Design thinking to enhance transformative learning

Stanislav Avsec

University of Ljubljana
Ljubljana, Slovenia

ABSTRACT: Design thinking is seen as a new paradigm for dealing with problems in various sectors, such as business or education, to meet the challenges of Industry 4.0 and to develop 21st Century skills. Despite its popularity and prevalence in various disciplines, numerous researchers reported pedagogical problems in design thinking. It is likely that ineffective design thinking teaching and learning could be the underlying problem. This study aims to investigate design thinking for transformative learning in a *Creative Technical Workshops* elective subject in the Faculty of Education at the University of Ljubljana in Slovenia. A sample of 76 pre-service teachers from two consecutive years of study was selected. Statistical analysis revealed significant ($p < 0.05$) differences in post-test/pre-test scores in the majority of the constructs of design thinking. The findings indicate that design thinking, supported by transformative learning theory, can be conducive for developing higher order thinking skills and meaningful learning experiences that influence a pedagogical shift and perspective of pre-service teachers from a variety of majors. Based on the results, a model could be created for facilitating pedagogical change in the context of higher education across different study programmes.

Keywords: Transferable higher-education skills, pedagogical change, engineering design, design thinking, transformative learning, creative technical workshops

INTRODUCTION

Every educational system starting from elementary to university studies faces the challenge of competitive knowledge provision and higher-order thinking skills development needed by graduates in the technology-enabled society and job market of the 21st Century [1]. Higher education requires special attention because its complex environment is directly related to the labour market, industry, society and sustainable development [2]. Hence, the need for pedagogical changes and technological innovations cannot be overlooked [3][4].

After years of study, it is not uncommon that students face completely redefined jobs or will be expected to undertake job roles that do not even exist yet after their graduation [3]. Therefore, educational institutions need to provide education for increasingly fragmented and complex markets that require different learning outcomes, delivery modalities and flexible learning approaches, while governments are expected to regulate higher education, provide quality standards and funding to reflect socio-economic policies [3-5].

Several authors [3][6-8] propose the use of a complex, self-organised and adaptive method of transactional distance education that encompasses current and emerging features of digital technologies, instructional and curricular systems, social and global systems that influence how institutions are supported, funded and managed [7]. The critical thing in the implementation of information and communication technology (ICT)-based teaching and learning is the pedagogy and not the physical or virtual approach in the use of digital technology [6][8]. Moreover, the implementation of strategic pedagogical changes through ICT means has produced several advantages and disadvantages related to the actual use of ICT in education [3].

Pedagogical change and the thoughtful use of ICT in teaching can be important tools to ensure that institutions are competitive in a modern higher education environment [3], however, caution must be exercised when using ICT. It has been found that ICT is more likely to be incorporated into education in an intuitive way [2][8].

If ICTs are only used in intuitive ways, it may not have an impact on the transformative learning that is necessary for educational change [3][9]. Therefore, the introduction of new educational technologies compels educators to change their pedagogical attitudes and practices, taking into account learners' self-efficacy [6]. This may be reflected in the acquisition of higher order thinking skills and help students to change their perceptions through critical reflection on real design tasks [3][10]. Moreover, Avsec and Jagiełło-Kowalczyk stated that:

> *…when students are engaged in real-world design tasks, they are more aware of and attentive to their thinking process, prefer goal orientation in their performance and they can impose learning strategies they need to enhance the design process and improve design outcomes* [3].

Design and design thinking are an integral part of many industrial and commercial activities [11]. Universities around the world have made great efforts to equip their students with the knowledge and skills needed by 21st Century organisations [4][11]. Numerous studies show that design thinking has gained popularity and importance in the context of higher education over the last decade [12-16], but these studies rarely address the impact of design thinking on student learning performance. Students develop interdisciplinary teamwork skills by involvement with interested stakeholders from society and business, while developing design thinking [17][18].

In the Faculty of Education at the University of Ljubljana in Slovakia, design-based learning for prospective teachers of science and technology is well articulated, and has been regularly implemented in both compulsory and elective courses over the past decade. However, in evaluating the design-based learning courses, a lack of international component and transdisciplinarity was identified. Therefore, in the academic year 2019/2020, the Faculty introduced design-based learning for the first time also in mixed courses with students from different majors. The subject *Creative Technical Workshops*, offered as an elective, was also designed with the aim of attracting students from different disciplines and courses, both domestic and international students. The basic content of the subject emphasised the following topics:

- Creative thinking and inventiveness in design, technology and engineering.
- Techniques, methods and strategies of creative thinking in design and engineering education.
- Design thinking in education.
- Integrated product development with evaluation and decision making [19].

The acquisition of knowledge and skills is required to undertake a new project or unit of study and progress in transformative learning. Students are provided with different types of learning strategies and methods, as well as creative techniques, while the knowledge and skills acquired include higher order thinking, with transferable skills:

- Collaborative working, team working, experiential working *hands-on* approach.
- Management, leadership, organisation and communication.
- The use of modern technologies to find and solve problems.
- Critical analysis, synthesis, decision making, proactivity and systems thinking [19].

The students' final projects, which were created using the design thinking approach to the topic, showed a great deal of innovativeness and creativity, and were tested in the target sample, such as elementary and secondary school students, students with special needs and disabilities, and gifted students. Observations during the testing and quantitative assessment of the projects and elaborations as their final grades indicate the successful implementation of the topic.

Nonetheless, the growing interest in learning design thinking as a pedagogical approach to fostering innovation in higher education has raised some unanswered questions. Of particular interest is how to quantitatively assess the impact of design thinking implementation on transformative learning. Transformative learning refers to the orientation or idea that learners who acquire new information also evaluate their previous ideas and knowledge, and change their own worldview in the process of absorbing new information and through critical reflection [20][21]. It goes beyond simple knowledge acquisition and is concerned with the way learners make sense of their lives and understandings [22].

When transformative learning occurs, learners' self-understanding may change, and they are able to look at the subject from a different perspective, also due to their changed belief system. Transformative learning is more likely to occur in international contexts or heterogeneous groups involved in the course [23]. But some limitations need to be considered and these are seen in the emotional disconnection, perceived powerlessness and leisure mode when studying abroad or remotely [23]. When transformative education is conducted, special attention should be paid to instrumental learning (task-oriented problem solving and evaluation of cause-effect relationships) and communicative learning (how students communicate their feelings, needs and desires) to challenge their previous understanding [21].

Since design and design thinking are very often used as an approach for competitive education towards sustainable development [24], it could be that the involved success factors of transformative learning stem from participation in interdisciplinary teams, social-emotional communication, creative problem solving, dealing with conflicting values, learning goal towards sustainable development and changing beliefs in a positive way [23]. The processes developed in transformative learning could be largely related to design thinking, especially in the cognitive process (critical reflection, experience, action, disorienting dilemma), extra rational process (artistic thinking, emotional, imaginative, dialogical) and social critique (ideology critique, empowerment, social action), as argued by Stuckey et al [25].

Against this background, the following research questions (RQs) guided this study:

1. What is the students' self-assessed change in design thinking after completing the Creative Technical Workshops subject?
2. What is the impact of design thinking on students' transformative learning?

METHODOLOGY

A quantitative research approach with an empirical research design was followed in this study. The study evaluates the Creative Technical Workshops subject to reveal its potential for transformative education and learning.

Subject Format

The Creative Technical Workshops subject was delivered in the form of interactive lectures (30 units of 45 minutes) and workshops (30 units of 45 minutes). The subject lasted 15 weeks, with four units per week (Figure 1). In the lectures, students worked on assigned design tasks in small groups of 4-5 students each, while in the workshops, as laboratory work, they worked more individually and co-operatively in sharing fabrication tools and ideas.

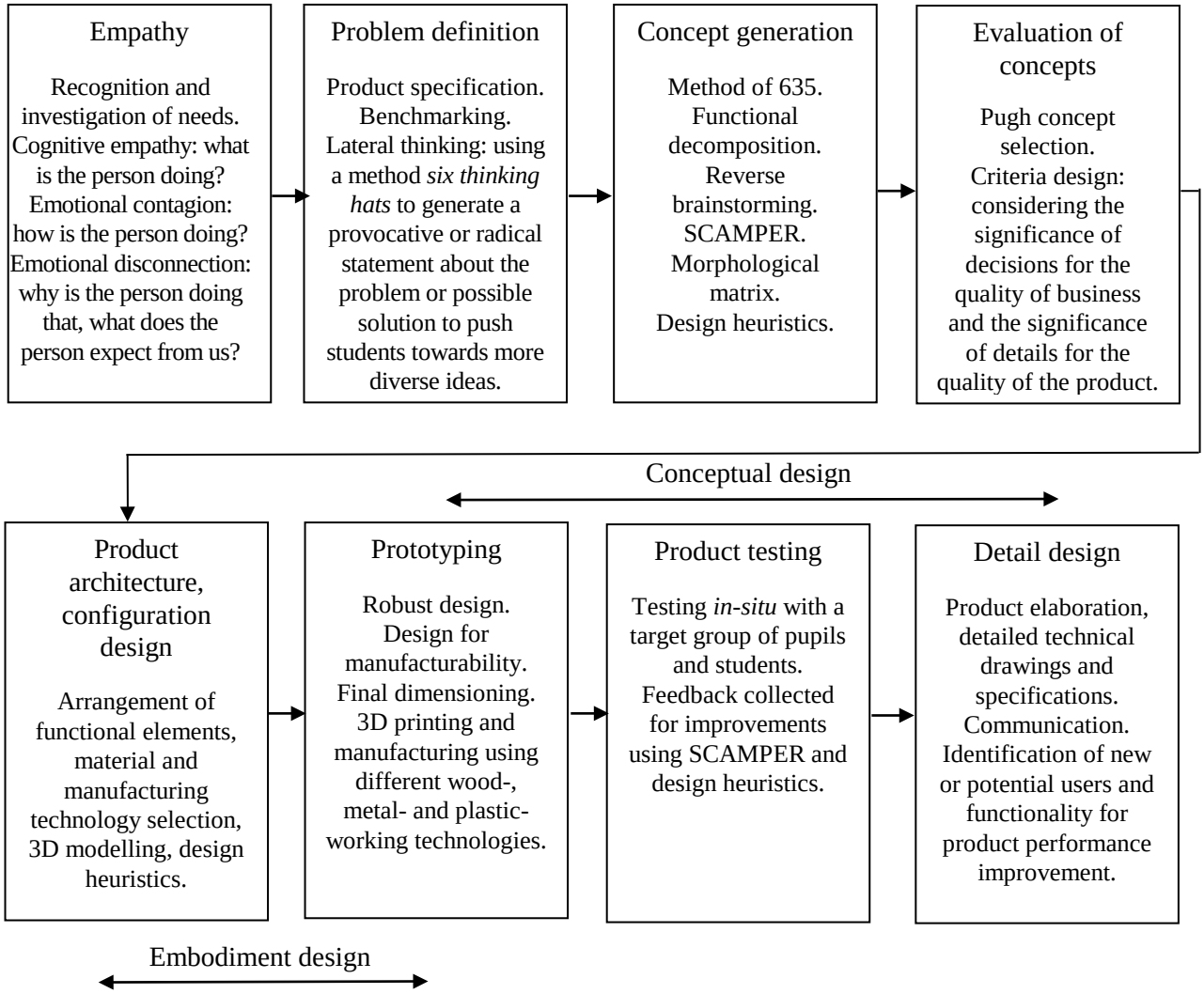

Figure 1: Format of the Creative Technical Workshops subject.

Sample

The study sample consisted of 76 pre-service teachers from different study programmes (science and technology, primary school teaching, social and general pedagogy) studying at the University of Ljubljana who were enrolled in the Creative Technical Workshops subject. Students were recruited in a two sequential academic years, 2019/20 (35 students) and 2020/21 (41 students).

The sample included more females (n = 61, 80.3%) than males (n = 15, 19.7%), while Erasmus students from different countries (Spain, Poland, Turkey, Czech Republic, Slovakia, Germany) accounted for 43.4% (n = 33) of the sample population. The average age was 22.3 years. Any participation in this research was completely voluntary, and an informed consent form was presented to the students, including safeguards for privacy protection of the participating students. Students were free to withdraw from the research at any stage.

Instrument

Design thinking in pre-service teachers was assessed using a questionnaire developed by Dosi et al, with a 6-point Likert scale (from 6 - strongly agree to 1 - strongly disagree) adapted by the author of the present study [26]. A design thinking

mind-set consists of 22 constructs with 71 items in total. The questionnaire in the present study proved to be moderate to highly reliable, with Cronbach's α values of the constructs between 0.70 to 0.91 (see Table 1).

Empirical Referents for Transformative Learning

Since the design thinking questionnaire from Dosi et al was used and the processes developed in transformative learning could be largely related to design thinking [26], the author identified the following higher order thinking processes as empirical referents of transformative learning based on the findings of Stuckey et al: acting differently, self-awareness, openness, shifting worldview, dialogue and emotion, imaginal, support, action, experience, critical reflection and disorienting dilemma [25].

This is well reflected in design thinking as tolerance for uncertainty, human centeredness, empathy, mindfulness and process awareness, holistic view, openness to other perspectives, learning from mistakes, transformation into something tangible, critical questioning, imagining something new, creative confidence and optimism to make a difference. These referents demonstrate the occurrence of transformative learning with their presence or perceived change [25][27].

Procedure and Data Analysis

A design thinking questionnaire was distributed on-line as a pre-test and post-test to pre-service teachers' email addresses, where a link to the questionnaire was provided in Google Forms. Students first completed the questionnaire one week before the subject began, then participated in the study during on-line distance learning sessions via MS Teams, and completed the questionnaire a second time one week after the subject ended.

The data were analysed with IBM SPSS (v.25) software. To support the reliability of the questionnaire, a Cronbach's alpha coefficient was used. Besides this, the standard tools of descriptive statistics were employed to present the student basic information, the mean score and standard deviations of dependent variables, while a paired *t*-test was used to compare effects of design thinking from the pre- to post-test. Multivariate analysis of variance (MANOVA) was used to find and confirm significant relationships between groups with an effect size *eta squared* (η^2).

RESULTS AND DISCUSION

Student design thinking results were obtained using a self-assessment questionnaire with 22 subscales (Table 1). Pre-service teachers reported above average design thinking skills on all subscales on both the pre-test and post-test, with the midpoint of the scale at 3.5. Visual inspection of the differences between the post-test and pre-test scores indicates the effectiveness of the subject in using a design thinking approach to teaching and learning.

Table 1: Students' average scores on design thinking expressed with a mean (M) and standard deviation (SD) at the pre- and post-test level with the corresponding Cronbach's α on the design thinking questionnaire's subscales.

Subscales of design thinking	Pre-test			Post-test			Differ.	Sign.
	Cronbach's α	M	SD	Cronbach's α	M	SD	$M_{post\text{-}test}$ -$M_{pre\text{-}test}$	*p*
Ambiguity and uncertainty tolerance	0.77	3.86	0.87	0.86	4.47	0.82	0.61	0.000
Embracing risk	0.84	3.76	0.92	0.80	4.22	0.94	0.45	0.013
Human centeredness	0.75	4.24	0.85	0.81	4.73	0.76	0.48	0.000
Empathy	0.85	4.88	0.86	0.86	5.25	0.62	0.37	0.005
Mindfulness and awareness of process	0.70	4.34	0.76	0.71	4.79	0.67	0.44	0.000
Holistic view	0.86	4.53	0.87	0.80	4.92	0.67	0.38	0.002
Problem reframing	0.75	4.54	0.89	0.85	4.86	0.83	0.31	0.016
Team knowledge	0.70	4.45	0.90	0.75	5.09	0.65	0.64	0.000
Team members' interactions	0.83	5.15	0.95	0.87	5.28	0.73	0.13	0.340
Multi/interdisciplinary collaboration	0.78	5.01	0.80	0.76	5.24	0.59	0.23	0.038
Open to different perspectives	0.83	5.23	0.74	0.84	5.28	0.59	0.04	0.691
Learning oriented	0.87	5.06	0.75	0.87	5.18	0.57	0.12	0.308
Experimentation	0.83	4.42	0.95	0.87	4.79	0.82	0.37	0.016
Learning from mistake or failure	0.73	4.51	0.82	0.79	4.89	0.74	0.37	0.006
Bias for action	0.84	5.15	0.89	0.82	5.56	0.55	0.40	0.005
Transforming into something tangible	0.82	4.59	0.94	0.86	5.07	0.78	0.47	0.001
Critical questioning	0.83	4.71	0.93	0.84	4.92	0.77	0.21	0.303
Abductive thinking	0.90	4.17	0.88	0.91	4.73	0.74	0.56	0.000
Envisioning new things	0.74	4.39	0.85	0.77	4.74	0.69	0.35	0.005
Creative confidence	0.80	4.54	0.88	0.88	4.86	0.81	0.31	0.024
Desire to make a difference	0.85	4.71	0.86	0.84	4.95	0.67	0.25	0.048
Optimism to have an impact	0.81	4.56	0.99	0.82	5.11	0.76	0.54	0.000

To find significant differences in means between the pre-test and post-test results, a paired samples *t*-test was used. The test revealed that significant differences occurred in the majority of the design thinking constructs ($p < 0.05$) as can

be seen Table 1. It appears that the implementation of the design thinking approach in the subject had no effect on the interactions of the team members ($p = 0.34 > 0.05$), which was expected since the subject was conducted remotely in on-line and off-line learning. This suggests ineffective use of the collaboration space created in MS Teams.

Since design thinking is inherently a non-linear and iterative process [28], it could be that asynchronous learning occurs when students interact with the content, peers or instructor. In addition, group diversity was not well addressed and students needed physical contact when working in groups to open up to different perspectives of other group members ($p = 0.69 > 0.05$). Since the subject aimed at developing higher order thinking skills, knowledge acquisition was not in the first plan ($p = 0.30 > 0.05$). It also proved that design thinking is more than just learning by doing through observations, prototyping and hypothesis formulation. Similarly, the subject did not place too much emphasis on developing critical thinking skills ($p = 0.30 > 0.05$), but rather on developing a general designer profile using design thinking for transformative learning.

Transformative learning as one of the subject outcomes occurred on a large scale. The changes in 12 transformative learning referents are shown in Figure 2.

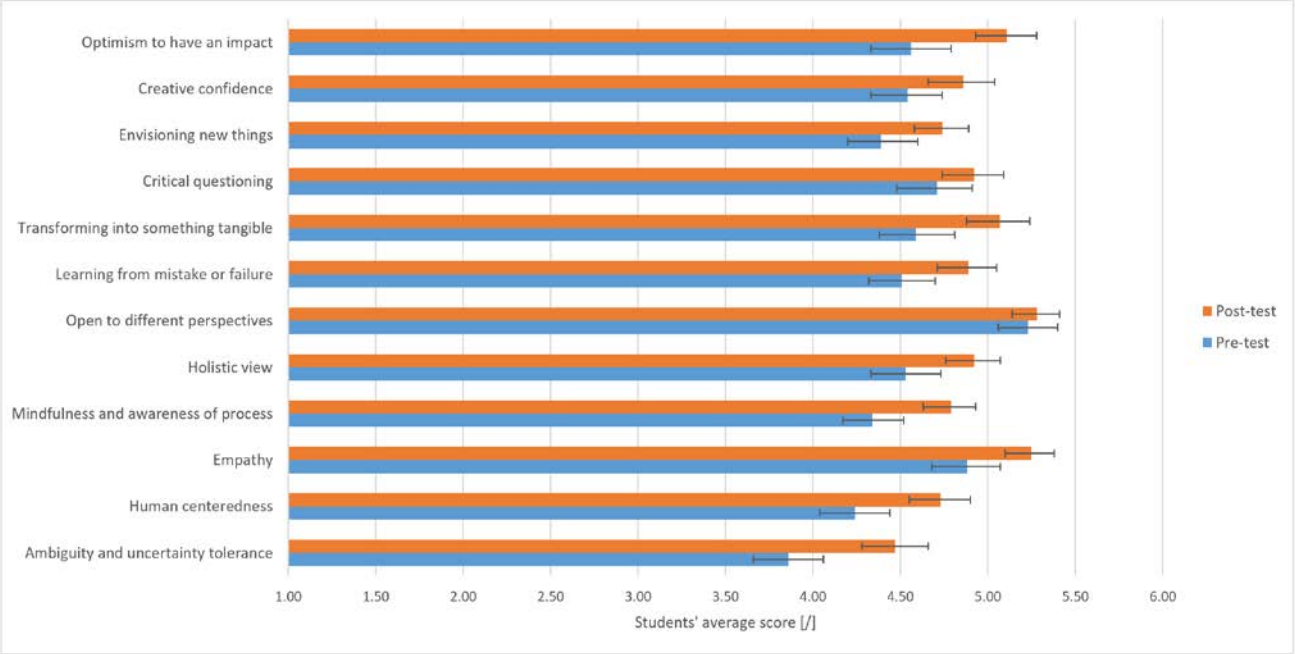

Figure 2: Students' perceived transformative learning scores in 12 referents with 95% confidence intervals.

Transformative learning was achieved in the majority of referents, and only in critical questioning and openness to other perspectives it was not found ($p > 0.05$). In order to develop a more open perspective, other tasks or a different learning environment are needed, where students can use their intuition to discern.

It seems that students did not experience a profound change in the way they see real things and products, which is very important in developing critical thinking as it allows them to go back or disassemble an existing product, learn the functional framework and modify it with improved functionality [25]. It also seems that using 3D modelling and prototyping tools in a virtual environment is not an effective way for transformative learning. This suggests a more intuitive use of ICT and digital technology in design thinking. It seems that the distance learning students were not able to challenge the real world with the virtual world to promote their social change. Critical reflection was more focused on reflection-on-action and not so much on reflection-in-action, as suggested by Woodrow and Caruana [27].

The results showed significant changes in the majority of the design thinking constructs as transformative learning referents, indicating the effectiveness of design thinking in achieving transformative learning. In addition, design thinking was found to enhance the rational process (action, experience, disorienting dilemma in learning from mistakes) and beyond the rational process (art-based, emotional, imaginative for creative ideation), while social critique requires more real-world cases, which strengthens the development of evaluative processes, so that the resulting decisions can support substantive change. It seems that students have also developed a visionary way of thinking about challenges, which enables them to be engaged and self-directed in shaping design ideas and concepts. More likely, these students also successfully inspire their peers in conceptualisation and embodiment design by applying multiple principles or rules in new situations and producing ideas that are original, elaborated and unique, as argued by Tsimane and Downing [29], and by Léger et al [30].

It was also of interest to investigate whether transformative learning occurs equally in female and male students. To this end, a MANOVA with Tukey correction due to unequal sample size was conducted. The analysis revealed significant differences ($p < 0.05$) only in ambiguity tolerance, uncertainty tolerance, human centeredness and optimism in favour of male students with small, moderate and strong effect sizes η^2 (0.04, 0.11, 0.15, respectively).

CONCLUSIONS

Design thinking, supported by transformative learning theory, was found to be a possible context for developing higher order thinking skills and meaningful learning experiences that influence a pedagogical shift and perspective of pre-service teachers from a variety of majors. The findings identified four categories of course outcomes (acting differently, having a deeper sense of self, imagining new things, experiencing a deep shift toward a holistic view) and their associated connotations that are reflected in various processes of transformative learning, as shown in Table 1 and Figure 2. The implementation of the findings may be possible in the development and description of a model to facilitate both innovative and transformative learning in higher education and lifelong learning, where there is a need for pedagogical change towards the development of 21st Century skills.

Some shortcomings can be seen in the design of the virtual learning environment for social change, collaborative learning and critical reflection on tasks, which is the focus for future research.

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BIOGRAPHY

Stanislav Avsec received a BSc degree in mechanical engineering, an MSc degree in economics and a PhD degree in technology education, all from the University of Ljubljana (UL), Slovenia. He works as an associate professor of teaching and learning strategies in technology and engineering education in the Faculty of Education at the University of Ljubljana. He is the Head of Department of Physics and Technology Education and Head of the Committee for International Cooperation, all at the Faculty of Education, UL. He also works as a manager, researcher, teacher and trainer at several EU and nationally funded projects. He is an active researcher in technology and engineering education, educational technology, creativity and inventiveness, and in environmental science and management. He aims to expand his knowledge by conducting research work also in other academic institutions, e.g. Cracow University of Technology, Poland, since 2015; Reykjavik University, Iceland, since 2020. He is a member of editorial advisory boards and a reviewer for several journals in the area of technology and engineering education, cognitive science, educational technology, environmental management and engineering. In September 2019, he was elected Fellow of the World Institute for Engineering and Technology Education (WIETE).