FROM BEATS TO BLUEPRINTS: RETHINKING CREATIVITY IN ENGINEERING EDUCATION

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ABSTRACT
Engineering education faces new challenges, including the rise of service-oriented products that integrate tangible and intangible features in their design. The traditional engineering design's preliminary phases, which centre on the artefact as the main object, are thus changing, calling for a more innovative and open approach. Intrigued by the clear behavioural difference observed between engineering and music students in how they approach open, openly defined educational tasks, this study contrasts music students' approaches with the early stages of engineering design to propose rethinking creativity training in engineering design education. The study draws on experience in teaching engineering design and music production, both of which share a common view of active pedagogy. As part of the Let's Create Music project, the ethnographic study has collected data through video recordings of online music camps featuring both non-professional and professional music producers. Observations in on-site camps also contributed to the study. The results illustrate differences and conclude with recommendations for rethinking engineering education, including integrating gender perspectives into assignments.

Keywords: Engineering design education, music production, design thinking, creativity, active pedagogy

1 INTRODUCTION
Sweden's music industry has achieved global success, thanks to producers such as ABBA, Dennis Z Pop, and Max Martin, as well as platforms like Spotify, and to a focus on popular music in elementary schools and Municipal Schools of Arts. Still, the engineer is regarded as a role model in Sweden's technical history, with acknowledgement of innovative solutions. Inventions such as the boat propeller, ball bearings, and the three-point seat belt are the result of creative engineering.

Both the engineer and the music producer share skills in innovation and creative product development, which, from a business perspective, have long been emphasised as critical to success [1]. From an engineering perspective, creative product development primarily involves the innovation of artefacts, i.e., products [2, 3]. Consequently, these processes are grounded in the designers' interaction with tangible objects [3]. In recent years, the vision of product-service systems has introduced the concept of product servitisation [4], highlighting the distinction between tangible products and intangible services and their combination [5]. Furthermore, combinations can be categorised as social and ill-defined, so-called wicked problems [6], for example, solutions to address climate change. However, even well-designed products can fail due to shortcomings in their digital interfaces. Contemporary engineering design calls for a more open approach, including the ability to identify and understand the problem from a user perspective. Such problems imply that teaching problem framing is as important as problem solving [7]. The issue of separating or defining the results of the development process is less evident in cultural creative industries, such as music production. Nevertheless, music and songs differ from material objects and manufactured goods. Despite this, music and songs play a role similar to that of engineering artefacts in driving creative and innovative processes. From an engineering perspective, it would be interesting to examine the behavioural differences between how engineering design and music students approach open problems.

This curiosity stems from 18 years of teaching creative development processes in engineering education and from participation in the research project called Let's Create Music. Meeting and interacting with professional music producers and students in the project's camps and masterclasses was an intriguing experience. As teachers, we were surprised that the music students, without hesitation, eagerly engaged with abstract instructions such as *"go to the studio and make pop music, you have 2 hours at your disposal"*. Given our background in teaching engineering students, we found this behaviour astounding, whereas the music researcher considered it normal. In our classes with engineering students, instructions that, in our view, clearly describe a challenge, its context, users, and constraints elicit many questions and hesitation. For example*, "design a shelter solution for people affected by a natural disaster, using a 20-foot-long standard shipping container as a base"*. Sometimes, students conclude that they have been given an impossible, abstract task because the instructions are insufficiently defined, whereas their lack of interest in problem framing seems to be the main issue [8]. Therefore, this study contrasts approaches to the creative stages of music production education and practice to inform the rethinking of creativity training within engineering design education.

The study design is briefly outlined below. Subsequently, an active pedagogical view is presented, followed by examples and a discussion of the creative stages. The paper concludes with recommendations and lessons learned that could inform the rethinking of engineering design education.

2 STUDY DESIGN

The EU-funded project Let's Create Music investigated the early creative stages of music production and proposed designs for innovative online support. The ambitious vision for this support was a virtual studio that, as realistically as possible, mirrored the co-creative process of a physical studio. The critical technical issue was assumed to be latency hindering online co-creation in music production, but technical researchers soon recognised that music production is often asynchronous. Instead, part of the project's research focused on designing technical support for remote, wireless work and the creative stages more generally, for example, whether to use a mood board or AI to support alignment in group creativity. These technical supports are excluded from this study, which focuses on contemporary music production that uses only established tools. Music production studios are highly digitalised, for example, equipped with digital audio workstations that are central to online work. Online music production also requires tools for communication and documentation, such as Microsoft Teams, SharePoint, and similar platforms.

The research examined both in situ and online creative music production. Interactions with professionals (active in the music industry), non-professionals (local music entrepreneurs and start-ups), and students from higher music education institutions were held through masterclasses and camps. The professionals were known nationally and internationally as music producers and topliners, meaning they created lyrics and melodies. A globally known American music producer also participated in the activities. In addition to engineering design and music education researchers, the project consortia included experts in digitalisation and communication. The masterclasses and camps were primarily held online via Zoom or Muse (a digital audio workstation) and recorded for further observations and analysis. Camps were also held in situ, where the project's researchers observed and took field notes. Five professional music producers observed the camps and supported the participants during short breaks. In turn, the researchers observed and spoke with the producers about their observations of studio activities. The co-located camps concluded with a presentation of the music created during the full-day camps, and the five professionals offered formative feedback to the participants, including suggestions and recommendations. Qualitative data were collected over the three-year project and can be categorised as participatory action research [9]. This implies that we studied social interactions among participants, including creative teamwork, and that we could introduce changes based on our observations. It also includes a cyclical, iterative approach to planning, action, analysis, and reflective-in-the-way conclusions, in which we naturally compared our previous studies of engineering design and music education. Hence, in one of these partial conclusions, we identified an interest in examining lessons learned from comparing engineering design and music education, thereby motivating this study.

3 ACTIVE PEDAGOGY

Active pedagogy, or active learning, focuses on strengthening students' learning. Quite some time ago, it was found particularly beneficial for STEM courses (Science, Technology, Engineering and Mathematics) as well as for all forms of learning [10], [11], [12]. Its opposite, so-called passive learning, can be useful when students must assimilate and translate subject-matter knowledge. However, that pedagogy falls short when personal development is central, as it is for both framing and solving complex problems; that is, learning should foster innovation and entrepreneurial abilities [13]. It is important to note that teachers' values and beliefs about the purpose of 'real' education often sustain prevailing passive pedagogy [14]. In earlier studies of engineering education, as well as in current ones, we encounter teachers expressing doubts, *"What should be removed?"* This doubt reflects an either-or attitude that impedes improvement. Barton [14] even calls it *traditionalist inertia*, because it resembles a not-invented-here tradition. In this view, one's own courses are perceived as proven successful and excellent, at least within the context of one country, so why change? However, teachers who, for example, applied design thinking to support the implementation of active pedagogy found that it broadened their instructional repertoire. Commonalities between active pedagogy and design thinking were particularly useful, including playful learning, collaboration, productive failure/resilience, creative confidence, facilitation, mentoring, advising, and counselling [15] (p. 302). The teacher's role shifts from instructor to facilitator in active pedagogy and learning, see Table 1.

Table 1. A changed role for teachers (Created by Authors)

Instructor (passive)	Facilitator (active)
Presents information	Designs learning experiences
Provides arguments	Supports dialogues
Shows a correct solution	Empowers plausible alternatives

The teaching and learning activities are suggested to be designed to enable investigations of realistic problems, promote self-development tasks, integrate pre-knowledge with new knowledge, and enhance task-based performance [16]. Furthermore, an inclusive atmosphere is required [16]. These dimensions constitute the grand challenges for teachers to address in course design, yet they are important for meeting the basic requirements of successful active pedagogy.

4 CONTRASTING APPROACHES

The study addresses approaches to the creative stages, implying that a deep dive into the term creativity constitutes a delimitation. Nevertheless, to operationalise creativity from an engineering perspective, it can be defined as *"a cognitive process culminating in the generation of an idea"* [17]. Within the design process, this idea should further develop into a product or process concept [17]. Additionally, in engineering design, creative work is applied in the early stages of the design or development process [17]. Creativity is both required and taught to understand the task and generate ideas, and it focuses on products, i.e., manufactured goods [18], [19]. Hence, the rationale is naturally centred on the product. Contemporary servitisation poses a cognitive challenge because it allows product replacement while the function remains unchanged. Such a change in the business model necessitates a corresponding shift in creative work [20]. That is, the creative process cannot begin with a product. This cognitive challenge lies in the contrast between the rationale for creativity in open-ended engineering design for servitisation (left in Figure 1) and the traditional design process (right in Figure 1).

In a previous study, an engineering student described the challenge of being assigned open-ended tasks. The student concluded: *"As an engineer, I like to take a thing, a product, look at it, twist and turn it, and then improve it or make it better"* [22]. Students' frustration typically stems from the perception that they receive insufficient theoretical subject knowledge, even though they often receive more than in a technically oriented course.

The frustration may relate to the multidisciplinary nature of creative work. We interpreted this as a shortcoming in recognising, or perhaps acknowledging, it as a different kind of theory [7]. Yet, starting in an open-ended state led engineering students to realise that they were designing products for others rather than for themselves. The approach to creative, open-ended tasks has been tested in a study of engineering design teams, which examined their tendencies in problem framing and solving [8]. The students were divided into homogeneous teams based on their learning preferences to either master (develop a deeper understanding) or solve a task. It was found, of course, with some plausible deviation, that mastery-oriented students were more likely to engage in problem framing through exploration and to view users as people rather than objects in the design process.

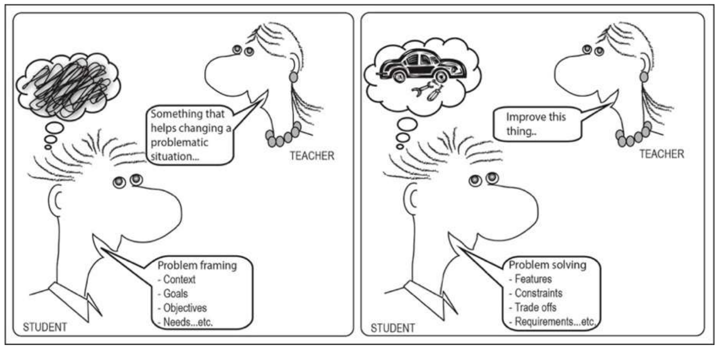

Figure 1. Problem-framing vs. problem solving. Source by authors (Revised from [21])

Understanding and treating users as people is considered essential for designing more sustainable or novel solutions to abstract problems [4], [8]. By contrast, music students and professional artists seem to adopt a more user-oriented approach as their natural way of working creatively, finding it normal to produce music with others and for listeners. To evaluate the result and progress of the music, they focus more on the actual musicking and the vibe the music and text can create, for example, a specific genre, a sunny day, driving a cabriolet through a scenic beach landscape with wind in the hair.

The intangible nature of music makes it easy to 'prototype' whenever and wherever a creative idea arises, for example, by humming a short melody into the voice recording app on a mobile phone and tapping the beat on the phone. Another observation is that in the early stages of music production, the team collaborates to develop a shared vision for the final product. This is done, for example, by nodding the head or stamping the foot to the beat, or by picking up an instrument and playing along. When engineering students learn about creativity as a cognitive process, music students and artists recognise emotional feedback from instruments and co-creators, as well as embodied and intuitive processes, as important inputs in the creative process. The creative process is a complex and holistic interplay of thoughts, feelings, sensations and shared experience*s.*

Creating a shared vision is a significant challenge in engineering design, particularly in open-ended contexts. Eifler and Myrup Andreasen [23] argue that embodiment design can better represent the physical artefact during the creative process than traditional conceptual design methods. Embodiment design, simplified as the materialisation of a conceptual idea, prevents design fixation and the common decision-making that leads to choosing between binary solutions, either one that delivers a certain function or not [23]. Such a selection disregards alternative, plausible solutions, thereby reducing innovation and the generation of more creative and better solutions. Embodied design, or cognition, emphasises that humans do not think only with the brain, as is the common approach in conceptual design, but also use facial expressions, gestures, body language, and so forth. Such visual representations are fundamental to the engineering design team's creative work [24], yet despite being generally recognised, embodiment design is not influential in advancing ideas and solutions [23]. The extensive literature on product design and development processes commonly suggests stage-gated process models to guide activities in the process, for example, starting from a problem or task, going through stages of generation, selection, testing, setting final or detailed specifications, and deploying a production plan, e.g., [18], [19]. The stage-gate process may also separate work between the potential user and the product, a practice previously known as an over-the-wall approach. Whereas music production begins with a brief idea, such as a title, lyric, or motif, that serves as the basis for the entire song [25]. The development process appears to be built upon the integral parts of the song's genre, such as the intro, verse, and bridge, and/or lead, drum, bass, etc. At a general level, the curricula for engineering design education and music production appear similar in their coverage of subject matter. One difference is that music production education, as an artistic discipline, explicitly addresses the development of students' own profiles. The core focus of engineering education is subject matter [19]. Consequently, it overlooks personal development. We have met many students again after they finished their engineering education. One of them said, *"As a project leader, I now understand the relationship between my education and the profession. I could not see how user-orientation concerned engineering, or why I should develop any 'people' skills."*

5 CONCLUDING DISCUSSIONS

It might seem like comparing apples and oranges, i.e., too different to be compared, when examining approaches to the creative stages with the aim of contrasting music production with engineering design. However, as our study progressed, we identified key approaches that can inform the rethinking of creativity training in engineering design education and ultimately help students become more comfortable with open-ended assignments.

One obvious approach is to view engineering design as artefact focused. In the same vein, engineering process models specify the team's *activities* required to design and develop a product. This creates a cognitive gap between designers' understanding of users' needs and the product's functional requirements. Music production is user-oriented, guided by holistic models that connect the idea to *all parts* of the song. Attempts to influence engineered products through a servitisation logic have long been proposed [26]. Such a model suggests that support for users' activities mediates the value of the solution rather than that of the physical product itself. Although servitisation is well-established as a model for sustainable development in industry, its impact on engineering education lags behind. A suggestion is to introduce open-ended, servitisation-like assignments gradually over the programme period, for example, as a complementary task in which students reflect on an alternative approach to servitising their proposed physical product. Appreciative inquiry [27] is grounded in exploratory dialogue, which aligns with design thinking. It could aid in designing servitisation-like assignments, for example, by guiding students to investigate a problem and who experiences it (What is the situation or problem?), envision a changed situation (What might be…?), generate creative ideas (What if…?), and select a solution by connecting 'what might be' with 'what is'. If so, engineering students would practise shifting the focus from a solution to its value for the client or user. Additionally, designing the assignment in iterations, with students providing feedback to peers, offers an opportunity to advance both ideas and the learning curve. Furthermore, teaching and learning activities would be more closely aligned with the complexity of the engineering profession, a central tenet of active pedagogy.

Another approach is that creative work in engineering design is typically confined to the early stages and is a cognitive analytical task of generating ideas [17]. Music production is a comprehensive creative process, from idea generation to the finished song. Music, simplified, is rhythm, sound, and harmonics that convey feelings and moods. Thus, producing music means that creators themselves will also be affected by it. Rhythm, sound, and tones embody the song's vision, for example, for the producer, the topliner, and the artist. Although considered beneficial to the creative process, embodiment design does not significantly influence engineering design [23]. However, servitisation designs, i.e., combinations of physical artefacts and immaterial services, may depend on the ability to empathise with others' perspectives and ideas to deliver value [26]. Empathy is cultivated through the practice of interpersonal skills, often referred to as soft skills, in engineering contexts. Emotional intelligence, behavioural traits, and the ability to build upon others' ideas are typical soft skills. Homogeneous teams can be beneficial because they influence one another in the same direction [8], but they are unfavourable when alternative solutions are desired. Engineering design, like other technical domains, is under-represented by women. In 2006, a study of 100 male and 3 female students suggested that interpersonal skills are needed in engineering education [28]. Such a gender imbalance persists 20 years later in engineering programmes; perhaps the comprehensive implementation of active pedagogy and a broader perspective on creativity could be the primary driver of a new paradigm in engineering.

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