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Becoming a Creative Genius: How a Creative Learning Environment Can Facilitate Transdisciplinary Engagement and Creative Mindsets in a Life-Long Learning Perspective

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ABSTRACT

The increasing complexity of society's sustainability issues requires new educational approaches that facilitate transversal skills and competencies suitable for the 21st century. Students must be equipped with discipline-specific expertise or technical skill; but also competencies to collaborate across disciplines in creating innovative solutions to complex problems. This paper explores whether a problem-based learning environment focusing on creativity facilitates transdisciplinary engagement and creative competencies and to what extent this manifests into transdisciplinary career paths and creative mindsets in a life-long learning perspective. An analysis of interviews with graduates from a transdisciplinary program, Creative Genius, at Aalborg University indicates that a pedagogical approach focusing on the embodiment of creative competencies helps prepare students to transition from student to professional and equip them to engage in transdisciplinary and complex problem-solving in industry and society. Based on the results, the paper proposes a model for creative transdisciplinary thinking and suggests a focus on creative self-efficacy as an essential learning outcome in transdisciplinary PBL environments.

Keywords: Problem-based learning, creativity, transdisciplinary engagement, higher education

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INTRODUCTION

Traditional discipline-specific approaches to research and education are increasingly challenged and considered insufficient when addressing complex and highly contextual problems in practice. Particularly concerning education for sustainable development, the transformation of scientific and educational settings and their interaction with society is required, combining ecological, economic, technical, and societal components to transcend disciplinary boundaries and strengthen shared understandings in the creation of diverse, culturally-responsive and sustainable solutions to society's grand challenges (Euro-CASE, 2020; UNESCO, 2021). With the implementation of the UN's 17 Sustainable Development Goals (SDGs) in 2015, new visions, guidelines, and shared goals for a joint contribution to a better, more sustainable world have created a call for transdisciplinary approaches to education, research, and practice (Khan, 2021). Thus, higher education institutions across the world are taking action to support the development of students' interdisciplinary problem-solving skills and competencies specifically related to sustainability, e.g., through project models such as Vertically Integrated Projects (Strachan et al., 2019), Experts-in-Team (Otte, 2016) and megaprojects (Bertel et al., 2021), or through new programs (Crawley, 2018; Gombrich, 2018) or even entire new institutions (London Interdisciplinary School, 2023).

Problem-based learning (PBL), originating as far back as the late 1960s and early 1970s (Hmelo-Silver, 2004), argues for contextually embedded and authentic real-world problems as a point of departure for both single-discipline and interdisciplinary learning (Kolmos & de Graff, 2014). However, designing interdisciplinary problems for sustainable development is challenging, even when PBL is implemented at the curriculum level, as it requires researchers and educators to collaborate across disciplinary boundaries and to balance an often academic-centered curriculum with professional, interdisciplinary, and collaborative knowledge and competencies and the tacit presence of sustainability (Guerra, 2017; Kolmos et al., 2020; Bertel et al., 2021).

A call for new inter- and transdisciplinary profiles in education

In interdisciplinary approaches to research and education, a distinction is often made between 'vertical' and 'horizontal' knowledge. Vertical knowledge covers discipline-specific knowledge or expertise within a given field, and 'vertical thinking' is the commonly accepted use of such knowledge within a given discipline. On the other hand, horizontal knowledge is knowledge from other fields that the individual has a generalized understanding of and the ability to access and expand through horizontal thinking. This distinction was used to categorize different professional profiles with various emphases on expert and generalized knowledge, coined as the 'I-shaped' and 'T-shaped' professional profiles (Guest, 1991; Oskam, 2009).

As the complexity of societal problems increases, so does the need for professionals who can expand their expert knowledge to different contexts, bridge disciplines, and create entirely new transdisciplinary knowledge and solutions. Here, we understand transdisciplinarity as creating new conceptual, theoretical, methodological, and translational innovations that integrate academic and non-academic perspectives and transcend traditional disciplinary boundaries to address a common problem (Klein, 2004; Nicolescu, 2010). Thus, in recent years the push for more T-shaped professionals is increasingly expanded to include a multitude of different variations in the integration of vertical and horizontal knowledge in education, emerging as so-called 'π-shaped' or 'H-shaped profiles' (i.e., professionals with expertise in two separate but connected fields) and the M- or comb-shaped profiles (i.e., professionals with broad horizontal knowledge and expertise in three or more separate fields to varying degrees of depth) (Demirkan & Spohrer, 2015; Kamp, 2016; Bierema, 2019; Babatope et al., 2020) (see figure 1).

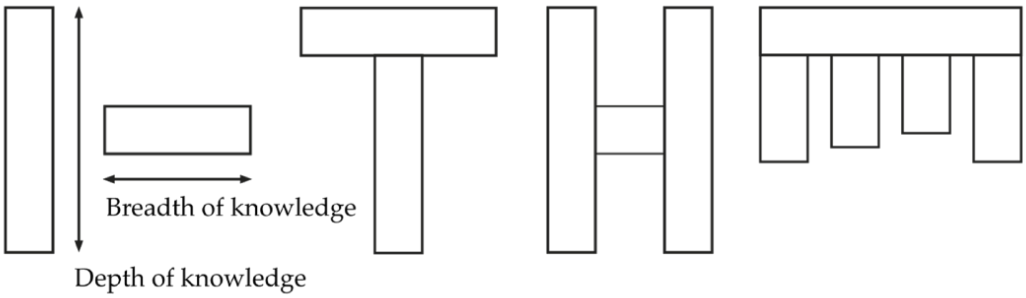

Figure 1. Different transdisciplinary professional profiles.

Creativity and transdisciplinary thinking in higher education

While T-shaped profiles and other variations of inter- and transdisciplinary competencies are increasingly encouraged in engineering education and higher education in general, the models offer little information on what happens in the intersections between vertical and horizontal knowledge and how the transformation of different kinds of knowledge takes place in complex problem-solving in practice. Creativity theory, on the other hand, offers a multitude of concepts related to the ability to identify, connect and make sense of knowledge across different fields otherwise considered unrelated, including competencies such as horizontal thinking (Byrge & Hansen, 2014; Kristiansen et al., 2018), lateral thinking (de Bono, 1992) and conceptual blending (Fauconnier & Turner, 2004). Furthermore, creative competencies combined with creative self-efficacy is previously found to enable teams to address and solve complex problems (Birgili, 2015; Gallagher, 2015; Byrge, 2021), which could be one reason why creative thinking continues to rank among the essential skills of the future in the Word Economic Forum's Future of Jobs reports (WEC, 2023).

The Creative Genius (CG) program at Aalborg University (AAU) (2013-2018) aimed to facilitate such competencies by combining PBL with scaffolding techniques derived from creativity theory to prepare students for working with complex problems in transdisciplinary settings (Byrge & Hansen, 2014). The CG program was popular among the participating students, with testimonials emphasizing particularly creative methods of approaching unforeseen and new situations and combining knowledge from different fields (Testimonials 2013-2018); however, little is known about how and to what extent such transdisciplinary competencies manifest into career paths and creative mindsets in a life-long learning perspective. Thus, this study seeks to explore how graduates from a transdisciplinary program such as CG experience the transition from student to professional and what elements in terms of competencies, methods, and creative mindset the graduates bring to their professional life; To what extent do a deliberate focus on creative competencies equip students to enter industry and society and engage in complex problem-solving? What can we learn from the CG program concerning the integration of creativity and transdisciplinarity into PBL environments?

THE CREATIVE GENIUS PROGRAM

The Creative Genius program was based on Creative Platform learning (Byrge & Hansen, 2015; Christensen & Hansen, 2015; Byrge & Hansen, 2014; Byrge & Hansen, 2009; Hansen & Byrge, 2009) and had two paths: the Creative Genius Semester (CGS) and the Creative Genius Professionals (CGP). CGS was a full-time 30 ECTS interdisciplinary study activity offered as an elective to all master students at AAU, hosting 15-30 students from different disciplines each semester. CGP was a 1-year, 50% part-time study activity welcoming professionals already working in industry, either in the private or public sector. More than 200 students from 56 disciplines across Social Science and Humanities (SSH), Science, Technology, Engineering and Math (STEM), and Health completed the program. During the program, the focus was entirely on developing students' creative competencies and how to use them in an interdisciplinary PBL project of their own choice. During the program, CG students did not receive additional lectures within their 'home' disciplines.

Whereas the Aalborg PBL model already naturally embeds a focus on generic competencies related to complex problem-solving (Boelt et al., 2021), the educational purpose of the CG program was to offer students at master-level experience working in an interdisciplinary setting, using creative competencies to solve complex problems. Thus, the program differentiated itself from the team-based AAU PBL model (Aalborg University, 2015) in the following ways:

- Starting with a two-month intense creativity training period (6 hours a day), creative thinking and creative competencies like horizontal thinking, open-

mindedness, and co-creation were embodied to help students build creative mindsets and creative self-efficacy.

- This training period was followed by a three-month individual project period, where each student was free to choose a problem with high complexity and no known solutions. During this period, the students were scaffolded in working “the CG way," using tools, methods, and mindset from the training period.
- Students collaborated in shifting, randomly formed group settings. In these groups, they co-created through transdisciplinary processes that informed their individual projects and facilitated a deep understanding of- and experience with doing transformative work.

The program was an educational experiment and research program, and experiences from CG and other interdisciplinary projects and programs are now to be integrated into AAU's strategy to become a mission-oriented university and to support the integration of SSH and STEM at curriculum level (Aalborg University, 2022; Bertel et al., 2021).

Horizontal thinking – a theoretical model for facilitating creative thinking processes

Where vertical knowledge is understood as the dominating knowledge inside the discipline, horizontal knowledge consists of latent knowledge, which becomes relevant and applicable through horizontal thinking. Inspired by the first known innovation model (Wallas, 1926), the horizontal thinking model consists of a series of creative thought processes that identify and transform horizontal knowledge to be used vertically (see Figure 2).

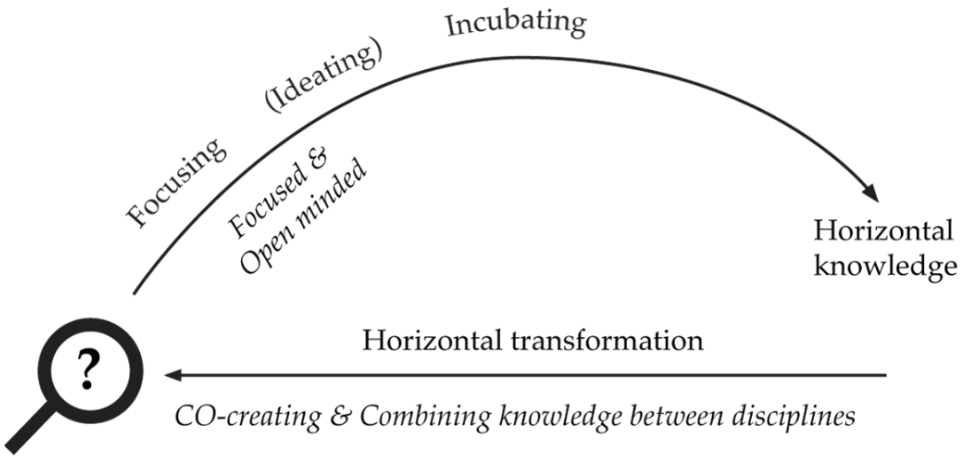

Figure 2. The horizontal thinking model applied at the Creative Genius Program.

As seen in Figure 2, focusing on a problem with an open mind provides new ideas by accessing horizontal knowledge, e.g., from other disciplines, contexts, or similar problems (analogies), and combining it. This combination of knowledge is a

transformative process that often involves co-creation. In CG, the different steps of horizontal thinking were facilitated to enable students to connect and combine knowledge from different disciplines despite their different ontological and epistemological underpinnings (Byrge & Hansen, 2014).

Focusing on a problem

The core of creative work is a continuous effort to focus on the problem at hand. This focus is essential and the first step in a creative ideation process, as it starts multiple chains of associations that will invite all kinds of horizontal knowledge, often initially considered irrelevant to the specific problem (Byrge & Hansen, 2014; Runco & Chand, 1995; Sternberg & Lubart, 1996). In education, facilitating a focus on a problem involves scaffolding the students in deliberately creating a strong focus on the problem by engaging in it and developing a strong inner motivation for dealing with it. When focusing on a problem, whether ideation techniques are applied or not, the unconscious brain will start incubating and return ideas relevant to the focus.

Inviting horizontal knowledge

Accessing and inviting knowledge from another discipline in a relevant and meaningful way becomes much easier when that knowledge is 'released' from its original context, tied to customs, methodologies, theories, practices, culture, and habits. In the form of principles, analogies, metaphors, fantasies, or other forms of horizontal knowledge, knowledge from any discipline can be ‘released’ and combined with another discipline (Byrge & Hansen, 2014; Kristensen et al., 2018). One such example could be when two disciplines, *in principle*, are dealing with similar issues and have the potential to transfer new knowledge to each other in a transformative process. For instance, when studying the flow in veins and arteries, it is possible to identify horizontal knowledge in the study of flow in pipelines for water or oil. The two fields of study are very different, but, in principle, both deal with "flow in a pipeline," which connects them horizontally and opens for the transfer of knowledge between them if they start interacting and co-creating. In terms of *vertical* and *horizontal* knowledge (figure 1), flow in veins and arteries is vertical knowledge for some professional profiles (e.g., hematologists) and horizontal knowledge for others (e.g., plumbers or petroleum engineers) that can be *transformed* into vertical knowledge using horizontal thinking. Thus, for students to access this horizontal knowledge, they must be scaffolded in broadening their perspective and remaining open and inviting toward other disciplines and professions, which can be challenging, especially since students are still in the process of developing their own professional identities (Bertel et al., 2022).

Horizontal transformation

Initial ideas, especially more radical ones, often will be *out of context* and, therefore, cannot simply be copy-pasted into a solution. The horizontal knowledge in the idea needs

to be combined in new ways or transformed for it to make sense vertically. For instance, if one's usual perspective on taking on a shoe is to 'tie' the shoe, potential solutions for the problem of 'tying shoes' will likely be similar to that of a shoelace. If, instead, the perspective on the task shifts to ‘closing' the shoe, several novel ideas might emerge by transferring knowledge or concepts from horizontal disciplines or professions, such as magnets, screws, or other "closing" mechanisms in novel ways that suit the ‘closing shoes’ task. However, when knowledge is transformed horizontally to another discipline, it will likely not be possible to simply 'copy-paste' it. Instead, it is a transformative process to transfer this knowledge between disciplines; simply using a screw will not close the shoe, but transforming the principal idea of the screw to this new context might result in ideas like the BOA® Fit System. Facilitating horizontal transformation in education thus involves inspiring students to rethink and reframe the problems they are working on and open their minds towards novel understandings and solutions that emerge when latent knowledge from different disciplines is combined in new ways.

A creative learning environment is a psychologically *safe* learning environment

To think horizontally involves creative competencies to stay open-minded, fearlessly combining seemingly unrelated knowledge from different disciplines while working with complex problems without known solutions (Byrge & Hansen, 2014; Byrge, 2021; Scharmer, 2016; Kelley & Kelley, 2012). Even in student-centered learning environments such as PBL, students may experience fear of making mistakes or be exposed to other sources of interpersonal risks, like lower grades or threats towards one's social or professional status. Thus, a creative learning environment with a high degree of psychological safety and acknowledgment of creative thinking is needed (Edmondson, 2019) and contributes to students’ development of *creative self-efficacy* (Bandura, 1997; Byrge & Tang, 2015). Creative self-efficacy results from multiple experiences with successful participation in creative thinking, e.g., through training exercises and creative problem-solving (Kelley & Kelley, 2012). Creative self-efficacy increases students’ confidence in their ability to engage in creative processes and is an important indicator of students' progression and creative competencies.

Embodied Creativity Training to facilitate creative competencies and creative self-efficacy

At CG, horizontal thinking, open-mindedness, and co-creation were learned and embodied during the initial 2-month training period. Embodied creativity training refers to an approach that focuses on the students *becoming* more creative (Byrge & Tang, 2015). Training exercises were facilitated throughout the day, preparing students for the following 3-month project period. Creativity training shows promising results in developing creative competencies (Scott et al., 2004) and creative self-efficacy (Byrge & Tang, 2015; Hänninen et al., 2020; Strachan et al., 2019; Trujillo & Tanner, 2014). Byrge

& Tang 2015 studied embodied creativity training using the same didactic approach as CG, also called 3D Didactic (Byrge & Hansen, 2014). It is developed to train specific creative competencies while solving small practical exercises (3D cases) using language, body, and attitude (Byrge & Hansen, 2014; Byrge & Tang, 2015). Another study reports that creativity training makes teams more confident in complex problem-solving and develops a creative team culture where team members are more willing to take risks and make mistakes (Byrge, 2021).

In summary, research shows how creative competencies can be learned through training and scaffolding, and creative self-efficacy can be developed and supported in psychologically safe and creative learning environments such as CG. In this study, however, we want to explore to what extent this creative self-efficacy or mindset is sustained in transitioning from student to professional and how creative competencies such as open-mindedness, horizontal thinking, and co-creation are applied in transdisciplinary problem-solving in a life-long learning perspective.

THE CREATIVE GENIUS GRADUATE: CASE STUDY DESIGN & METHODOLOGY

To explore and understand how graduates from the CG program have experienced the transition from student to professional and to what extent they feel equipped to engage in transdisciplinary and complex problem-solving in a life-long learning perspective, we conducted individual, qualitative semi-structured interviews with five graduates from the program. The interviewees were recruited through convenience sampling, and the interviews took the point of departure in an interview guide with open-ended questions about the participants' initial motivation for enrolling in the CG program, their perceptions of the learning environment, and their experiences entering the industry upon graduating as well as in their following career.

Interviewees (pseudonymized)	**Educational background**	**CG line** CGS: Full-time semester CGP: 50% 1-year study	**Current occupation**
A	Mechanical engineer	CGP (2017)	Construction engineer
B	Biomedical Engineering and Informatics	CGS (2016)	Project manager in Health care
L	Computer Science	CGP (2016)	Agile coach
M	Biomedical Engineering and Informatics	CGS (2017)	Quality assurance in healthcare
J	Animal science, PhD	CGP (2018)	Software development Partner in company

Table 1. Interviewee profiles.

The interviews were recorded and analyzed using thematic narrative analysis identifying themes emerging from the data and the stories that participants construct based on their own experience as 'creative geniuses.' These themes include creative processes (alone and co-creating with others), horizontal thinking, facilitation of others' creative thinking, and development of creative self-efficacy.

Limitations of the study

The thematic narrative analysis in this paper is based on in-depth interviews with just five out of approximately 200 CG graduates. Thus, it is not meant to be considered representative for or generalizable across all CG cohorts. Whereas the data aligns with previous testimonials from students enrolled in the program, this analysis focuses on each interviewee's perspective as a unique CG program experience, creative competencies development, and perceptions of creative self-efficacy in the transition from student to professional.

FINDINGS

The following section provides an overview of the five Creative Genius graduates' different motivations for joining the CG program and their perceptions of the learning environment while enrolled as students in the program. The following themes emerging from the interviews are identified and analyzed: transition from student into industry and work, their experience as professional 'creative geniuses' facilitating creative processes (alone and with others) in transdisciplinary settings, their perceived ability to think horizontally and their experience of creative self-efficacy. Neutral pronouns are applied. Quotes are translated from Danish and presented in italics.

Motivations for enrollment in the CG program and perception of the learning environment

The motivations for participating in the Creative Genius Program differentiated depending on whether the graduate followed the CGS or CGP line. A, L, and J all followed the 1-year part-time CGP line for professionals as a deliberate choice to pursue becoming more creative. In contrast, B and M chose the full-time day study, CGS, somewhat 'by accident' and mainly because their fellow students chose to enter an internship or to study abroad, leaving B and M "behind." Thus, they found CGS to be an interesting alternative to internships.

Whereas all graduates positively perceived the CG learning environment, each interviewee highlighted different aspects of the learning environment as particularly important to their experience and development. For instance, A emphasized the many training exercises and the high intensity at CG as essential to developing creative competencies, while B emphasized the many deadlines together with what was

considered as having "enough time" between each deadline as crucial because it supported an experience of being 'forced' to take steps into the unknown; Realizing that, using their training and the toolbox, they were able to succeed in getting ideas and solving problems *"...because there is always something I can't figure out. Giving me time to be in a frustrating process. That is also something I learned from there (*ed: from *CG)".*

L and J both appreciated the thorough understanding of creativity theory and a framework for utilizing their creativity. A and L got confirmation of their own creativity and experienced an environmental framework to practice their creativity. L particularly enjoyed being in a learning environment where everybody was accepted and appreciated for their 'crazy ideas': *"I am a playful child myself and think it is fun to make things... and I often hit the wall in relation to what others could accept... so this was also a way to get an outlet where I could play with someone who wanted the same".* J considered CG the best part of their academic life, where they learned to use the rest of their education better.

Career transitions and creative mindsets

All interviewees generally report a smooth transition from the CG program to the professional career of their choice. Furthermore, their experienced creative self-efficacy makes them feel confident in using competencies and methods from CG. A and B, though, mention limitations in collaborative processes with colleagues who are not equally confident about being part of a creative process that requires open-mindedness and creative self-efficacy to be playful and willing to accept new ideas. Interviewee A mentions meetings where especially superiors tend to turn proposals down before exploring their full potential: *"Then we have an innovation manager, and you can say that the way it works is that he is the one talking, and his ideas come forward. So that is just the way it is. It is simply too big a task to throw yourself into getting him converted. Here in the company, plenty of people have 30 years of experience. It does not necessarily mean that they are the ones who get the good ideas, but they are the ones in power, you could say. (...) Breaking out of our roles, or getting someone to break out, is the hard part".* J, on the other hand, feels confident in using the methods and competencies from CG. As a partner in the company, they are in a position where they can arrange and facilitate meetings with both colleagues and customers as creative processes.

Transdisciplinary engagement, co-creation, and creative self-efficacy

In general, the graduates are confident about engaging in transdisciplinary problem-solving. In the following, we describe examples to illustrate how they use their creative competencies to do that.

Focusing and incubating a problem

A describes that, when facing a problem, their creative method is to first arrange a timeslot free of any disturbance, both physically and mentally, and afterward collect and arrange (by drawing/writing down) all kinds of vertical and horizontal knowledge that could potentially be relevant for the problem. The primary source of horizontal knowledge is old projects from are previous jobs and TED talks from different fields of knowledge that A continuously watches for inspiration: *"This collects many different kinds of information. I am interested in all sorts of strange things, watching videos with all sorts of weird technologies. So, you kind of have some things that can be pieced together so that you can make that horizontal transfer and get things from another industry over to what I am doing".* During this process of focusing, ideas flow even after work hours when A deliberately engages in incubation activities like trivial activities that will keep the mind busy without removing focus from the problem: *"Usually, it takes place outside working hours, going for walks or doing various trivial work tasks, where you sort of switch off your brain*." This method neatly follows the processes of horizontal thinking in Figure 2. Having their first experiences at Creative Genius, A spent years refining their creative method until today and uses it often, confident that it helps produce the ideas needed to ponder and solve a problem.

M also makes deliberate use of focusing and incubation in the creative process. When working on a problem and for some reason getting stoked, M deliberately puts the task "on hold," takes a break, and starts incubating, trusting that the unconscious mind will come up with useful ideas. *"It has given me such a sense of security (…) to know that you just have to focus a little on it to the extent that you can now, and not go so much in-depth with solving the problem but just gather some information and then trust that when you walk away from it and just have a break or look at something else, then yes, the solutions can suddenly come to you, and that there is actually a reason for that. You often talk about how all the ideas arise in the shower and then know why it is like that and also be able to trust that it IS like that."*

Transforming horizontal knowledge through co-creation

For most interviewees, the involvement of horizontal knowledge from other disciplines comes from colleagues in other departments, customers that are involved in the creative process, previous personal experiences in (work)life, TED talks, and, as in J's following example from transforming knowledge from horizontal professions as part of the creative process. J is an engineer specialized in designing software for agricultural cattle breeding, often deliberately working on transforming knowledge from people working in horizontal 'breeding fields,' including pigs, goats, and even humans. J also turned the sales process into a creative process called the "discovery phase," in which potential new customers and colleagues are facilitated using different ideation techniques: *"It is fun, but they do*

not want to (ed: work creatively*) themselves. I am the one who has to run it, but also because I have gone through that education. I am the one who thinks of it. (…) when you facilitate such a process, you actually get the good ideas or the best things that are said. They are said by people where you did not expect it. We had a meeting about something very technical. Fodder and all sorts of health-promoting things blah blah, but the most important thing that was said in that meeting was by a man who was a salesman but who had previously worked selling two trays. I think he had the freshest input. Everybody else, it was just the same. They really had to be pushed"*. J also emphasizes the importance of establishing a creative working environment at meetings and, as a company partner, often designs and runs meetings for colleagues and customers as creative processes.

All the interviewees describe different ways of facilitating meetings with colleagues or customers through creative processes. When M is in a meeting, M likes to provide more open-mindedness and ideas by challenging standard views or positions taken by others by using the method of "Six thinking hats" (de Bono, 1985): *"Then we were introduced to the six thinking hats, or whatever it was called. Something like that, I will also take it with me further. Just like trying to see things from a different angle, or you are sitting in a meeting, and there is someone who is taking on a different role in relation to asking the right questions. At least I can become aware of asking some questions I would not ask myself if you can put it that way. Actually, get some different attitudes than the ones I have. To push the others a little"*. M uses this method when experiencing resistance towards new ideas: "*I think I have many opportunities to do it myself (*be creative, red*), but as soon as you try to involve others, then there is a bit of a blockage in it. And, also, the thing about just asking stupid questions to arrive at the best solution. It is very difficult because others say NO because they feel it sounds stupid instead of just running with the idea. So, I think it is really difficult because others do not have the same mindset that now we just brainstorm or come up with wild ideas because something might come out of it*". This quote highlights the importance of persuading colleagues to follow new ideas by pitching them and trying to facilitate small creative processes that reveal the idea's potential and persuade others to work on it.

Creative self-efficacy

All the interviewees emphasized the importance of developing creative self-efficacy, enabling them to face and navigate the unknown as a key takeaway from CG. In fact, creative self-efficacy seems to be one of the most important gains from CG and could be why all interviewees, 5-7 years after leaving CG, still use the creative competencies they learned with great confidence.

For example, B is a project manager responsible for designing a new department in a hospital. They emphasize the importance of allowing oneself to have many ideas before deciding. To be stubborn and tolerate the frustration that often follows deliberately to

refuse to make decisions based on one or only a few ideas, to keep a task open for more and better ideas. This strategy requires creative self-efficacy and confidence that the good idea *will* come sooner or later. B considers this ability the most important competence of attending CG. When asked what takeaways from CG B would recommend to include in any future PBL-based curriculum, they used an analogy used in CG: how to pass a dragon to get to the gold. *"We had plenty of time to do things. I had time to be in the process, to be in the discomfort, and also be forced – because of a deadline – to make some choices and do something. It is like having to defeat a terrifying dragon, and you define how big such a dragon should be. But there is a reason why it is scary, and that is because the dragon hides much gold... and that is self-development. It is a potential in one's self-development. That is why it is very worth it, and it is only if you get past those first steps and defeat the dragon, well then, you will get it. And you have to face the discomfort. And maybe the learning that it is OK that it is uncomfortable."*

DISCUSSION

The 'dragon' in the above analogy represents the fear of dealing with a problem with little idea about how to understand or solve and approach it with an open mind, forcing one to take steps out into unknown territory. This analogy fits well with what Otto Scharmer calls stepping out in the space of nothingness (Scharmer, 2016). In Scharmer's theory U, the dragon is replaced with three enemies called Voice of Judgement, Voice of Cynicism, and Voice of Fear, i.e., the three inner voices that must be passed to open one's mind when engaging with problems in unknown territory (Scharmer, 2016). The 'gold' you get after passing the dragon or Scharmer's three voices is a creative self-efficacy that lets you embody a creative mindset as second nature and with self-confidence, equipped with the creative competencies and methodologies to 'pass any dragon' in the future in terms of complex problems that defy current understandings and solutions.

A similar emphasis on self-efficacy is found in recent approaches to developing a sustainability mindset, highlighting the need for transformation from resignation, rigid, resistant, and reactive responses to sustainability challenges to innovative, flexible, adaptive, and reflective responses to complex problems (Rimanoczy, 2020). Findings from this study indicate that creativity and creative competencies play a crucial role in this transformation.

Thus, whereas creative thinking is already linked to transdisciplinarity in the act of borrowing from, integrating between, or merging with other disciplines, we would argue that a focus on creativity in PBL goes beyond and transcends the distinction between 'academic' or 'professional' knowledge and other types of inherent, latent or potential knowledge that could be relevant in complex problem-solving in the pursuit of a sustainable future. This includes horizontal knowledge from other disciplines, but it also

includes horizontal *thinking* and emerging or 'latent' knowledge, i.e., memories, imagination, and intuition (De Bono, 1992; Byrge & Hansen, 2014) and encourages risk-taking by embracing "failure" as a positive learning experience and source of new knowledge and ideas (Connor, Berthelsen, et al., 2014; Barile & Saviano, 2013). Thus, in addition to the representation of different interdisciplinary 'T,' 'H' or 'comb'-shaped professional profiles, we would argue that 'zooming in' on the integration of vertical and horizontal knowledge reveals an organic and dynamic interconnectedness of knowledge 'in use' (of which some is professional expertise) and 'latent' (horizontal) knowledge. Thus, inspired by human biology and our own experience with horizontal thinking and creative exploration of knowledge from other fields following a presentation on genetics research by Professor Eske Willerslev at a science education conference (Big Bang, 2023), we suggest that the integration of vertical and horizontal knowledge can be illustrated as a continuous and transformative creative process, with creative competencies such as horizontal thinking (Byrge & Hansen, 2014; De Bono, 1992), open-mindedness and co-creation (Byrge & Hansen, 2014; Scharmer, 2016) providing the links between these two 'strands' of 'knowledge in use' and 'latent' or emerging knowledge, much like a 'double helix', as a model for creative transdisciplinary thinking (Figure 3).

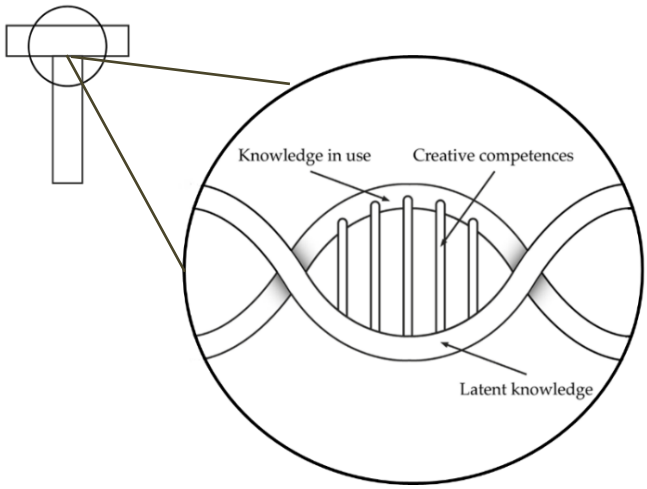

Figure. 3. Model for creative transdisciplinary thinking.

This horizontal thinking model emphasizes the need to support students' creative approaches to processing knowledge through novel combinations and transformation of knowledge, not just across disciplines but also across tacit and emerging horizontal knowledge that can be made explicit and used vertically through ideation, incubation, horizontal transformation, and co-creation to offer new innovative perspectives and possible solutions to complex problems.

This study indicates that a PBL environment with an added focus on creativity can equip graduates with such creative competencies and creative self-efficacy to use horizontal

thinking in their studies and future professional life. Graduates from the Creative Genius program generally experienced the transition from student to professional as smoothly, using their creative competencies and training from the program to engage in transdisciplinary and complex problem-solving with a creative mindset, especially when working individually and with colleagues who are open-minded and willing to engage in a creative process. The study also highlighted the need for creative leadership in complex problem-solving and how co-creating with colleagues, particularly superiors, who are unfamiliar with creative processes or acknowledge the value of horizontal thinking, can be challenging. Hierarchies and power dynamics can make it difficult to engage in horizontal thinking with colleagues and superiors, even when the candidates have been trained to handle this by engaging and acting as role models facilitating a creative learning and working environment.

Being open-minded and able to co-create across disciplines using horizontal thinking to combine and connect transdisciplinary knowledge in a transformative process was one of the learning goals at the CG program. The study suggests that it is possible not only to educate students with these competencies but for graduates to sustain this creative mindset through the transition into industry and work. All CG graduates did possess a relatively high degree of awareness about creative competencies and processes in their everyday life, expressing a high degree of creative self-efficacy and highlighting this as one of the most critical gains from CG in the transition to a professional work life. Thus, this suggests that creative self-efficacy and the embodiment of creative competencies also outside the classroom or inherently creative learning environment is key when solving complex problems and thus could be an important learning outcome in any PBL learning environment seeking to integrate more transdisciplinary approaches to problem-solving.

CONCLUSION AND PERSPECTIVES FOR FUTURE WORK

This paper introduced the Creative Genius Program as an innovative approach to transdisciplinarity in higher education and, based on interviews with graduates from the program, explored whether a problem-based learning environment with a focus on creativity facilitates transdisciplinary engagement and creative competencies and to what extent this can manifest into transdisciplinary career paths and creative mindsets in a life-long learning perspective.

Whereas results from the study indicate that a focus on the development of creative self-efficacy and the embodiment of creative competencies do support students in the transition from student to professional and help equip them to engage in transdisciplinary and complex problem-solving in industry and society, the study is limited to a small sample of graduates and further research needs to be conducted to verify results, both

across the Creative Genius cohorts and for graduates from other similar transdisciplinary and creative learning environments in higher education.

Furthermore, while the Creative Genius Program was considered a successful educational experiment and research program with high student and stakeholder satisfaction, this does mean that the pedagogical model is a 'one size fits all' and applicable to all other learning environments or that CG should be compulsory at curriculum level across all programs. Rather, it suggests a need for PBL environments that seek to integrate transdisciplinary approaches to complex problem-solving, to explore and experiment with establishing creative and psychologically safe learning environments with learning outcomes that explicitly address creative problem-solving to support students in developing creative self-efficacy and embody creative competencies to make the needed connections between their discipline-specific or vertical knowledge 'in use' with broader, horizontal and 'latent' knowledge through creative transdisciplinary thinking, open-mindedness, and co-creation to address and engage with transdisciplinary and complex problem-solving in industry and society.

The first step to achieving this could be to develop awareness among PBL facilitators and supervisors about their own experiences and capacity as 'creative geniuses' and how they might utilize their creative competencies, horizontal thinking skills, and creative self-efficacy when teaching in problem-based and transdisciplinary settings in higher education.

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