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Pre-Service Teachers' Attitudes Towards Technology, Engagement in Active Learning, and Creativity as Predictors of Ability to Innovate*

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Teacher's subject matter knowledge, pedagogical content knowledge, skills, attitudes and self-efficacy guide teacher's behaviour in the classroom. Little is understood how pre-service teachers' beliefs, affective and conative abilities along with creative potential support their technological and engineering behaviour necessary for inventiveness. The purpose of this study was to examine relationships among pre-service teachers' attitudes towards technology, perceptions and experiences with their own engagement in technology and engineering activities, and their creative potential that have been shown to support their innovative behaviour. A total of 124 pre-service teachers participated in this study. The Twenty-five-Item Technology and Me survey, the Test of Creative Thinking-Divergent Production, and the Twenty-three-Item Action and Me survey were used to measure the teachers' attitudes towards technology, creative potential, and their situational interest, perceived course learning value, satisfaction, and technological and engineering behaviour. A conceptual model was hypothesized, tested, and supported by the results using confirmatory factor analysis with structural equation modelling. Findings indicate that pre-service teachers who had higher scores on interest for technology had higher situational interest, higher creative performance, and higher ability to innovate. Students who had higher scores on perceived consequences of technology had less creative performance while students who had higher scores on perceived technology difficulty had lower scores on perceived learning value of the course and lower scores on course design quality. Pre-service teachers own creativity, perceived course design, situational interest, and perceived learning value mediate the relationship between attitudes towards technology and perceived ability to innovate. Our results offer important implications about how to prepare pre-service technology and engineering teachers for innovative performance towards enhancing technological knowledge and skills.

Keywords: technology and engineering education; pre-service teachers; attitudes towards technology; creative potential; ability to innovate

1. Introduction

Technology and engineering (TE) education as part of pre-university education is a growing academic discipline; it emanates from the need to find more competitive ways to educate future technicians and engineers to meet the challenges of a rapidly developing technological world [1]. However, even in the primary and secondary school period, it is necessary to promote TE as an essential element in effective pre-university education. More than ever, there is a great need for highly competent professionals to teach the curriculum and provide instruction that is aligned with appropriate developmental practice and that can optimally shape students' outcomes [2]. TE literacy in primary and secondary education appears to cultivate a positive identity, which promotes long-term interest and development of TE tasks [1, 3].

Despite its importance in developing higher-level reasoning and communication skills, TE constitutes a domain where creativity is often untaught and untested neither in pre-university and university engineering education [4]. Engineering itself is alive with questions about the role and teaching of creativity in the making practical and necessary things [5] but still majority of TE activities during schooling are rather algorithm-based activities, using mono-disciplinary knowledge applying several rules and explicit procedures to reach design-based learning outcomes. TE activities are aimed specifically at addressing learners' abilities to apply domain knowledge. Instead of this, a need for scholastic activities arise which require the use of multidisciplinary knowledge [4]. Despite many approaches for teaching pre-service teachers to be innovative, many still believe that TE education does not adequately prepare students for the real-life problems in the professional world, due to education system's in-the-box thinking which may not be reflective of the real world [4–6].

Studies of technology education have found that hands-on manipulation and TE activities enhanced

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students' competences only when the students had incorrect prior knowledge [2, 6]. Moreover, several researchers [1, 6, 7] identified a lack of primary and secondary school teachers' knowledge of TE and a lack of understanding of engineers' work and their behaviour. Knowledge of the subject matter of TE is an important prerequisite for both pedagogical content knowledge and self-efficacy; those in turn have a strong influence on teachers' attitudes towards technology [6].

With respect to attitudes towards technology (ATT), it has been suggested that there should be strong emphasis in teacher-training course design on both subject matter knowledge and pedagogical content knowledge; that would positively affect the teachers' confidence in teaching in this area and thus their ATT [6]. Primary and secondary school teachers' professional development should also focus on their ability to understand the educational environment and reflect on contemporary technological changes [7]. Technological and engineering behaviour on the part of teachers affects students' persistence with different technical and engineering tasks as well as triggering and maintaining the students' interest during such activities; the result is that student show higher cognitive gains. Research has determined the following relationships with teachers' attitudes: the teachers' own behaviour in the classroom [6]; their potential creative development [8, 9]; and teaching practices [10]. Studies have also identified links between teachers' beliefs, perceptions and experiences and their teaching practices [2, 8].

The present study was designed to examine the relationships among pre-service teachers' attitudes, their engagement in creative TE activities, and perceived TE behaviour. Hitherto, very little research has examined the effects of ATT on creativity in which multiple constraints are applied and mediators are included to predict TE behaviour.

2. Literature review and definitions

2.1 *Teachers' attitudes towards technology*

Attitude indicates a learned predisposition or tendency to respond favourably or unfavourably to a given object, person, idea, or situation [11]. Hence, teachers' ATT is affected by their concept of technology, feelings about technology [6], and experiences with it [12]. Teachers' ATT includes cognitive aspects (held beliefs and opinions), affective aspects (liking technology or enjoying the use of technology; [6], and behavioural aspects (anxiety or self-confidence in using technology and positive or negative responses to stimuli; [11]. Such factors as beliefs, feelings, opinions, inclination to action and prior knowledge (whether incorrect or correct) directly affect the impact that technology training will have on teachers' perceived learning value [12], their situational interest [10], perceived cognitive load [13, 14], and creative performance [8, 14, 15]. Six dimensions of ATT were defined: (1) technological career aspirations; (2) interest in technology; (3) tediousness towards technology; (4) technology as a subject for both genders; (5) consequences of technology; and (6) technology difficulty. All these dimensions support the multidimensionality of attitudes [16].

2.2 *Situational interest*

Teachers' situational interest emerges as an affective response to certain situations, conditions, or stimuli in the learning environment during an assigned task [10]. Situational interest can increase when learners perceive knowledge gaps [17] and when students work with real rather than abstract content [18]. Correspondingly, students working in more concrete task conditions performed better than in abstract conditions—especially when a learning environment was highly organized, structured, and peer- and other-scaffold learning was enabled [18]. Moreover, students perceive a low cognitive load when situational interest is higher perceived–especially when the teacher understands the students' level of interest and manages it in the course of a lesson [19]. Situational interest may affect both students' perceived learning value and their behavioural intention, which leads to positive emotions and interest awareness [20, 21]. An intrinsic motivation significantly improves student imaginative capabilities at TE subject matter [22]. A study by [19] revealed that situational interest influences conceptual change using several discrepant events to arouse curiosity and sustain learning, whereby the perception of learning value and knowledge develops simultaneously [21]. However, using discrepant events is insufficient for abandoning previous beliefs and accepting alternatives.

2.3 *Perceived course design quality*

Course design seems to play a crucial role in perceived learning value, motivation, and behaviour for innovative performance [3, 12, 18, 23]. That is especially true in the case of technology education in which hands-on activities are needed to increase student confidence and develop the ability to recognize the added value of high-quality TE education [6]. When designing a learning environment, task structure should be considered—especially for students with a high need for structure. Moreover, task structure can both stimulate and inhibit creative performance [24]. Nevertheless, the course designer should attempt to create a learning environment that promotes the students' intention to learn and control efforts during conceptual change [23, 25] as well as facilitate the development of creativity and progress in education [26]. For successful learning outcomes, it is recommended that subject content should be developed towards learner-centred exploratory production using cases from the learners' own life-world—rather than adopting a domain-specific approach [12]; technology should be taught only for everyday life purposes.

2.4 Perceived learning value

Design-based learning may appear to pose problems because students may generate incorrect solutions. An incorrect solution may be viewed as a productive failure [27]. TE activities can be effective even when not optimally performed [28]. Design-based work in TE laboratory exercises can affect motivational states [6, 28]. Experiencing learner-centred learning and peer- and other scaffold learning is predictive of effective TE behaviour [12]: declarative, procedural, and meta-cognitive technological knowledge was enriched, and engineering skills were enhanced. Meta-cognitive self-regulation markedly affects student satisfaction; student self-efficacy predicts learning outcomes—especially those at higher cognitive levels [3, 17, 29]. Moreover, scaffolded learning and practice could improve pre-service teachers' self-efficacy [3, 6, 7]. It would appear that self-efficacy is a key to enhance learning.

2.5 Creativity

Creativity seems to be crucial to inventive behaviour [9], where openness to experience can predict creative performance [8]. Further, a lack of opportunity and encouragement to raise creative potential is associated with a less creative achievement [8]. Low motivation [21], a prevailing algorithmic structure of technology education activities, and lack of developed heuristics [26, 30, 31] combined with multiple constraints can douse creativity. Nevertheless, a study by [15] revealed that persistence is a critical determinant of creative performance; persistence combined with well-processed tasks supports higher course satisfaction and improves belief [8] and interest in technology [9]. It was found by [30] that well-organized, less open-ended and controlled projects resulted in less student creativity: the students' limited conceptual technological knowledge decreased their creative ability. Potential constraints to creativity development were identified by [26] with traditional teaching, a stringent focus on learning outcomes defined by the curriculum, and teacher-directed work tasks with already prepared technical sets or incompletely finished materials.

2.6 Technological and engineering behaviour

Today's teachers need to be creative to enhance inventiveness in the field of TE [9] and in their personal development [7]. TE behaviour can be seen as an individual's behaviour that is enhanced by confidence, self-regulation, and a positive mindset contributes to the quality of design, processes, technological knowledge enrichment [9, 13], and self-efficacy [6]. Today, an internally driven TE behaviour is necessary on the part of students in TE education [6, 12, 30]. TE behaviour is self-initiated, future-focused, and involves taking the initiative to effect change [32]. In the subject matter of TE, students encounter various problems and constraints. Students' ability to innovate can be seen as their potential for divergent and convergent thinking, constraint satisfaction, problem finding and problem solving ability [9] where the inventive TE behaviour is focused on the conceptual designing processes whereby creative designs are developed.

The present study examined the general dynamics of TE behaviour and how it fits the needs and goals of technological subject matter in hands-on work and practical creativity as the ability to discover solutions that will solve TE problems [9]. In order to be creative in TE activity, solving problems is vital; however, determining when there is a problem to solve may be even more important. Students with TE behaviour will be able to observe basic dimensions, design constraints, embodiments, processes, consequences, and prior design failures. Thereafter, such developed behaviour together with cognition and meta-cognition will support the meaningful learning, decision making, and critical thinking needed for engineering design [9], [25, 26, 31]. Proactive TE behaviour is largely enhanced by situational interest, performance approach, and creative self-efficacy [29]; it increases the ability to resolve ill-defined problems, adapt solution-focusing strategies, employ adductive thinking, and use of spatial modelling media [25]. Moreover, innovative teachers' behaviour is supported by well-designed TE activities, which enable collaborative learning and group cohesiveness [7]. Through a practical, interactive and experiential process in TE education it is possible to convey attitudes, creative potential, skills, and ways of implementation of each of the approaches considered to students, and at the same time introduce TE behaviour-shaping strategies into the teaching-learning process [9, 32].

2.7 Proposed model

The complex model to be tested appears in Fig. 1. We tested 12 hypotheses *(H1–12)*. First, we

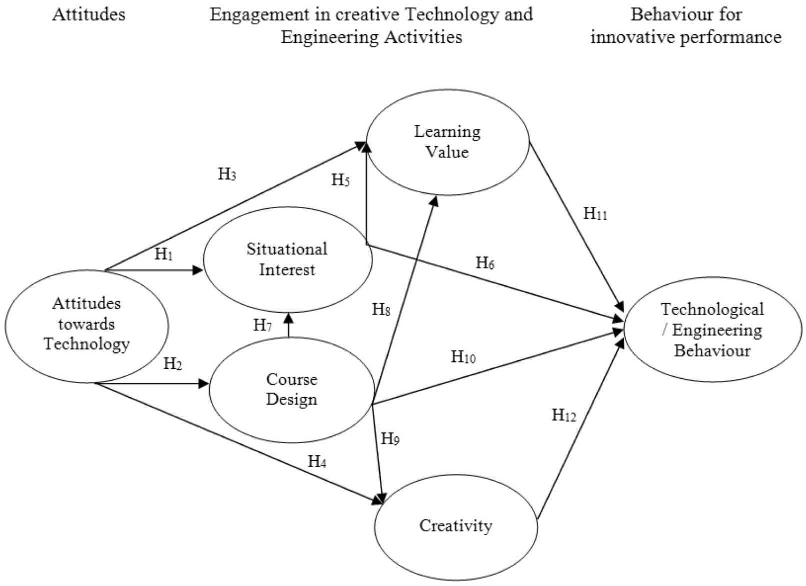

Fig. 1. Conceptual model of the study.

hypothesized that some components (sub-factors) of pre-service teachers' ATT would be significantly and positively related to their (*H1*) perceived situational interest, (*H2*) perceived satisfaction with course design, (*H3*) perceived learning and training value, and (*H4*) creativity.

Next, we hypothesized that situational interest of pre-service teachers engaged in a TE course would be significantly and positively related to their (*H5*) perceived learning value and (*H6*) perceived TE behaviour. We also hypothesized that pre-service teachers' satisfaction with TE course design would be significantly and positively related to their (*H7*) situational interest, (*H8*) perceived learning or training value, (*H9*) creativity, and (*H10*) TE behaviour. Finally, we hypothesized that pre-service teachers' engagement in a TE course would mediate the relationship among some components of the pre-service teachers' ATT, where their (*H11*) perceived learning or training value and (*H12*) creativity would be significantly and positively related to their TE behaviour for the innovative performance.

3. Methods

3.1 Creative TE course format and research design

In the academic year 2015–2016, a subject matter called *Creative technical workshops* was introduced for the first time in Faculty of Education, University of Ljubljana. The subject aims to improve creative ability in pre-service teachers who will teach technology and engineering subject matter in primary and/or secondary school. Moreover, the content of *Creative Technical Workshops* subject matter is focused on [31]: to get in-depth knowledge about materials, tools, devices and machines. The use of working procedures that can teacher use in the manufacturing of means/assets, different projects in the field of design, technology and engineering (multifunctional toys, games, learning aids, functional artefacts, . . .) for educational work in primary and secondary school. Evaluation of products created as a design-based work in primary or secondary school. The subject appears as general optional subject and might be taken by all students in the faculty. Allotted time for pedagogical forms is 30 hours of interactive lectures plus 30 hours for laboratory work. During the lectures, a creativity course defined by [33] was conducted followed by hands-on laboratory work where students first learn technical concepts, afterward master their technical and engineering skills by product improvement tasks. To sustain motivation, a reverse engineering method is applied along design-based work. A final panel reflection was done where students proposed product and/or process improvements to extend their learning.

3.2 Participants and procedure

In all, 124 pre-service teachers participated in this study from Faculty of Education at the University of Ljubljana. Faculty of Education educates and trains teachers and other professional workers in the field of education. It trains all kinds of professionals, from primary school teachers to educators who specialize in teaching two subjects or subject areas at primary school and in certain secondary schools. University of Ljubljana has a strong tradition in educating future teachers and present itself as national educational leader.

The participants were third—and fourth-year students, all undergraduates, and they had experience of working with pupils and students in elementary settings through teaching practice or internships. Among the participants, 48.4% were third-year students and 51.6% were fourth-year students. The participants' age ranged from 22 to 24 years; the great majority (82.2%) were women. Selected students passed a basic course about TE and undertook teaching practice, which was offered as a course in either their third or fourth year of study. We obtained an effective sample of 124 (out of 137) students from the University of Ljubljana. This study was conducted in the academic year of 2015–16 (59 students) and of 2016–17 (65 students).

3.3 Measures

3.3.1 Attitudes towards technology

To assess the pre-service teachers' ATT, we used a revised version of the 25-item test Pupils' Attitudes Toward Technology [34]. One of our questionnaires included 10 questions on demographics. The demographic questions covered sex, age, family background, and home education background. The instrument developed in the Slovene version, called Technology and Me, included six constructs: (1) technological career aspirations, four items; (2) interest in technology, six items; (3) tediousness towards technology, four items; (4) technology as a subject for both genders, three items; (5) consequences of technology, four items; and (6) technology difficulty, four items. In the assessment, we used a five-point phrase completion scale, as recommended by several researchers [13, 16, 35]. In the present study, we treated the scale questions as being equal-interval spacing. That approach enabled the investigation of nominal properties (whether responses were different), ordinal properties (which responses had the greater magnitude), and interval properties (distance between two responses). The intervals in the scale were continuous, from 1 (very unlikely) to 5 (very likely). This approach does not present means, but it ensures the comparability of continuous responses [35].

Cronbach's alpha estimates ranged from 0.80 to 0.91, indicating appropriate internal consistency [36]. A factor correlation matrix reveals very low values of correlations among the six factors, i.e. the correlations did not exceed 0.41 (the upper limit was 0.7). The factors were distinct and uncorrelated, which indicates high discriminant validity of those factors [37].

3.3.2 Creativity

The Test for Creative Thinking-Drawing Production (TCT-DP) has been used to measure pre-service teachers' creative potential [38]. The test has two forms (A and B), but we used only form A in the present study. However they wish, subjects complete drawings that are initially incomplete. They may draw whatever they like and how they like: all responses are permissible and correct. The assessment uses 14 criteria, as defined by [38]. The maximum score for the test is 72 points. A number of studies have confirmed the good reliability, and validity of the TCT-DP [31, 38].

We calculated the corrected Pearson correlation coefficient, r_{xy}; acceptable criterion validity was evident. All the inter-item (criteria) correlations were less than 0.7. All the test criteria were appropriately designed and each measured exactly what it had been designed to measure. Thus, we avoided overlapping test items. Also, Cronbach's alpha coefficient of the instrument based on the 14 assessment criteria was 0.89, indicating appropriate internal consistency of the instrument.

3.3.3 Engagement in creative TE activities

We used a self-developed questionnaire called Action and Me to collect information for the present study. The questionnaire items were designed based on previously developed theories and studies. The questionnaire included four constructs in the proposed research model: situational interest, perceived learning/training value of the course, satisfaction with course design (perceived cognitive load), and technological/engineering behaviour. For the assessment, we used a six-point phrase completion scale. The intervals of the scale were continuous, from 0 (very unlikely) to 5 (very likely).

Situational interest. We based the measure of situational interest on the definition proposed by [10] [20]. Situational interest emerges in response to features in the environment. Situational interest consists of both an attentional and affective reaction to the situation and can be differentiated into two forms: triggered and maintained situational interest. Triggered interest involves heightening the affective experiences with the environment; we designed four items to identify the perception of interest at the beginning of the TE course. Conversely, maintained interest enhances students' meaningful connections with the material content, and it attains a deeper significance [10, 20, 21]. We designed four items to identify the perception of interest in the TE course. This dimension thus had a total of eight items.

Perceived learning/training value. In a complex task, mental processes include the integration of multiple pieces of information to discern the best course of action and imagination of alternative actions [17]. It was found [39] that when engaging in science and technology activities, students' thinking capacity can be enriched and knowledge expanded. Researchers [3, 6, 39] determined that perceived learning value is a significant predictor of the quality of an intensive course in technology. Cognitive course outcomes can be described as different facets of competences, e.g., theoretical and methodological knowledge, skills required for problem solving, social competences, and technological competences [12]. In accordance with the above findings, we designed four questioner's items in the present study to test the perceived learning value of the pre-service teachers.

Satisfaction with course design. Perceived satisfaction with the learning environment and organizing work so as to allow peer- and other scaffold learning may reduce the perceived cognitive load and increase innovative performance [7, 12, 13]. A high level of satisfaction leads to lower attrition rates, higher persistence in learning, and higher motivation in pursuing additional TE courses [3, 15, 18]. Structured tasks in TE courses could reduce the cognitive load and enhance creativity [24]. In accordance with the above findings, we designed six items for this dimension.

Technological/engineering behaviour. Behaviour for innovative performance occurs when individuals, driven by internal motivators, actively search for problems to solve and create new theories, technologies, or ideas [32]. This often leads to finding an improvement in a process or product to improve efficiency. Based on the results of some recent studies [29], we designed a categorization of proactive actions: (1) to prevent a situation getting out of control; (2) to determine the quantity, scope, and impact of error consequences; (3) to find a temporal solution and keep a situation under control; and (4) to find a permanent solution to a particular problem. In line with that categorization, we designed five question items for the construct of innovative work behaviour in the TE course design.

Cronbach's alpha estimates ranged from 0.88 to 0.97, indicating appropriate internal consistency. All the Cronbach's alpha values were >0.60, which presents an acceptable level of reliability [36]. The factor correlation matrix reveals very low values of correlations among the six factors, i.e. the correlations did not exceed 0.39 (the upper limit was 0.7). The factors were distinct and uncorrelated, which indicates high discriminant validity of those factors [37]. In addition, we calculated the factor loadings using Oblimin rotation, where the pattern matrix revealed that all the survey items had significant loadings greater than the threshold of 0.5 (0.7). The final PCA of the four-factor solution with 23 items accounted for 73.4% of the total variance. This provided evidence for high validity; thus, the high concurrent and predictive validity of the results was verified [36].

4. Results

4.1 Pre-service teachers' background

For this study, we collected some demographic variables of the pre-service teachers. Those variables served as a measure of the pre-test as co-variables. We obtained some interesting results in this area. Parental involvement in a technological or engineering occupation was rated above the mid-point of 3: the average for the father was 3.52, and for the mother 2.85. Among the pre-service teachers, 65.6% had various technical sets or toys at home, e.g., Lego, Fischertechnik; 53.25% had a technical workshop or room at home. Only 21.43% of the participants used computers for higher-order cognitive tasks, such as advanced information-communication technology use.

4.2 Pre-service teachers' ATT

The pre-service teachers' descriptive statistics for all six sub-scales of ATT in university education appear in Fig. 2. Some participants still had aspira-

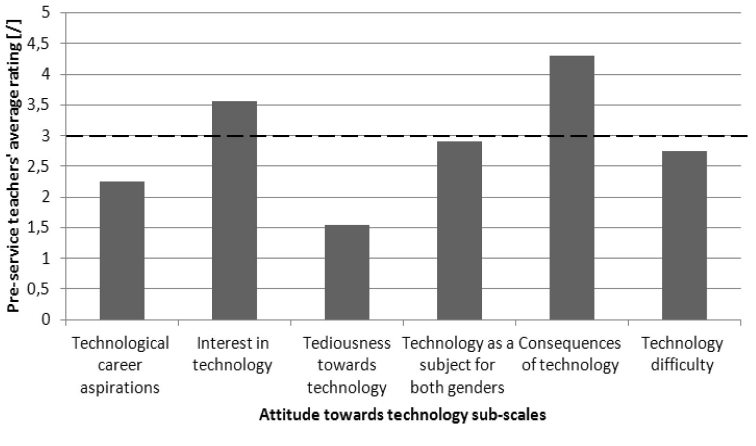

Fig. 2. Pre-service teachers' attitude towards technology with a mid-point of 3 (dashed line).

tions for technical or engineering occupations even though they had already chosen a career in technology and engineering teaching. The perceived interest for technology was above average on the scale, which had a midpoint of 3 (mean [M] = 3.51, standard deviation [SD] = 0.80). Pre-service teachers who had already undertaken some technical or industrial arts education were more interested in technology than those who had not. Regression analysis also revealed that students with some technical workshop or place were more interested in technology ($\beta = 0.22$, $t = 2.490$, $P = 0.014$) as well as those who had aspirations to work in TE ($\beta = 0.26$, $t = 3.108$, $P = 0.002$). Regression analysis for tediousness towards technology, beliefs about gender differences, and perceived consequences of technology regressed on the students' demographic covariates revealed no statistical significance ($P > 0.05$). Regression analysis for perceived technology difficulty on the students' demographics showed significant differences regarding possession of technical sets or toys ($\beta = -0.23$, $t = -2.896$, $P = 0.004$), perceived intention for jobs in TE ($\beta = -0.16$, $t = -1.986$, $P = 0.049$), and experience with technical or industrial art education ($\beta = 0.22$, $t = 2.836$, $P = 0.005$).

4.3 Pre-service teachers' creativity

We measured creativity using the TCT-DP test, which has a maximum possible score of 72 points. The participants scored an average of $M = 40.25$ (SD = 11.05) points. The minimum recorded score was 11 points, the maximum 64 points. Regression analysis for creativity regressed on the students' demographics revealed that students whose father had a technology or engineering occupation had significantly less creative potential ($\beta = -0.16$, $t = -1.986$, $P = 0.049$) than those where parents did do not have such employment. Conversely, students with a workshop or technical room at home showed significantly higher creative potential ($\beta = 0.17$, $t = 1.996$, $P = 0.047$) than those without such facilities. Pre-service teachers with experience in technology or industrial arts education scored significantly higher in the creativity test ($\beta = 0.30$, $t = 3.50$, $P = 0.001$) than with only general education.

4.4 Pre-service teachers' engagement in TE activities

The pre-service teachers' descriptive statistics on their situational interest, perceived learning value, perceived satisfaction with course design, and proactive TE behaviour appear in Fig. 3.

Pre-service teacher engagement in TE activities could also be affected by demographic factors. We used linear regression to assess the predictive effect of demographics on situational interest, perceived learning value, perceived satisfaction with course design, and perceived engineering behaviour of the participants. First, we found no statistically significant ($P > 0.05$) influence of the students' demographics on their situational interest. Second, a significant impact was evident of the students' experience with technology and industrial arts education on perceived learning value ($\beta = -0.22$, $t = -2.55$, $P = 0.012$). Third, we observed no significant differences ($P > 0.05$) of the students' demographics on course design satisfaction. Finally, participants who used computers for advanced tasks, e.g., 3-D modelling, technical drawing, and programming, displayed higher-level TE behaviour ($\beta = 0.17$, $t = 2.01$, $P = 0.048$).

4.5 Path model

A path model can show student performance variables (creativity) and variables describing the students' attitudes, perceptions, experiences, and satisfaction. Structural equation modelling has evolved into a mature, popular methodology for investigating model-derived structural hypotheses

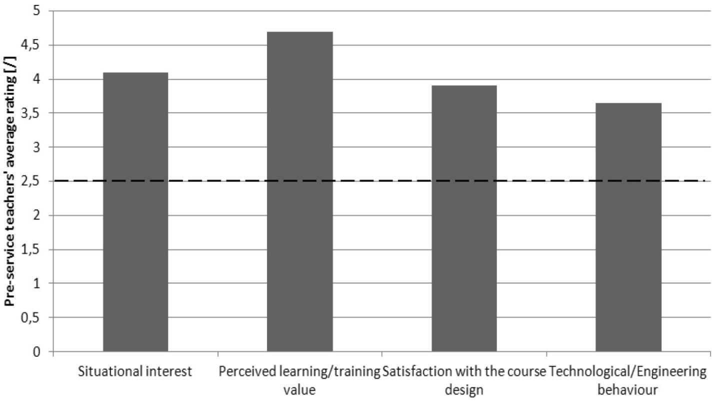

Fig. 3. Pre-service teachers perceived and experienced engagement in creative TE activities with a mid-point of 2.5 (dashed line).

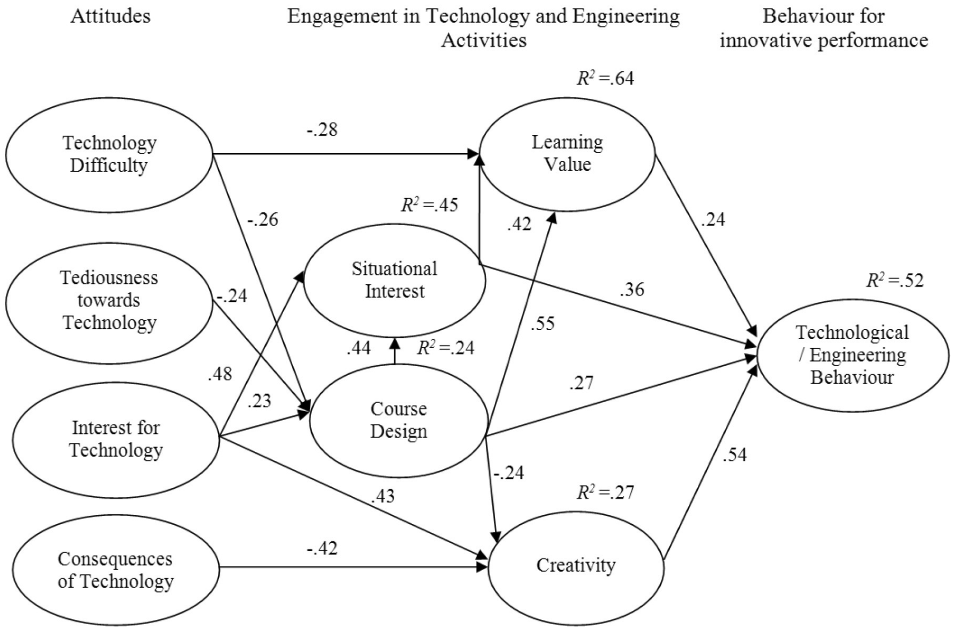

Fig. 4. Path model of creative technology and engineering activity factors with significant ($P < 0.001$) standardized path coefficients (n=124).

[40]. We conducted model fit tests using AMOS IBM software (version 20; Meadville, PA, USA). A path model of TE activity factors with statistically significant ($P < 0.05$) standardized path coefficients is presented in Fig. 4.

Exogenous entries in the model were components of ATT; endogenous variables were perceived situational interest, course learning value and design, creativity, and perceived technological or engineering behaviour. We hypothesized that components of ATT as exogenous variable effects would be significantly correlated with both positive and negative outcomes. We hypothesized that situational interest, perceived course design, learning value, and creativity would have mediating effects on TE behaviour.

Figure 4 also illustrates the path model. TE activity perceptions, experiences, satisfaction, and creative potential were influenced by variables with significant standardized path coefficients ($P < 0.05$). According to commonly used fit indices [40], we found a good fit of proposed model. We observed a nonsignificant P value (0.75) in the chi-square test (11.03); the chi square divided by its degrees of freedom was smaller than 5 (0.73). The GFI, CFI, and TLI values were greater than 0.95 (0.97, 0.98, and 0.99, respectively); the RMSEA and root mean square residual were smaller than 0.05 (0.00 and 0.04, respectively). The PCLOSE was greater than 0.05 (0.93). The probability level of the test of close fit was also higher than a proposed threshold level of 0.50 for a good model fit [40]. These results indicated that the robust initial model did not require need any improvement. All the paths in the model showed significant effects.

The significant path coefficients varied from medium (0.24) to strong (0.55), and we considered the absolute rate. In all, 44.6% of the variance in perceived situational interest was explained by influencing variables. The most influential variable was interest in technology. With regard to the participants' satisfaction with course design, 23.78% of the variance was explained by technology difficulty, interest in technology, and tediousness towards technology. Variables that correlated with course design satisfaction did not have a uniform effect. Technology difficulty and tediousness towards technology showed a negative correlation; interest for technology was positive. The absolute degree of the variable effect was similar. The high variance (63.9%) in perceived learning value was explained by perceived course design quality and situational interest; technology difficulty was negatively correlated with perceived learning value. The 26.7% variance in creativity was explained by interest in technology (strongest positive predictor), consequences of technology (strongest negative predictor), and course design quality. The 51.8% variance in TE behaviour was explained by creativity as a heavy component in proactive behaviour, situational interest, perceived learning value, and course design quality. All the influencers had a positive effect.

Five path coefficients had negative estimates. There was a negative path coefficient for the consequences of technology on creativity: creative students are mostly non-conformists, and as such they are not so sensitive to consequences of technology. Thus, clearly organized, attractive content with feedback mechanisms and a well-designed learning process can douse creativity. If students consider technology dull, boring, tedious, or nerve-wracking, their perceived quality of the course design will decrease. Students who regard technology as difficult may also be frustrated with the learning environment; they probably also have low self-esteem, which leads to perceived low achievement. We calculated the explained variances using R^2 from the path model, where $R^2 = 0.02$ signifies a small impact, $R^2 = 0.13$ a medium effect size, and $R^2 = 0.26$ a large effect size [37].

5. Discussion

This study examined the following: (1) the relationship between pre-service teachers' ATT and their perceptions and experiences of TE behaviour; (2) the relationship between pre-service teachers' engagement in TE activities and their perceptions and experiences of TE behaviour; and (3) the role of pre-service teachers' engagement in TE activities as a mediating variable among their attitudes, perceptions, experiences of TE behaviour.

We found that four sub-factors (technology difficulty, tediousness towards technology, interest in technology, and consequences of technology) of attitudes significantly ($P < 0.05$) predicted mediating variables. We observed no significant ($P > 0.05$) direct effects on TE behaviour. Pre-service teachers' ATT would appear to be a dynamic phenomenon; despite the efforts taken, ATT diminishes with time, being accelerated by inactive years of technology or engineering education. This finding is consistent that of [16]. Moreover, we found that pre-service teachers who had higher scores for interest in technology had stronger situational interest; those who had high scores for situational interest had higher perceptions and experiences of TE behaviour. Students' increased situational interest enhanced both their learning and behaviour, which confirms the findings of [17].

Our participants' interest in technology affected their perceived course design quality: those who had high scores on perceived course design quality had higher scores on perceived TE behaviour. Moreover, students with higher scores for interest in technology had higher scores on creative potential needed for innovative performance.

Pre-service teachers who had higher scores for perceiving technology as difficult and for tediousness towards technology had lower scores on perceived course quality; students who had higher scores on technology difficulty had lower scores on perceived learning achievements. This finding means that the pre-service students' perceived ease of use of technology correlated positively with behavioural use; this result is consistent with those of [14].

Our participants who had higher scores for consequences of technology had lower scores for creativity. Our results support the proposed model and confirm the findings of several researchers, who reported the following: positive attitudes towards technology could raise creative potential [8] and increase persistence with TE tasks [6, 15]; however, traditional teaching and algorithmic designed tasks with constraints and control could repress creative performance [26, 30]. Our participants with lower scores on creativity had higher scores for consequences of technology since they were taught using a domain-specific approach. Those pre-service teachers may have had little or no experience with real-life technological situations and cases: they thus needed to learn how to cope with failures and frustrations, as reported by [12].

We found that the pre-service teachers' situational interest was positively related to their perceived learning value and perceived experiences of behaviour for innovative work; this result is in agreement with those of [20, 21]. Our participants who had higher scores for course design quality also had higher scores for situational interest, perceived learning value, and perceived TE behaviour. Thus, we were able to confirm the findings of several studies: [3, 6, 18, 28]. Pre-service teachers with higher perceptions of course design quality showed lower performance in creativity. Students with a low need for structure may have been frustrated with a well-organized learning process and highly structured tasks; consequently, they scored lower on the creativity test. This finding confirms that of [24].

Our participants who had higher scores for perceived learning value had higher scores for their TE behaviour. Highly creative pre-service teachers also had higher scores in their innovative performance as perceived TE behaviour. TE behaviour is self-initiated: it is largely enhanced by maintained interest in TE activities and by creative self-efficacy in a dynamic learning environment. Thus, we are able to confirm the proposed model and expand upon previous studies that have found similar relationships [12, 29, 32].

We observed a very interesting point with our path model: the typical behaviour of an engineer is indicated by the path from consequences of technology to creativity, and it extends to TE behaviour. Engineers have a higher awareness of consequences related to the implementation and use of technology. However, they tend to be more convergent random thinkers, which means that algorithmic behaviour prevails. Conformists like to use rules, constraints, and close-ended cases when designing [26, 30, 31]. Thus, conformists had lower scores in the TCT-DP test, which measures divergent thinking.

6. Conclusions

This study is the first of its kind, and so a direct comparison with other studies on pre-service teachers is difficult. Thus, only partial comparisons are possible with respect to the scope of the proposed model. The results of our study suggest that pre-service teachers' engagement in a TE course is strongly predictive of their TE behaviour. Our participants who had more experience with TE activities reported greater agreement with the importance of course design, methods and materials used, and learner-centred approaches (where control and teacher direction should be balanced to enhance deeper knowledge and engineering skills). ATT is a dynamic characteristic, and it is a sensitive measure of the predictive power related to the multidimensionality of sub-factors. Our findings suggest the necessity of using several mediators to determine the power that fosters and shapes desired behaviour.

Creativity occupies a special role in our model. Creative behaviour is indispensable for any innovative performance. However, owing to its rules, constraints, and limitations, TE education uses natural laws and mathematics, which are very often ineffective in raising the creative potential of students. Our results suggest the need for real-world cases and active work with less technology domain instructions while considering students' needs for structure.

Lessons in the technology domain should be undertaken through peer or other scaffolding–on both horizontal and vertical levels of learning outcomes. Experimentation, design-based work, project-based work, and inquiry-based learning are approaches to promote higher cognitive levels of achievement and creative performance. Nevertheless, we achieved our main goal in the present study: we produced a model of how to foster TE behaviour among pre-service teachers. That should play a decisive role in TE tasks in kindergarten education.

The limitations of this study are follows: (1) sample size—much bigger sampling would have added to the generalizability of the results; (2) direct observations of pre-service teachers and in-service teachers would have contributed to understanding the teachers' TE behaviour; and (3) measuring the students' academic, social, and cognitive outcomes would have extended the explanatory power of the model.

Further study is needed to extend our understanding of these matters based on the current findings. The initial focus should be on engineering design creativity measurement and finding more support for course design quality; a performance-based approach needs to be implemented. Moreover, further investigations should consider whether gender differences exist in these effects.

References

1. K. Yelamarthi, B. Dejong, T. Kaya, M. Prewett and D. Chen. Engaging Secondary School Teachers in Engineering Design: Lessons Learned and Assessment of a Research Experience for Teachers Program, *International Journal of Engineering Education*, **33**(5), 2017, pp. 1699–1709.
2. K. Nguyen, J. Husman, M. Borrergo, P. Shekhar, M. Prince, M. Demonbrun, C. Finelli, C. Henderson and C. Waters, Students' Expectations, Types of Instruction, and Instructor Strategies Predicting Student Response to Active Learning, *International Journal of Engineering Education*, **33**(1(A)), 2017, pp. 2–18.
3. S. Avsec, D. Rihtarsic and S. Kocijancic, A Predictive Study of Learner Attitudes Toward Open Learning in a Robotics Class, *Journal of Science Education and Technology*, **23**(5), 2014, pp. 692–704.
4. P. Ogrutan, A-M. Cazan and L. E. Aciu, Difficulties of Evolution from Imitation to Creativity in Engineering Education, *International Journal of Engineering Education*, **33**(6(A)), 2017, pp. 1815–1823.
5. K. Leahy, D. Philips, E. Debartolo, P. Brackin, S. Chenowet and A. White, Encouraging Creativity in Capstone Design, *International Journal of Engineering Education*, **33**(5), 2017, pp. 1468–1484.
6. E. J. Rohaan, R. Taconis and W. M. G. Jochems, Analysing teacher knowledge for technology education in primary schools, *International Journal of Technology and Design Education*, **22**(3),2012, pp. 271–280.
7. J. C. Chang, Y.-M. Yeh, S.-C. Chen and H.-C. Hsiao, Taiwanese technical education teachers' professional development: An examination of some critical factors, *Teaching and Teacher Education*, **27**(1), 2011, pp. 165–173.
8. I. R. Lee and K. Kemple, Preservice teachers' personality traits and engagement in creative activities as predictors of their support for children's creativity, *Creativity Research Journal*, **26**(1),2014, pp. 82–94.
9. D. H. *Cropley, Creativity in engineering: Novel solutions to complex problems*, Academic Press: San Diego, CA, 2015.
10. S. Hidi and K. A. Renninger, The four-phase model of interest development, *Educational Psychologist*, **41**(2), 2006, pp. 111–127.
11. S. Oskamp and P. W. Schultz, *Sociology, Attitudes and Opinions*, Lawrence Erlbaum: New Jersey, NJ, 2005.
12. M. Kallio and M. Metsärinne, How do different background variables predict learning outcomes? *International Journal of Technology and Design Education*, **27**(1), 2017, pp. 31–50.
13. S. Avsec and S. Kocijancic, A Path model of Technology intensive Inquiry-based Learning, *Educational Technology & Society*, **19**(1), 2016, pp. 308–320.
14. K.-C. Yu, K.-Y. Lin, F.-N. Han and I.-Y. Hsu, A model of junior high school students' attitudes toward technology, *International Journal of Technology and Design Education*, **22**(4), 2012, pp. 423–436.
15. B. J. Lucas and L.F. Nordgren, People underestimate the value of persistence for creative performance, *Journal of Personality and Social Psychology*, **109**(2), 2015, pp. 232–243.
16. J. Ardies, S. De Maeyer, D. Gijbels and H. van Keulen, Students attitudes towards technology, *International Journal of Technology and Design Education*, **25**(1), 2015, pp. 43–65.
17. J. I. Rotgans and H. G. Schmidt, Situational interest and learning: thirst for knowledge, *Learning and Instruction*, **32**, 2014, pp. 37–50.

18. A. Tapola, M. Veermans and M. Niemivirta, Predictors and outcomes of situational interest during a science learning task, *Instructional Science: An International Journal of the Learning Sciences*, **41**(6), 2013, pp. 1047–1064.
19. A. Loukomies, K. Juuti and J. Lavonen, Investigating Situational Interest in Primary Science Lessons, *International Journal of Science Education*, **37**(18), 2015, pp. 3015–3037.
20. M. Knogler, Situational Interest: A Proposal to Enhance Conceptual Clarity. In: O'Keefe P., Harackiewicz J. (Eds.) *The Science of Interest* (pp. 109–124), Springer International Publishing AG: Cham, Switzerland, 2017.
21. K. A. Renninger and S. Hidi, *The Power of Interest for Motivation and Engagement*, Routledge: New York, NY, 2016.
22. C-T. Liang, F. Zenasni, Y-C. Liu and C. Liang, The Role of Intrinsic Motivation in Student Imagination: A Comparison Between Engineering and Science Majors, *International Journal of Engineering Education*, **33**(5), 2017, pp. 1672–1683.
23. G. L. Herman, D. E. Goldberg, K. F. Trenshaw, M. Somerville and J. Stolk, The Intrinsic-Motivation Course Design Method, *International Journal of Engineering Education*, **33**(2(A)), 2017, pp. 558–574.
24. E. F. Rietzschel, J. M. Slijkhuis and N.W. van Yperen, Task structure, need for structure, and creativity, *European Journal of Social Psychology*, **44**(4), 2014, pp. 386–399.
25. D. Barlex, Creativity in school design and technology in England: A discussion of influences, *International Journal of Technology and Design Education*, **17**(2), 2007, pp. 149–162.
26. Y. L. Wong and K.W.M. Siu, Is there creativity in design? From a perspective of school design and technology in Hong Kong, *Asia Pacific Education Review*, **13**(3), 2012, pp. 465–474.
27. K. Loibl and N. Rummel, Knowing what you don't know makes failure productive, *Learning and Instruction*, **34**, 2014, pp. 74–85.
28. I. Glogger-Frey, C. Fleischer, L. Grüny, J. Kappich and A. Renkl, Inventing a solution and studying a worked solution prepare differently for learning from direct instruction, *Learning and Instruction*, **39**, 2015, pp. 72–87.
29. M. Li, Y. Liu, L. Liu and Z. Wang, Proactive personality and innovative work behavior: The mediating effects of affective states and creative self-efficacy in teachers, *Current Psychology*, 2016.
30. B.-T. Esjeholm, Design knowledge interplayed with student creativity in D&T Projects, *International Journal of Technology and Design Education*, **25**(2), 2015, pp. 227–243.
31. S. Avsec and V. Šinigoj, Proactive technical creativity: mediating and moderating effects of motivation, *World Transacitions on Engineering and Technology Education*, **14**(4), 2016, pp. 540–545.
32. K. L. Unsworth, Unpacking creativity. *Academy of Management Review*, **26**(**2**), 2001, pp. 286–297.
33. A. Szewczyk-Zakrzewska and S. Avsec, Predicting academic success and creative ability in freshman chemical engineering students: a learning styles perspective. *International Journal of Engineering Education*, **32**(2(A)), 2016, pp. 682–694.
34. J. Ardies, S. De Maeyer and D. Gijbels, Reconstructing the pupils attitude towards technology—survey, *Design & Technology Education: An International Journal*, **18**(1), 2013, pp. 8–19.
35. J. Dawes, Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales, *International Journal of Market Research*, **50**(1), 2008, pp. 61–77.
36. G. R. Hancock and R. O. Mueller, *Structural equation modeling: A second course* (2nd Eds.), Information Age Publishing: Charlotte, NC, 2013.
37. J. Stevens, *Applied multivariate statistics for the social sciences*, Routledge: New York, NY, 2009.
38. K. K. Urban, Assessing creativity: The Test for Creative Thinking-Drawing Production (TCT-DP), *International Education Journal*, **6**(2), 2005, pp. 272–280.
39. N. T. Huang, L.C. Chiu and J.C. Hong, Relationship amongst students' problem-solving attitude, perceived value, behavioral attitude, and intention to participate in a science and technology contest, *International Journal of Science and Mathematics Education*, **14**(8), 2016, pp.1419–1435.
40. N. Blunch, *Introduction to structural equation modeling using SPSS and AMOS*, Sage Publications: London, UK, 2013.

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