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A high school bridging course to enhance readiness for architectural education

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ABSTRACT: Several technology and engineering universities are facing a threefold problem in a lack of students, underprepared freshmen and an increase in dropouts from study. This incurs additional costs to the education system, and can result in a lower quality of studies when instructors adjust teaching/learning methods. One way to reduce such negative consequences to education is a high school bridging course. For the purposes of the study outlined in this article, the Faculty of Architecture at Cracow University of Technology organised a course and provided interventions that helped high school students aspire to, prepare for, and achieve architectural education enrolment. Reported in this article is the effectiveness of the bridging course conducted in the study year 2017/18. Findings from this study suggest that an effective architectural education bridge course: a) improves students' self-efficacy; b) enhances students' aspirations and interest in technology and engineering studies; c) increases design ability needed for architectural education; d) enables innovative learning; and e) may improve university entrance levels and procedures.

INTRODUCTION

The education system today is much expanded and more than half of cohorts have been enrolled in higher education in innovation-driven economies [1]. More than before, universities compete for students in the marketplace, sometimes resulting in a decline in the quality of students' competencies, several dropouts from the first choice study and a swap in study discipline out of technology and engineering [2]. Modern information communication technology allows students to better access the broader world, to widen interactions in social networks and consequently, the 21st Century jobs are for young graduates with predominantly communication skills, creative and critical thinking skills and digital competencies. Thus, traditionally oriented design and engineering studies needs rethinking.

To enrol the best students in architectural education several innovative approaches have been proposed, which include an entrance examination based on various qualifiers [3]. If these procedures are omitted, it could result in more unprepared students being enrolled in the study and a decline of study quality may occur. Moreover, universities must define the competitive competencies that should be acquired by students [4]. Architectural education aims to increase building efficacy, to improve interaction between the natural and sociocultural environment and to predict the consequences of the decisions in different environments [5].

To overcome known problems, several good practices from other disciplines can be transferred to architectural education [6]. One approach to increasing students' readiness for university enrolment is a bridging course. Kallison and Stader provide evidence on how to prepare high school students for success at university [6]. Students in the bridging course are given not only content knowledge, but also appropriate academic behaviour, communication skills, inquiry skills, creative and critical thinking skills with the ability to make decisions [2][6].

To address acquiring the aforementioned skills, an interdisciplinary approach is suggested for modern architecture, when local and global factors may need to be taken into account [7]. Several researchers found design was a central activity in science, technology, engineering and mathematics education [2][8-10]. According to expectancy-value theory a student's learning objectives are tied to their self-efficacy and a task value [2]. The assumption is that students' self-efficacy can shape their design and innovation learning, thus consequently improving their readiness for the higher levels of study.

SELF-EFFICACY AND DESIGN THINKING

Several studies have revealed that self-efficacy in engineering is important, because individuals with low self-efficacy have lower levels of achievement and persistence in technology and engineering majors [2][10-12]. Bandura also identified self-efficacy dimensions, such as task selection, stability, focusing and ability to affect behaviour [12].

Design self-efficacy is highly dependent on experience [2][10]. According to Bandura, individuals can build their self-efficacy through experience [12]. Studies focused on undergraduate students have shown that students' academic self-efficacy predicts both academic achievement and persistence [13]. When students believe in their own efficacy to achieve tasks, they become motivated to act in ways that make their success more likely [12]. Students who believe in their own capabilities also tend to engage in their work for their own mastery and find their work useful and interesting [2].

Moreover, for design, graduates require sophisticated problem-finding and solving skills, critical thinking and quantitative reasoning skills [2][8][14], especially where they connect design to real-life situations [8]. The effectiveness of technology and engineering education might increase creativity [14], multiple learning and visualisation ability [9], especially in the increasingly complex world, where technology and engineering students need to learn innovation and complex problem-solving in sociotechnical contexts [2]. Innovation in functional design and embodiment design is less necessary, since industry requires mostly design improvements, with a focus on reducing costs and increasing the quality and variety of products, to meet changing market demands [8]. Further, the focus in innovation learning using different technologies should be on managing the technological world and students must be able to improve their lifeworld through exploratory production activities [15].

Based on the theory in the literature mentioned above, on self-efficacy and design thinking, the research questions that guided this study are:

1. What is the level of self-efficacy and attitudes towards technology in high school students?
2. How to measure the effects of the bridging course?

METHODS

Participating Institutions and Individuals

A bridging course was held in *V High School* in Kraków, Poland. For research design, two groups of students were organised: the experiment group, comprised of those who took part in the course; and the control group, the students who had not taken part in the course.

Students were from the Grow Students' Scientific Club, under the supervision of instructors who are academic teachers at Cracow University of Technology. Course participants were high school architectural class students under the supervision of a high school teacher.

Student populations of the participating schools were of similar size. Of the 27 high school students enrolled in the study, 14 took a course (13 females, 1 male) while 13 students did not take the course (8 females, 5 males). Females outnumbered males by 77.8% to 22.2%. They were aged between 16 and 18.

Description of a Pre-preliminary Design Course for High School Students

The bridging course was organised by the Grow Students' Scientific Club operating as a part of the Institute of Urban Design of the Faculty of Architecture of the Cracow University of Technology. The course has been carried out since the 2015/2016 academic year.

The goals of the course include:

- stimulating spatial imagination and sensitivity in students;
- making students aware of the value of the urbanised landscape;
- instilling respect for the environment and the general surroundings;
- instilling a sense of participation in creating surrounding space;
- shaping architectural and urban awareness;
- making students aware of the significance of shaping space in an aesthetic manner that meets users' needs;
- promoting the idea of caring for spatial order;
- familiarising students with the principles of structural analysis;
- presenting the capabilities of modelling using spatial elements and light;
- developing students' creativity;
- perfecting their manual precision;
- preparing them for work as a team;
- introduction to architectural and urban design;
- developing skills in operating ArchiCAD software.

The course takes place between October and June of a given school year. For the purpose of this study, data were collected for the study year, 2017/18. Meetings take place once a month. High school students in the bridging course were engaged in a sequence of architectural design challenges. The subject of the course is the design of a spatial form that is an answer to the following assignments:

- The logo of my school.
- The logo of a faculty of architecture.
- A student's initials.
- A simple seat.

Design challenges were organised in two stages as:

- Stage I: conceptual proposal in the form of manual drawings.
- Stage II: preparing a presentation sheet in ArchiCAD (top view, two side views, spatial drawing).

Students were allotted 2 to 3 hours per month, in total 20 hours over a seven-month period. Students' Projects were entered into a competition presided over by a jury comprising students and teachers. The student projects were assessed against the assessment criteria below:

- Answering the given assignment subject.
- Concept - an original, synthetic idea.
- Proper drawing preparation.
- Presentation sheet aesthetic.
- The best projects would be given an award.

Quantitative Analysis and Instruments

For a small sample size, the use of highly sensitive instruments was proposed [2]. Students' achievements in design, their attitudes towards technology, and self-efficacy were measured through a set of tests and surveys.

To assess creativity specific to design, a modified test for creative engineering design assessment (CEDA) was used for pre- and post-testing [16]. The instrument consists of three design problems, each with five parts to assess an individual's ability to formulate and express design ideas through sketching, descriptions, identifying materials, identifying problems that the design solves and its potential users. Participants were to generate up to two designs per problem. Total time for this assessment was 30 minutes for three problems or about 10 minutes per problem. Measured dimensions of the assessment tool included both problem-solving and problem-finding abilities. Problem-solving is the ability to derive a solution to a problem or situation. Problem-finding is a skill often found in art, yet is also necessary in science, technology and engineering. Problem-finding is the ability to identify problems or be able to foresee potential problems that may occur, but have not yet occurred.

As well as the above abilities, the instrument also assessed constraint satisfaction, where students use shapes and materials within the parameters or constraints of a design. Moreover, both convergent and divergent thinking was measured by this instrument. Problem-finding, problem-solving, constraint satisfaction, divergent and convergent thinking are relevant to an engineer's creativity. Students were evaluated by:

- Fluency: number of ideas; number of responses (0-100).
- Flexibility: number of response categories defined as the variety of responses or number of category types (0-100).
- Originality: qualitative number assigned to each design and to the entire problem (0-10).
- Usefulness: qualitative number assigned to each design and to the entire problem (0-4) [16].

For surveying this group of students' attitudes towards technology, a 25-item test was used [17]. The survey entitled *Technology and me* consisted of six categories of attitude, measured on a 5-point Likert scale:

- technological career aspirations (TCA) - 4 items;
- interest in technology (IT) - 6 items;
- tediousness of technology (TT) - 4 items;
- technology and sex - differences (TS) - 3 items;
- effects of technology (CT) - 4 items;
- difficulty of technology (DT) - 4 items.

The scale goes from 1 (very unlikely) to 5 (very likely).

The self-efficacy items were developed and evaluated to reflect the multifaceted nature of self-efficacy in design. The authors' goal was to create self-efficacy items that represented beliefs about design and technology, and that would relate to students in most technological and engineering disciplines. The developed instrument was based on a questionnaire by Gaumer Erickson et al [18], using a 5-point Likert scale (1 - not very like me to 5 - very like me) comprised of 21 items; the sub-dimensions are:

- showing stability - being flexible (SS-BF) - 8 items;

- feeling itself efficient (FIE) - 8 items;
- making an effort (ME) - 5 items.

Procedure and Data Analysis

During a real-world class, students were invited to complete two surveys and a test. A total allotted time for administering the survey was 35 minutes. A pre-test of CEDA and the *Technology and me* survey were conducted in October 2017 while a post-test of CEDA and *Self-efficacy* survey were conducted in June 2018, when workshops ended. A high response rate was obtained because of the direct presence of teachers or instructors and the way the survey was administered.

Descriptive analyses were conducted using SPSS software. Both ANOVA and MANOVA analyses were conducted to determine significant relationships between groups with an effect size calculated using eta squared - η^2.

RESULTS AND DISCUSSION

Cronbach's alpha coefficient values, based on the sample of this study, indicated that the instruments are moderate to highly reliable (Table 1).

Table 1: Cronbach's α on *CEDA*, *Self-efficacy* survey and *Technology and me* survey subscales.

Test	CEDA		Self-efficacy			Technology and me					
Subscale	Pre-test	Post-test	SS-BF	FIE	ME	TCA	IT	TT	TS	CT	DT
Cronbach's α	0.91	0.93	0.76	0.74	0.84	0.96	0.77	0.92	0.90	0.74	0.73

Descriptive and variance analysis

The null hypothesis was tested that the observed covariance matrices of the dependent variables are equal across groups. Levene's test suggests the use of parametric statistics ($p > 0.05$). Error variance of the dependent variable is equal across the groups. Figure 1 shows the students' average values on *Self-efficacy* with a mid-point of 3. Students had perceived values of self-efficacy above the mid-point; only experimental group students perceived their proactivity as under average. The test of between-subjects effects revealed significant differences only in a subscale of Showing stability-Being flexible ($p = 0.023$; $\eta^2 = 0.19$). It seems that control group students show a higher ability to take action. Thus, they can solve complex problems when encountered. In contrast, individuals with lower self-efficacy would avoid tasks, and are less able to resist the difficulties they encounter.

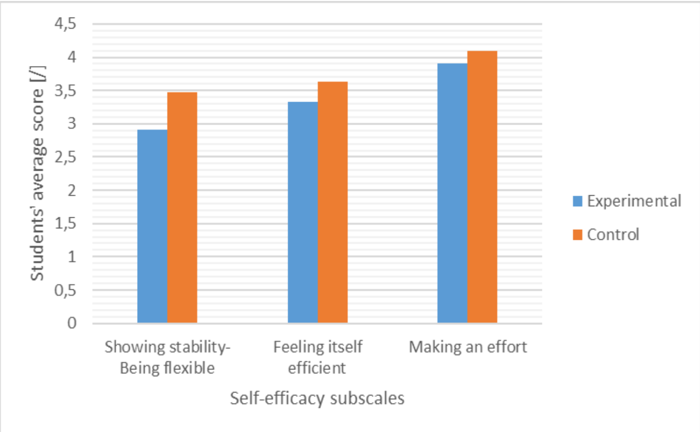

Figure 1: High school students' perceived self-efficacy across groups (mid-point of 3).

The poor attitudes towards technology by students in upper secondary school, where the technology and engineering subject matter is seldom in the curriculum, were expected and confirmed, as is shown in Figure 2. Technology and technological knowledge and skills are highly important for further school and education, especially in engineering studies. It was found that high school students do not have a high inclination for further study in engineering disciplines, being just about the average. Also, their interest in the technology and engineering subject matter is around the mid-point. However, such students are not resistant to technology in society, where they can see the engineering profession apply to both males and females. Students seem to have a high ability to analyse, to think logically and algorithmically, and they are above average in awareness of the consequences of technology. The technological literacy and technical competence acquired during the study was assessed at around average in terms of difficulty. Students in both groups have very similar preferences and attitudes towards technology, and no significant differences were found ($p > 0.05$).

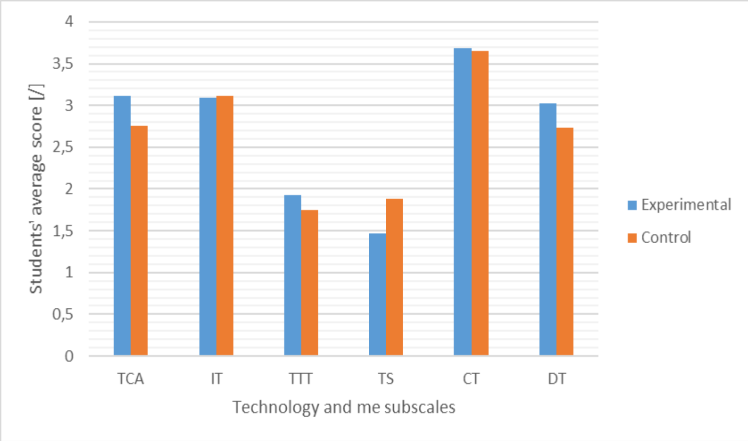

Figure 2: High school students' perceived attitude towards technology across groups (mid-point of 3).

To find within (effect over time) and between (group of students) subject effects a two-way ANOVA with repeated measures was used. The experimental group pre-test mean was M = 74.92 (SD = 32.11), while post-test results were higher, with M = 107.42 (SD = 31.32). The control group scored higher on pre-test M = 87.15 (SD = 39.49), while the post-test was M = 98.52 (SD = 37.17). Moreover, calculating the difference, delta (Δ), between pre- and post-test mean scores, and using the design score gain (Δ) as a dependent variable, ANOVA revealed the experimental group score gain in the course was M_{Δ} = 32.50 (SD = 28.12), while the control group score gain was M_{Δ} = 11.31 (SD = 20.39). The effect of teaching/learning methods on design ability was found to be significant (p = 0.043) with a strong effect size (η^2 = 0.16). The effect of the use of approaches to teaching of architectural content for high school students is shown in Figure 3.

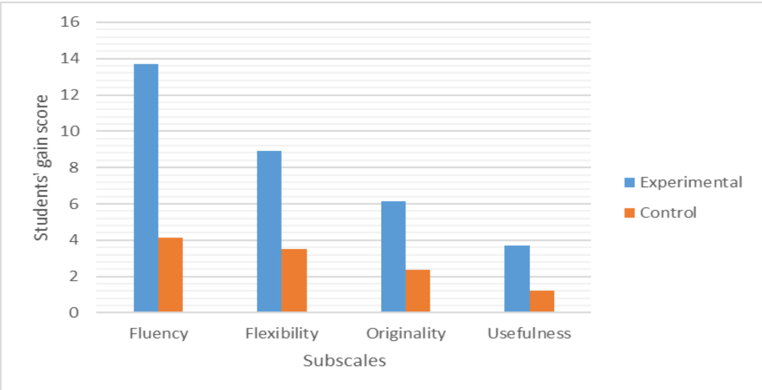

Figure 3: High school students' design gain (Δ) on CEDA subscales for experimental and control groups.

A bridging course brought significant gains, especially in fluency and flexibility of ideas, as well as resource identification. These skills revealed that students proactively took responsibility for their own learning.

Methods used to teach the course seem to have motivating elements where triggered and maintained interest for design activities. Moreover, students of the experimental group had lower proactivity regarding this subscale, *Showing stability-Being flexible*, but an excellent didactical design of the course mobilised them in learning and in creative work. Further, a predictive value of self-efficacy was found on design and innovation learning with a strong beta = 0.59, p = 0.008. Course methods and activities enhance students' flexibility in design thinking and may boost motivation. Moreover, a real-world experience with design can help students to be prepared for future challenges and consequently may be helpful for a future career choice in design and engineering.

CONCLUSIONS

A bridging course for architecture fulfilled expectations. For the first time, the authors succeeded in measuring the course effects through a creative design assessment tool. The learning effects of the architectural design workshops were demonstrated as strong. However, given a small sample size, the results might be non-representational, and thus should be treated with caution.

Instruments applied to this study were highly sensitive and reliable, and, despite the small sample size, the authors were able to calculate the effects and found important predictors in design thinking. The self-efficacy factor of *Showing stability-Being flexible* predicts students' achievement in design tasks, while students' attitudes toward technology are not decisive in predicting success in design activity.

Moreover, perceived feelings about efficacy and that hard work pays off were not found to be predictors of successful design thinking. Such experiences and perceptions need time to be acquired and stabilised within a cognitive structure, and the authors had limited time to run workshops.

Qualitative observations showed that peer support was a highly important factor in bridging participants. Undergraduate students, who served as peer advisors and tutors, created a learning community, where team learning was established and social skills were acquired to improve problem-finding and decision-making ability [19].

Course designers were excellent in shaping the bridging course, where variations of design task were included to transfer team learning through divergences in conceptual models. Some enrichment activities; for example, a guest speaker from the community, a trip to university and a trip to business, were well received by high school students. With several humorous inserts in the course design, mutual trust between students and teachers can be increased and social inclusion in collaborative learning might be facilitated [20]. The foregoing also may enhance higher order skills, such as critical thinking, to cope with constantly changing building practices [21]. Further studies will be focused on the long-term effects of a bridging course and evaluation of the follow-up activities.

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