussion and reflection on the approach LiD has taken on creative processes until now.

3 RESULTS

The survey was carried out in April 2019 at AAU Copenhagen, with 20 participants (9 male and 11 female), all being active 2nd semester graduate students at LiD. Participants ranged between 11 nationalities, and represented 17 different undergraduate certificates, prior to their LiD graduate program admission. Distribution was carried out digitally via hyperlink. Participants were all situated in the same room, while observed by an attending author.

3.1 Domain-relevant skills

The questionnaire results of stage one, are shown in Table 1. Here, medians between 4 and 5 suggest a fairly solid impression of the *domain-relevant skills* with participants, based on both responses on basic knowledge and technical skills. Ratings for the *transfer* of

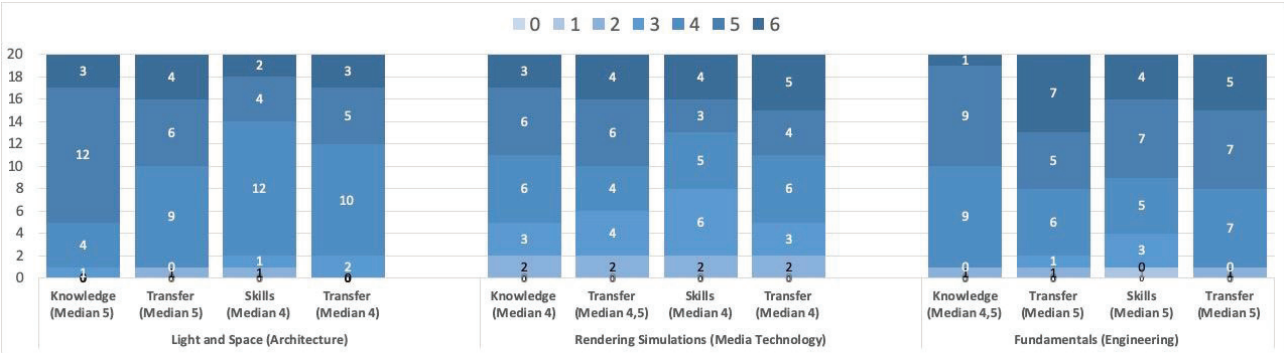

Table 1. Rating of domain-relevant skills and knowledge from each course as well as perceived ability to transfer these into the semester project.

knowledge and skills from each course into the semester project, are very consistent between three courses, and ratings are very similar to the corresponding knowledge and skills ratings of each course. It suggests that students, already in the first semester, are confident in their knowledge and skills within each academic field, despite the different academic backgrounds within the sample group *and* despite the very different knowledge areas and methodologies represented in the three courses/fields. The ratings demonstrate that the students believe in their ability to transfer and combine knowledge and methodologies, from the different fields into the semester project. It indicates that students working according to the LDE model, experience ability to work in the desired transdisciplinary problem-based context already during their first semester.

3.2 Creativity-relevant processes

Second part of the questionnaire looks at the students' experience of creativity-relevant processes in the design process. The median values in Table 2 are lower compared to Table 1, but also, here staying consistent, mostly on a median of 4. Participants also believe that LiD is a creative education to the degree of a median 4. For more insight into students' experiences and contextualization of these scores concerning creativity in the process, we will look into the qualitative responses in the questionnaires.

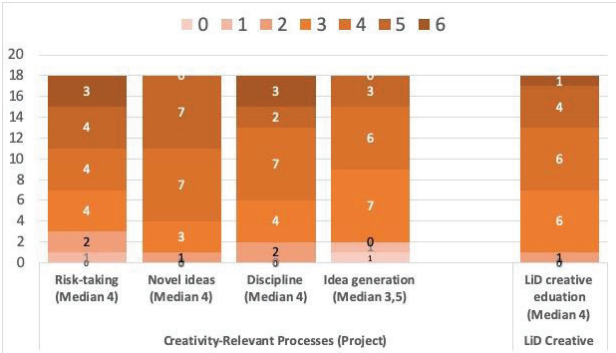

Table 2. Students rating of creativity relevant processes

3.2.1 Willingness for risk taking

Within this topic, students commented that the framing of the project could have more focus and encouragement for the willingness of risk taking. 7 of 19 students mentioned (in no particular ranking) a) the openness of the project description, b) the technical requirements, c) the format of the final scientific report, d) the examination and e) lack of time, as relevant for their willingness for risk taking. One student stated that "*it's hard to take risks if it's the only main projects we do for the finals. There are no low-stake assignments where we're encouraged to take risks and make mistakes*." Another student pointed out the technical and applied approach to the design as limiting for the willingness for risk taking. However, a student also stated: "*project requirements give a lot of freedom regarding the area we would like to work with. It is challenging but also nice to decide yourself your field of interest within the project.*" Within the project format, students experience time pressure, and the "danger" of risking, due to the lack of time; "*As long as the risk and decisions are backed up by facts, no problem. On the other hand, it might be dangerous to risk not having the time to finish the goal/ambition*." Risk-taking willingness also relates to the approach taken by facilitators/professors, specifically their role for framing the need for- and rewards of a more determined risk-taking approach. Group work dynamics can limit willingness towards risk-taking, when there are no constructive attitude or conductive consensus dynamics found within the project group. A student states that "*I would take risks to lead it to the field, I would like to work with lighting, but it is difficult when we work in groups, because we are 4 people wanting 4 different directions so I don't think it is that possible - also because the assignment on 7th semester is very specific. But I like that we have a specific frame, because we are new to everything concerning lighting*". The acquisition of new skills, knowledge areas and processes also reportedly hinder risk taking: "*The first semester we pretty much went by the book, mostly to properly learn all the new information about light we had not had from our respective bachelors. It was in that sense less interesting; however, we also learned a lot. This second semester, the "risk-taking" to explore interesting subjects will be more prevalent.*"

3.2.2 Ability to push for novel ideas

The way the assignment has been defined referring to the five steps and the integrated experiments push for novel ideas, according some students' input: "*The frame of the semester project was formed in a way that new ideas could be easily implemented on as long as the appropriate research and experimentation has been done, that could be used*

as productive argumentation during the presentation of a proposal." "*[…] I had no experience with lighting design, it showed totally new perspective on the problem. Supporting courses played important role in the process of finding new angle to the design approach*." These statements suggest that the project can cater to creative freedom, and how domain-relevant skills paved way for a creative mindset in project work. However, the lack of fundamental knowledge on lighting and new technology from the undergraduate level, naturally limited students' ability to push hard on new ideas: "*I think it was easy to identify the weakness of the light in the space which made it also easy to come up with a solution to that problem, but I feel we lacked information on the available technology that could have been used to solve the problem.*" Here, group dynamics is also considered both a challenge and a potential, to push new ideas: "*The cross-disciplinary backgrounds of the group members helped the semester project to develop. Difference in viewpoints and experiences paved way for new ideas - although sometimes on the back of heavy discussion and disagreements.*"

3.2.3 Disciplined work-style

Distraction affect a disciplined work-style, both based on all three courses running parallel, and on different work style and experience between students: "*We had a lot of distractions with handing in (assignments for) other courses (presentations, etc.) at the beginning. Especially between two pinups. But in the end of the semester when we had a lot of free time, it was easier to concentrate on the semester project*". Meanwhile, despite their distraction from the project, some students also attribute motivational aspects for the project, from doing course work; "*The semester project required a lot of time of doing disciplined work. It is a good idea to be free from other activities or courses. However, I do not support their complete absence, since sometimes they are inspiring or maybe even help you to see things in your project in a different way*". The process model (LDE) was also mentioned as a help in structuring the work "*I personally felt not distracted when we were implementing different ways of working like idea generation sessions, experiments, readings...*". Some responses affiliated group dynamics with challenge, for the disciplined work, though not an unsolvable one: "*Coming from different backgrounds, it took time for us to get into a disciplined and structured style of working - but eventually we did and the flow felt natural.*"

3.2.4 Skills for generating ideas

A combination of (domain relevant) skills and knowledge was stated to promote idea generation: "*Being creative can be difficult when the boundaries seem very strict, but that is also where the best creative endeavors stem out from.*" Also, a perceived lack of application of skills and tools, specifically relating to idea generation knowhow, was mentioned: "*Problem solving happens in the groups but not in classes or with any supervision. It's good to be on our own in some circumstances but it would be helpful to skills for generating ideas within the context of the classes or with supervision to introduce us to the process of generating ideas.*" Group dynamics was mentioned as essential for generating ideas: *"The group dynamic is so vital for how you generate ideas through a project. In my case we had an okay process, but the idea generation for the design was totally lost."*.

3.3 Results summary

After their first semester, LiD students appeared confident in their *knowledge and skills* within their required academic fields, despite their different undergraduate backgrounds, and

different knowledge areas and methodologies represented through their course work. They also believe in their ability to transfer and combine knowledge and methodologies from the three fields into the semester project. Students' experience of *creativity-relevant processes* in the design process, is rated a little lower but still ranked above average. The qualitative responses pointing towards *creativity-relevant processes,* demonstrate a potential for improvement. These improvements can be defined within three areas of attention; the framing of the project, tools for idea generation and attention on the group dynamics. The qualitative data suggest that a stronger focus on introducing specific tools for different steps of the process, would be interesting. In relation to the *project framing,* requirements should point towards a creativity-driven methodological design approach, where the constructive potential of risk-taking and making mistakes, is both inherent to the framework, and explicitly included in its presentation. Students need 'creative' support through information and guidance, on the balance of acquiring new skills and knowledge, while being willing to take risk. And how this balance can be advantageous and push for new ideas in this process. The LDE process in the semester project, integrated experiments in the design process and awareness of combining knowledge, push positivity towards novel ideas, according the students. Including explicit expectations for creativity into the project evaluation, with emphasis on the applied and implemented creative methods and approaches within the project processes (and not simply the final product), seems important to students' willingness to include risk, as well. In all four characteristics of creativity-relevant processes, *group dynamics* is mentioned by the students as a challenge or barrier, due to lack of specific shared experience in creativity management in groups. Meanwhile, group dynamics is also described as vital for generating new ideas, perhaps especially due to how LiD students come from vastly different backgrounds, which can be a creative strength, especially if managed well. Group work requires time and skills to establish a disciplined and structured work flow, but is still considered essential by many, to develop and push for new ideas, in the semester project.

4 CONCLUSION AND PERSPECTIVE

We asked Lighting Design (LiD) students at Aalborg University (AAU) about their experience of the creative and transdisciplinary process within the "Lighting Design Experiment" (LDE) approach, in their 1st LiD semester project. By structuring this investigation around Amabile's creativity components, we have been able to better understand how students experience the interplay of domain relevant skills and creativity relevant processes in such transdisciplinary context. The results illustrate that the students are confident in regard of their relevant knowledge and skills, in their semester-given LiD fields, and that these abilities transfer well into their semester project through the LDE process model. Specifically, how to combine knowledge and methodologies from the three different academic fields, and to transform this into one problem-based project. Students do experience creativity-relevant processes in the semester project, to have yet unfulfilled potential.

Three areas of attention have been identified; The framing of the project, group dynamics and tools for idea generation.

The framing of the actual semester project can support the creative processes by informing the students about how creativity can be supported through an understanding of the balance of acquiring new skills, combining different knowledge areas and processes and willingness

for risk taking. These elements must be balanced in the process to support pushing for new ideas. The investigation also indicates a potential for an awareness of the curriculum defining more precise expectations for the final semester report and examination. A focus on the creative processes should here be stresses rather than the final design.

The creative processes can also be supported through introduction of specific tools for idea generation in the transdisciplinary design process. In all four characteristics of creativity-relevant processes students have pointed out that the group dynamics is vital for how to generate new ideas. This challenge and potential must have attention by the facilitators/professors.

This definition and integration of creativity aspects in the project framing, tools and group dynamics will support a more nuanced definition and understanding of the transdisciplinary creative design process. A process where there is an empathy on combining skills and knowledge from different fields and awareness of how this can be supported through an understanding of how creative processes can promote risk-taking, push for new ideas, disciplined work and idea generating results. These categories can be stressed in the different steps of a process like the LDE model through the “framing” of the assignment, introduction of idea generating tools as well as an awareness of group dynamics in the different steps of the process.

The investigation also stresses the awareness on how we should strive to integrate knowledge domains and creative processes as one collective approach, integrated in transdisciplinary and academic PBL models like the LDE. The findings from this investigation will be used to improve the curriculum and project framing, as well as sharpen the awareness on the group dynamics and introduction of specific tools for creativity for the future semesters at the LiD programme. The findings will as well be used to strengthen the creative potentials of the general LDE process model.

These initial findings will lead to further investigations integrating the two last creativity components by Amabile: task motivation and the surrounding environment.

The transdisciplinary approach through the LDE process model and PBL approach seems to create the desired synthesis of knowledge and skills from the different academic fields. But the investigation of the processes referring to Amabiles definition of creativity relevant processes, described through risk taking, new perspectives disciplined work and generating new ideas points out a general potential for combining the transdisciplinary approach with specific focus on the creative processes.

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