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PREDICTIVE MODELLING OF PRE-SERVICE SCIENCE AND TECHNOLOGY TEACHERS' INNOVATIVE BEHAVIOUR

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Abstract. *Science and technology (S&T) plays a central role in today's knowledge- and technology-based society. The transfer of S&T from the education system to the economy should be promoted by teachers using innovative behaviour as an important aspect of providing high-quality education. Several studies have found that a mismatch exists between the economy and the education sector, and that this can be gradually reduced by innovation in the education system. This research aimed to examine the innovative behaviour of pre-service S&T teachers. A sample of 140 pre-service teachers from the University of Ljubljana, Slovenia was selected, and a set of instruments was used to measure their innovative behaviour in classrooms during the 2019–2020 academic year. A model was created and evaluated using multiple regression analysis. The results showed that self-efficacy and attitudes towards S&T strongly predict innovative behaviour, while situational interest may vary depending on the cognitive demands of tasks. A proactive personality was found to be a key factor determining innovative behaviour, while self-efficacy has direct and indirect influences on innovative behaviour, with its indirect influence mediated by creativity and situational interest. These findings have implications for the redefinition of educational design to enhance innovation in the classroom.*

Keywords: *innovative behaviour, predictive modelling, pre-service teachers, science and technology*

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Introduction

The strategic orientation of nowadays society, in which innovations in science and technology (S&T) play an important role and are closely linked to achieving economic competitiveness and social development, suggests that the trend towards technological transformation is likely to continue. To foster innovation, holistic strategies are needed, but these have not yet been mastered by most economies, as reported by the World Economic Forum (WEF) (WEF, 2019). Innovation, especially incremental technological innovation of products and services, appears to be an important factor of productivity growth and value creation in the fourth industrial revolution (WEF, 2019), in which S&T is playing a transformative role, especially in the face of increasing global integration and interconnectedness. The Organisation for Economic Co-operation and Development (OECD) reported that S&T developments and innovation can trigger the necessary changes in the social, economic and physical environments to cope with the challenges of globalization, changing demographics and intensive industrial production (OECD, 2018a). The OECD (2018a) has proposed that countries introduce changes to their science, technology, and innovation policies to develop more economically, socially, and environmentally beneficial technologies, and use big data to analyse the relations between S&T spending and outcomes.

The development of S&T, which is increasingly characterized by epistemological, methodological, and technological convergence at different levels, promises increasingly fundamental and precise interventions in living systems, especially in relation to the natural, economic, and social environments. Today, broader educational goals are urgently needed to mitigate inequality and social fragmentation, and to enhance individual and collective well-being (Paniagua & Instance, 2018). S&T education across the entire education system is playing a prominent role in developing students' knowledge, skills, attitudes, and values to enable them to contribute to and benefit from a sustainable future (Paniagua & Instance, 2018). In addition, the OECD (2018b) has proposed the active contribution of teachers to shape their work and of students to shape their learning and its conditions. This points to development of ability of teachers and students to take control over their work or learning and successfully cope with the challenges they encounter. The traditional role of the teacher has expanded in recent decades, and a

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skilled teacher should now be able to recognize a wide range of factors affecting students' innovative learning (Klaeijsen et al., 2018; Könings et al., 2017).

The behaviour of the teacher in guiding learning in the classroom should be based on the acquisition by students of (a) a wide range of knowledge, (b) cognitive, interpersonal and psychomotor skills, and (c) attitudes, values and subjective norms (OECD, 2018b; Paniagua & Instance, 2018). The students in such a classroom actively navigate through the uncertainties of the real world in different contexts (time, social, and digital space) and create new values, reconcile tensions and dilemmas, and take responsibility (Paniagua & Instance, 2018). Therefore, innovative teaching requires a range of learning, educational, social, and technological competences, as proposed by Zhu et al. (2013).

Thus, pre-service teacher education programs must strive to incorporate the most appropriate methods and content (Keinänen et al., 2018). The acquisition of disciplinary knowledge and skills is no longer sufficient to meet the complex requirements of teaching (Keinänen et al., 2018). Students require different knowledge and skills, imparted through a set of values and attitudes, in unfamiliar and evolving circumstances where innovative behaviour is required. The acquisition of interdisciplinary knowledge and skills is a complex process in which students' self-regulation should be used to take advantage of their developing functional literacy, which acts as a catalyst for the use of higher order thinking skills that enable them to make informed decisions and respond appropriately in challenging real-life situations (Cencelj et al., 2019). The competencies required for innovative teaching can be nurtured during training and beyond (Konst & Kairisto-Mertanen, 2020; Slavinec et al., 2019). This suggests that S&T teacher training institutions should balance different types of teacher knowledge, including new knowledge arising from different disciplines and educational sciences (OECD, 2019), to develop students' capacity for innovation (Konst & Kairisto-Mertanen, 2020). In this way, pre-service teachers can work more efficiently and be more motivated, more creative, and develop a positive attitude towards S&T in the lead-up to commencing service, while they actively participate in a creative, social, and collaborative environment that enables them to utilize and further develop their metacognitive and psychomotor skills (Keinänen et al., 2018).

The primary goal of high-quality pre-service teacher education should be the development of innovative behaviour that reflects a proactive personality and systems thinking in identifying and solving problems identified in different environments (Klaeijsen et al., 2018). Moreover, innovative behaviour might help teachers, both pre-service and later in service, to implement new learning units or a new course, that improves various elements such as (1) the curriculum and learning design itself, (2) the school as an institution, (3) the students' competencies, and (4) the teachers' own competencies, as noted by Könings et al. (2007).

Literature Review

Innovative Behaviour

Innovative behaviour as a proactive response by humans to changes in their environment (Thurlings et al., 2015) is connected with the development of new technologies and social and economic changes, and manifests itself in the design of new objects, processes, or ideas (Richmond & Tatto, 2016). The present research focuses explicitly on innovative behaviour defined by Janssen (2000) as "the intentional creation, introduction, and application of new ideas within a work role, group or organisation, in order to benefit role performance, the group or the organisation" (p. 288). Messmann (2012) has proposed multi-phases model aimed for development of innovative behaviour explicitly in educational context based on (1) opportunity exploration, (2) idea generation, (3) idea promotion, and (4) idea realisation. This model based on creativity development can be used in an iterative and non-linear dynamic way, where phases are partly dependent. Innovative behaviour is much more than the creativity of individuals, and involves a proactive personality, which is highly correlated with teachers' innovative work behaviour (Li et al., 2017) in adopting and implementing ideas generated while at work in the classroom, or in the laboratory and workshops during the study, as self-initiated actions.

Klaeijsen et al. (2018) and Hero et al. (2017) presented a systematic review of studies exploring the innovative behaviour of teachers. Several factors influencing innovative behaviour were revealed, for example, tasks with different cognitive demands, self-efficacy, creativity, engagement in work or learning, motivation, and satisfaction with learning or work (Klaeijsen et al., 2018), while Hero et al. (2017) identified flexibility and stability in relation to learning activities, achievement orientation, social skills, self-regulation, critical and creative thinking, and content knowledge, together with the ability to create or make. In addition, Avsec and Sajdera (2019)

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presented a model of engineering thinking that can be used to describe the innovative behaviour of pre-service S&T teachers in the vast majority of cases. The model describes the effects of the attitudes of pre-service S&T teachers on their situational interest and perceived control over learning, and the inclusion of creative thinking skills to predict engineering thinking based on a proactive personality.

Pre-service Teachers' Attitudes towards S&T

In addition to knowledge and skills, attitude is an important factor in predicting human behaviour (Eagly & Chaiken, 1993). Attitude is defined as a person's predisposition to responding favourably or unfavourably to a given object (Oskamp & Schultz, 2005). The object can be anything, for example, an idea, a topic, a physical object, a process, others' behaviour, or a situation. For the purposes of this research, the following objects were selected to provide a contextual framework related to S&T: (1) professional career aspirations in relation to S&T, (2) interest in S&T, (3) feelings of boredom or tediousness regarding S&T, (4) gender sensitivity in relation to S&T, (5) perceived effects of S&T on the social, economic, and natural environments, and (6) difficulty of the topic. These objects were selected based on studies by Ardies et al. (2015), Cheung (2011), Gräber (2011), and Vishnumolakala et al. (2018).

Avsec and Sajdera (2019) argued that pre-service teachers' attitudes towards technology can be used to predict their perceived level of control over learning and creative potential. In addition, they stated that attitudes can moderate engineering thinking and proactive behaviour, especially when tasks involve higher-level cognitive demands. Vishnumolakala et al. (2018) presented evidence that pre-service teachers' attitudes towards chemistry improved when the students were able to engage in active participation in the laboratory and in lectures. Students' attitudes towards the topic might also be related to self-efficacy, and both attitudes and self-efficacy can affect students' perception of control over learning the topic using structured learning materials, real-life problems, working in small groups where multiple interactions are enabled (Vishnumolakala et al., 2018), imparting positive learning experiences, individual-oriented feedback, and cooperative and collaborative learning with changing reference groups (Gräber, 2011).

Several studies have examined students' attitudes towards technology, chemistry, biology, and physics (Ardies et al., 2015; Avsec & Jagiełło-Kowalczyk, 2018; Avsec & Sajdera, 2019; Gräber, 2011; Maison et al., 2019; Vishnumolakala et al., 2018), or to science, technology, engineering, and mathematics (STEM) in general (Kim & Bolger, 2017), but studies focused on pre-service S&T teachers are scarce, and thus the findings are inconclusive.

Pre-service Teachers' Self-Efficacy

Self-efficacy plays a crucial role in human behaviour and determines whether one reacts either positively or negatively to stimuli on the basis of one's abilities and experiences (Bandura, 1997). A combination of cognitive, social, emotional, and behavioural sub-skills is required for effective functioning (Bandura, 1997). Self-efficacy can influence motivation, interest in the subject, academic performance (Mohtar et al., 2019; Vishnumolakala et al., 2018), satisfaction of basic psychological needs, and innovative behaviour as a proximal variable (Klaeijsen et al., 2018), especially when social cognitive theory is applied to innovation learning (van Dinther et al., 2011). Moreover, self-efficacy might be decisive in predicting a student's level of creativity (Chen & Zhang, 2019).

In addition, Gräber (2011) highlighted students' self-concept regarding their abilities as a factor that could influence their interest in science and subsequently their performance in terms of knowledge, skills, or intended behaviour. Students who believe in their own abilities, are interested in the topic, and enjoy learning and working in workshops and laboratories will find it easier to develop new ideas for improvements and to implement them successfully in different real-world contexts (Klaeijsen et al., 2018). In addition, pre-service teachers' self-efficacy can be a predictor of different types of classroom teacher behaviour and could be useful for understanding their perception of learning control in different learning environments (Fishbein & Ajzen, 2009; Klaeijsen et al., 2018; Maison et al., 2019).

Pre-service Teachers' Perceived Control Regarding Learning S&T

Pre-service teachers' engagement in S&T activities may be reflected in different ways. Different cognitive demands trigger different levels of situational interest in learning (Avsec & Sajdera, 2019) as an affective response to

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the assigned task. Situational interest, together with perceived learning value and course design satisfaction, can influence innovative behaviour, especially in terms of the level of proactivity in relation to learning and working in laboratories, seminars, lectures, and workshops (Avsec & Sajdera, 2019).

The belief of pre-service teachers that their skills increase with effort expended can influence the generation of new ideas and concepts that are contextualized in different learning environments and disciplines (Haase et al., 2018). Creative students may have a higher level of self-efficacy based on previous success in the subject, and this can also influence their innovative performance (Haase et al., 2018). In contrast, those who demand more information or want to acquire more skills and knowledge from their creative work or learning feel less useful and less creative if the learning environment and tasks are not well designed (Amabile et al., 1996; Tierney & Farmer, 2011).

When developing proactive behaviour among pre-service teachers, some constraints on the development of creativity should be taken into account. These are related to the learning outcomes specified in the curriculum, limitations in relation to available materials and equipment, and a lack of systems thinking necessary to integrate knowledge and skills from other disciplines (Haase et al., 2018). In addition, pre-service teachers' self-regulation can influence their perception of the task-related environment (Klaeijsen et al., 2018). Those who are promotion-oriented will tend to broaden their attention and focus less attention on the task at hand, while prevention-oriented individuals will try not to make mistakes at work or while learning (Lee et al., 2019). If a high level of creativity is required in tasks or assignments, higher support from teachers, peers, or supervisors is needed to encourage creativity, otherwise creativity may decrease even as students' proactive behaviour intensifies (Kim et al., 2010).

Research Focus

The innovative behaviour of teachers in the classroom has been the subject of numerous studies and various models have been proposed on how to measure and develop innovative behaviour (Chen & Zhang, 2017; Keinänen et al., 2018; Klaeijsen et al., 2017; Li et al., 2017; Zhu et al., 2013). The majority of these models are based either on social cognitive theory (Bandura, 1997) or on the theory of planned behaviour (Ajzen, 1991). Despite the large number of models, several common drawbacks have been identified, such as a lack of deep understanding of cognitive aspects and motivational factors (Klaeijsen et al., 2018), the effects of various uncertainties and individual differences on planned behaviour, the inclusion of social aspects (Ajzen, 2011), attitudes towards contemporary S&T, the impact of creativity on proactive behaviour (Avsec & Sajdera, 2019), and the role of flexibility/stability in predicting students' level of achievement. These findings point to the need to recognize pre-service teachers as an important element in the process of transferring knowledge and skills between education and practice to assist in identifying the factors influencing innovative behaviour and further career development.

The aim of this research was twofold: (1) to develop a model of pre-service teachers' innovative behaviour based on a combined theory that includes socio-cognitive and behavioural aspects, and (2) to improve the understanding of the impact of self-efficacy, attitudes towards S&T, motivational constructs, and perceived control over S&T activities on pre-service teachers' innovative behaviour while considering the interrelationships among these constructs. This knowledge is helpful in educational design of stimulating S&T environment in which the determinants, and thus the innovative behaviour of pre-service teachers, can be enhanced.

The research was guided by the following research questions (RQs):

RQ1: What is the relation between pre-service teachers' self-efficacy and attitudes towards S&T, and their perception of learning of S&T?

RQ2: What is the relation between pre-service teachers' perceived control over learning of S&T and their behaviour in terms of innovative performance?

RQ3: Do pre-service teachers' self-efficacy and attitudes towards S&T predict behaviour in terms of innovative performance?

RQ4: Does pre-service teachers' creativity predict their level of proactive behaviour?

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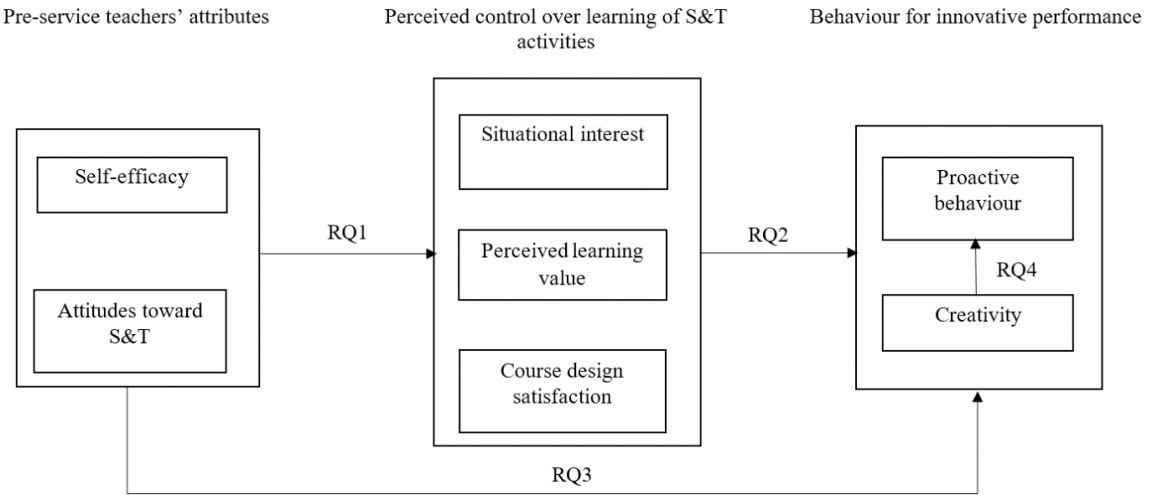
Research Methodology

General Background

The conceptual framework for this study was constructed on social cognitive theory (Bandura, 1997) and the theory of planned behaviour (Ajzen, 1991). Ajzen's (1991) theory can be used to predict intentions and behaviour, while also avoiding uncertainties and demonstrating the effects of individual differences and social support. Social cognitive theory, as proposed by Bandura (1997), defines the interactions between learners' cognition, learners' behaviour, and the learning environment. Based on this theory, it is expected that self-efficacy can affect behaviour and is related to both cognitive factors (beliefs, perceptions) and affective factors (emotions, interest), while cognitive processes in relation to creativity can mediate the influence of self-efficacy on pre-service teachers' behaviour (Bandura, 1997) when they study S&T.

A combined model provides a prediction of innovative behaviour based on self-efficacy, attitudes towards S&T, motivation, creativity, and perceived control over learning of S&T, which relates to situational interest in the learning of S&T, perceived learning value and perceived S&T course satisfaction based on experience gained from lectures, laboratory work, seminars, and other technology-enhanced workshops (see Figure 1).

Figure 1
Theoretical Framework and Study Design Showing the Relations among the Research Questions RQ1–RQ4



Study Sample

The study sample consisted of 140 pre-service S&T teachers from the University of Ljubljana, Slovenia during the 2019–2020 academic year. The sample included significantly more females (n=123, 87.9%) than males (n=17, 12.1%), and was fairly evenly distributed across the study disciplines, with 72 pre-service technology teachers (51.4%) and 68 pre-service science teachers (48.6%). The numbers of students in their first, second, third, and fourth year of study were 27, 33, 55, and 25, respectively.

Any participation in this research was completely voluntary, and informed consent form was presented clearly to the students, including safeguards for privacy which were needed to protect the privacy interests of the participated students. When all possible questions from students were answered to their satisfaction, they signed the consent form agreeing to the research. Moreover, students were also informed that their participation in research, or lack thereof, has no impact to their grade. Students were free to withdraw from the research at any stage. Thus, researchers succeeded to collect 140 students out of 182 in total who were enrolled in the undergraduate study programme of S&T teacher education. This sample size was checked against the values produced by GPower 3.1

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analysis program (Faul et al., 2009). A power analysis using GPower with a power (1-β) set at 0.90, α = .05 indicated that a total sample of 130 participants would be needed to detect moderate effects (F^2=0.15) for the *F*-test using multiple regression with a maximum of seven predictors in one level of the model.

Instruments and Procedures

Three questionnaires and a test of creative thinking in drawing production (TCT-DP) were used.

The pre-service teachers' self-efficacy was self-assessed using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). A questionnaire titled *Self-efficacy and me* was constructed based on Gaumer Erickson et al.'s (2016) questionnaire and included sections on *Feeling efficient* (eight items), *Making an effort* (five items), and *Showing stability/being flexible* (three items). Showing stability and being flexible are important characteristics of pre-service teachers that can affect innovative behaviour, both directly and indirectly (Ionescu, 2017) in the context of Bandura's theoretical concepts framed in social cognitive theory (Bandura, 1997).

Attitudes towards S&T were assessed using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) using a questionnaire titled *S&T and me* that included six sub-scales as constructs: (1) S&T career aspirations (four items), (2) interest in S&T (six items), (3) tediousness of S&T (four items), (4) suitability of S&T for both genders (five items), (5) consequences of technology (four items), and (6) difficulty of S&T (four items). The 27-item questionnaire was based on Ardies et al.'s (2015) questionnaire for measuring attitudes towards technology with a focus on science activities.

Perceived control over learning of S&T activities and level of proactive behaviour were assessed using a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) using a questionnaire called *Action and me*. The questionnaire consisted of five constructs: (1) proactive behaviour (five items), (2) triggered interest (four items), (3) maintained interest (five items), (4) perceived learning value (four items), and (5) satisfaction with course design (seven items). The questionnaire was based on Avsec and Sajdera's (2019) questionnaire for assessing the level of perceived control over learning of technological and engineering activities.

The pre-service teachers' creative potential was measured using the TCT-DP test (Urban, 2005). This test is detailed in Urban (2005), while the implications in relation to educational studies presented in Avsec and Sajdera (2019). The students' level of achievement in terms of drawing production were assessed based on the 14 criteria reported in Urban (2005), and the maximum possible score on the test was 72. Three raters with different levels of experience in relation to assessing TCT-DP test results assessed the students' drawings. The intraclass correlation coefficient reflects the degree of correlation among measurements and was calculated as .971 (99% confidence interval .962 to .983).

The chosen instruments were assessed for evidence of reliability in terms of the criteria used in social science research (Pituch & Stevens, 2016). Table 1 shows the reliability of the instrument sub-scales based on Cronbach's α.

Table 1
Reliability of Instrument Sub-scales

Instrument	Cronbach α
Self-efficacy and me questionnaire	
Feeling efficient	.76
Making an effort	.74
Showing stability/being flexible	.78
S&T and me questionnaire	
S&T career aspirations	.89
Interest in S&T	.73
Tediousness of S&T	.82
Suitability of S&T for both genders	.78
Consequences of S&T	.86
Difficulty of S&T	.71

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Instrument	Cronbach α
Action and me questionnaire	
Proactive behaviour	.88
Triggered interest	.87
Maintained interest	.88
Perceived learning value	.87
Satisfaction with course design	.90
TCT-DP creativity test	.84

All the instruments used in the present study proved to be moderately to highly reliable, with Cronbach's α >.70 (Pituch & Stevens, 2016).

The research was carried out in a real-life classroom in the presence of the researchers. Each student was asked to complete three questionnaires and a TCT-DP test using the paper and pencil method, beginning with *Self-efficacy and me*, followed by *S&T and me*, *Action and me*, and the TCT-DP test. The questionnaires and TCT-DP test took 45 minutes to complete.

Data Analysis

Data analysis was carried out using SPSS v.25 to obtain the mean scores, standard deviations, and maximum and minimum scores of the dependent variables. Data distribution was checked using measures of skewness and kurtosis. Multiple regression analyses were used to explore how independent variables predict pre-service teachers' innovative behaviour.

Research Results

Before evaluation of the model against the testing data, a descriptive analysis was performed. Table 2 shows the means, standard deviations, maximum and minimum values, and measures of data normality.

Table 2
Descriptive Statistics for Sub-scales Measuring Pre-service Teachers' Self-efficacy, Perceived Control over Learning, and Innovative Behaviour (n=140)

Instrument sub-scales	Min.	Max.	*M*	*SD*	Skewness	Kurtosis
Self-efficacy and me						
Feeling efficient	2.00	5.00	3.96	0.55	-0.77	1.14
Making an effort	2.60	5.00	4.43	0.53	-1.07	0.88
Showing stability/being flexible	1.00	5.00	4.01	0.72	-0.89	1.44
Attitudes towards S&T						
S&T career aspirations	1.25	5.00	3.69	0.94	-0.36	-0.48
Interest in S&T	1.83	5.00	3.93	0.63	-0.62	0.10
Tediousness of S&T	1.00	3.50	1.53	0.65	1.12	0.49

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Instrument sub-scales	Min.	Max.	*M*	*SD*	Skewness	Kurtosis
Suitability of S&T for both genders	1.00	4.60	2.40	0.87	0.12	-0.75
Consequences of S&T	2.50	5.00	4.33	0.59	-0.70	-0.08
Difficulty of S&T	1.25	5.00	3.09	0.72	-0.11	-0.11
Action and me						
Proactive behaviour	1.80	5.00	3.78	0.70	-0.75	0.16
Triggered interest	2.75	5.00	4.43	0.61	-0.83	-0.23
Maintained interest	2.60	5.00	4.32	0.64	-0.77	-0.24
Perceived learning value	1.50	5.00	4.17	0.68	-0.92	1.35
Satisfaction with course design	1.29	5.00	4.13	0.79	-1.00	0.87
Creativity	7.00	61.00	37.20	10.19	-0.55	0.84

The measure of asymmetry (skewness) and the measure of distribution outliers (kurtosis) were in the range from –1.5 to +1.5, and thus are considered acceptable (Tabachnik & Fidell, 2013), indicating a normal distribution.

Pre-service S&T teachers reported above-average self-efficacy, and slightly above-average attitudes towards S&T. They felt that S&T was not boring and perceived that S&T was appropriate for both genders. Despite the perceived difficulty of S&T, they were aware of the impact of S&T on the social, economic, and natural environments.

Pre-service S&T teachers' perceived control over learning of S&T subject matter was above average, and their situational interest in S&T activities was high. It is presumed that situational interest can be controlled by teachers using several learning tasks and environments to enhance students' motivation. It seems that pre-service teachers undertake tasks with high-level cognitive demands, and thus it is expected that their learning behaviour and level of achievement will be higher.

Pre-service S&T teachers did not receive any creativity training during their study and were only given lessons to develop their subject matter knowledge, general pedagogical knowledge, knowledge of context and pedagogical content knowledge. Their creativity potential ranged from 9 to 61 points out of a maximum possible score of 72, with an average score of 37.2 (*SD*=10.19).

The present study sought to answer RQ1–4. Thus, a complex theoretical model was created, in which a linear relationship between the variables studied at each level of the model was proposed. The regression model predicts relationships with a standardized β ranging from –1 to +1, where an increase in one variable is expected to be associated with an increase (plus sign) or decrease (minus sign) in another variable (Paechter et al., 2010). The standardized regression coefficient β values present a good estimation of predictor-criterion relationship. Figure 2 shows a path model developed using the multiple regression analyses with significant β values ($p < .05$).

It was established that pre-service S&T teachers' self-efficacy is a significant predictor of their perceptions of and experiences with S&T activities, and of innovative behaviour, whereby a belief that one's ability can increase with effort significantly predicts triggered interest (β = .29), perceived learning value (β = .42), proactive behaviour (β = .29), and creative performance (β = .32) (Tabachnik & Fidell, 2013). Their belief in their ability to meet specific learning achievements significantly predicted their proactive behaviour (β = .20). A combination of previous knowledge or approaches and new approaches to S&T activities when called on helps students to maintain their level of activity (β = .21) and leads to improved learning outcomes at higher cognitive levels.

Pre-service S&T teachers' attitude towards S&T is a significant factor in predicting triggered interest (β = .22), maintained interest (β = .30), and satisfaction with work and learning (β = .20). Moreover, students' perceptions of S&T as being tedious might reduce their proactive behaviour (β = –.24), triggered interest (β = –.29), maintained interest (β = –.23), and satisfaction with course design (β = –.20).

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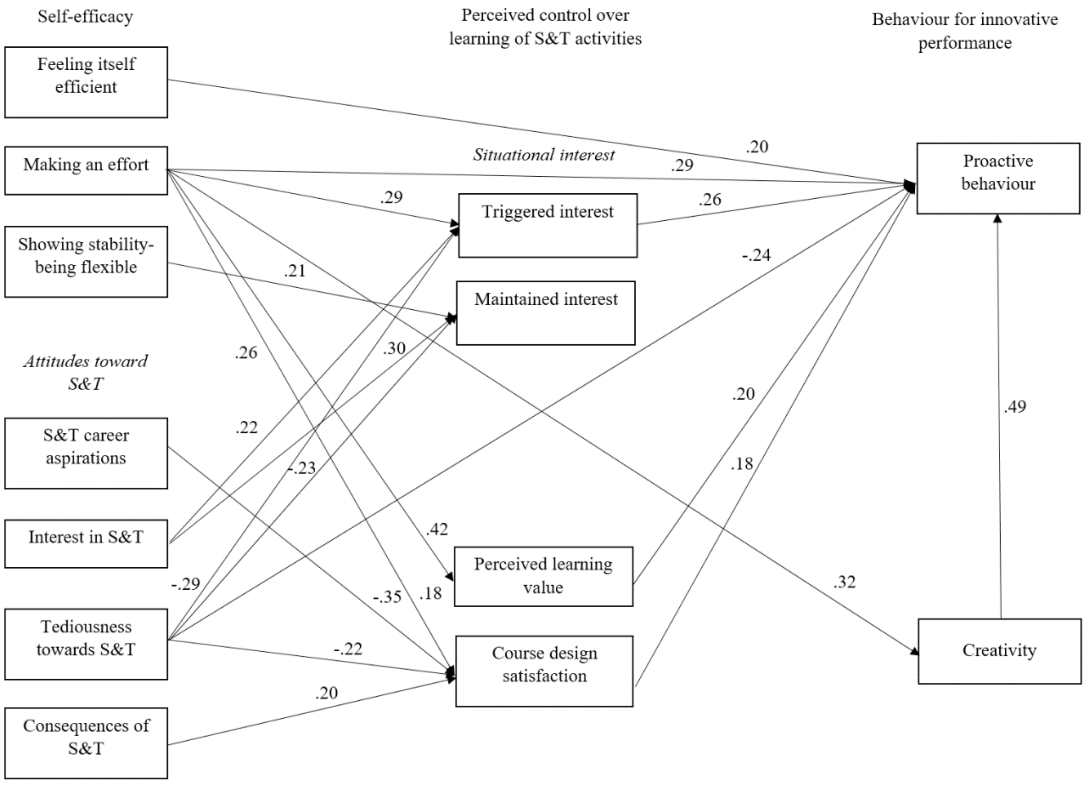
Figure 2
Path Model to Pre-service S&T Teachers' Innovative Behaviour



Pre-service S&T teachers' proactive behaviour was found to be an important factor driving their innovative behaviour. Proactive behaviour is largely affected by triggered interest (β = .26), perception of learning value (β = .20), satisfaction with course design (β = .18), and self-efficacy, while boredom with S&T might reduce this behaviour (β = –.24). Proactive behaviour is highly correlated with the level of creativity (β = .49).

Discussion

The professional development of teachers begins during their studies in their chosen discipline. Together with their innovative behaviour, this represents an important means of meeting the challenges of the fourth industrial revolution by preparing pre-service teachers to develop their potentials to create competitive knowledge and skills.

This research aimed to create an insightful model with various constructs that can influence the innovative behaviour of teachers in the lead-up to service. It has been established that pre-service teachers' self-efficacy is an important predictor of their perceived control over learning of S&T and motivation what confirms findings of several researchers (Fishbein & Ajzen, 2010; Klaeijsen et al., 2018; Maison et al., 2019; Mohtar et al., 2019; Vishnumolakala et al., 2018). Moreover, we found that pre-service teachers who believe that their ability increases with effort are task-oriented and more likely to be engaged with higher cognitive demand tasks, but they need support from their peers or instructors to complete their tasks without mistakes. This might increase their perception of learning value and course satisfaction, as argued by Lee et al. (2019). As argued by Chen & Zhang (2019), teachers' self-efficacy might predict their level of creativity, and the present research revealed that a subscale of *Making and effort* directly predicts this level of creativity while proactive personality mediates creativity when pre-service teachers feel themselves very efficient.

Pre-service teachers' attitudes towards S&T can predict their situational interest, both positively (interest in S&T) and negatively (tediousness of S&T). Those who were aware of the consequences of S&T were more aware of their own learning, while those with higher demands who wanted a career in S&T were not satisfied with the

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existing design of S&T activities. Thus, the present research confirms findings of several studies where examined students' attitudes towards single discipline e.g., technology, chemistry, biology, and physics (Ardies et al., 2015; Avsec & Jagiełło-Kowalczyk, 2018; Avsec & Sajdera, 2019; Gräber, 2011; Maison et al., 2019; Vishnumolakala et al., 2018). In the contrast with previous studies, the present research did not reveal any relation of students' attitudes towards S&T to their level of creativity. It seems that pre-service teachers felt useless because their creative work was not sufficiently encouraged, as already argued by Amabile et al. (1996) and Tierney and Farmer (2011) and/or pre-service teachers did not regulate their behaviour as a function of interests in learning of S&T, based on autonomy control of intrinsic and extrinsic motivation, as argued by Lee et al. (2019).

Perceived control over learning of S&T activities was found to be an important predictor of proactive behaviour, as already argued by Avsec and Sajdera (2019). It seems that student-centred activities in S&T subjects may enhance their perceived control of learning, resulting in improved proactive behaviour leading to innovative performance. It was also found that situational interest affects behavioural intentions, which leads to positive emotions and influences conceptual change where learning and acting can develop simultaneously, confirming the findings of Avsec and Sajdera (2019) and Gräber (2011). Contextual motivation could also be a strong predictor for perceived learning achievements and course satisfaction, and mediates innovative behaviour (Klaeijsen et al., 2018). Innovative behaviour, as a desired outcome of an S&T course, can be viewed at the situational level as the consequence of pre-service teachers successfully performing their allocated tasks in lectures, workshops and laboratories. Moreover, the present research revealed that pre-service teachers' self-reported learning value and satisfaction with S&T courses do not significantly predict a level of creativity. It points to the creativity of non-sensitive tasks or assignments where prevention-oriented students were favourite. This research provides also an evidence that perceived control over learning of S&T activities has not predicting value in the level of creativity, what points to the lack of students' self-regulation, argued by Klaeijsen et al. (2018) and Kim et. al. (2010).

The findings of previous theoretical studies (Ionescu, 2017; Klaeijsen et al., 2018) indicated that pre-service teachers' maintained interest in S&T could also predict innovative behaviour, especially if it was influenced by the individual's ability to remain flexible while displaying stability. The present research revealed no predictive value of maintained interest in both innovative behaviour and in the level of creativity. One possible reason is pre-service teachers' perceptions of their future work, especially first- and second-year students who have no experience of teaching. The other reason could be that a level of pre-service teachers' self-regulation is low (Klaeijsen et al., 2018), and they were not able to develop autonomous forms of extrinsic motivation in S&T activities (Avsec & Sajdera, 2019).

The present research revealed that the proactive behaviour is negatively influenced by increasing boredom with S&T, while pre-service teachers' belief in their ability to achieve their goals and belief that their ability can grow with the effort were positive predictors of proactive behaviour, already argued by Avsec and Sajdera (2019), and van Dinther et al. (2011). As S&T activities are based on learning outcomes defined by the curriculum, students are more prevention-oriented, tending to apply creativity to less cognitively demanding tasks rather than risking making mistakes in their laboratory work or learning. In this case, proactive behaviour can be developed without extensive support from colleagues or teachers, confirming the findings of Kim et al. (2010).

Creativity was found to be an important predictor of pre-service S&T teachers' proactive behaviour, especially among promotion-oriented students, already argued by Avsec and Sajdera (2019). These students display flexibility in relation to data collection, absorb information and seek out new experiences. It seems that intrinsically motivated students perceived their learning and work as an opportunity for their cognitive abilities to grow with effort and where their creative potential could be improved with less monitoring or intervention by the instructor or teacher, confirming the findings of Lee et al. (2019). The use of self-efficacy and creativity could be useful in the search for feedback as an act of proactivity, in which the people seeking feedback can ask their peers, supervisors, and teachers, and in this way deal with the higher cognitive demands of the assigned task to improve their innovative behaviour. This finding supports the findings of Chen and Zhang (2019). It seems that the social skills that are essential for teamwork, networking, and interactions are an important predictor of innovative ability, as well as a means of coping with complex real-world contexts and working environments. Moreover, creativity was found also as a moderator variable to strength influence of a self-efficacy on proactive behaviour. On the other hand, creativity was not affected by situational interest. It points to S&T tasks or assignments with rather convergent outcomes, where possibilities for interest development from situational to individual were rather seldom.

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Conclusions and Implications

A teacher's ability to innovate appears to be an important factor in improving the quality of teaching in the 21st century and a key characteristic of a high-quality education system that is able to implement contemporary technology-based educational designs. The process of innovation in teaching commences in pre-service training, where future teachers can encounter innovative pedagogies and progressively integrate them into their cognitive, affective, and conative structures while developing a proactive personality for innovative behaviour in work or learning.

The model developed in this research presents an evidence that innovative behaviour goes beyond the creativity, and an application of combined learning and behavioural theories was estimated as successful.

The social-cognitive theory and theory of planned behaviour were predictive of some direct effects: higher self-efficacy and higher attitudes towards S&T were associated significantly with greater perceived control over learning of S&T activities, and with higher level of creativity and proactivity. Moreover, greater attitudes towards S&T and higher perceived control over learning of S&T activities were not directly associated with creativity. For indirect effects, higher self-efficacy moderated with creativity and triggered situational interest influenced stronger proactive behaviour. Moreover, greater attitudes toward S&T career, greater affinity towards S&T, and greater awareness of consequences of S&T operating through perceived course design satisfaction influenced stronger proactive behaviour.

It has been also found that current design of S&T educational activities does not facilitate development of individual interest. S&T tasks and assignments seem to be too general, at low taxonomic levels and less interactive, less challenging, an absence of scaffolding strategies was detected. Providing scaffolding strategies might be helpful for deeper understanding and explanation for tasks which help students preserve learning and skills acquiring. For advancement of S&T, it is critical that students, teachers and researchers understand the potential effects of the cognitive and affective factors connected to behaviour for innovative performance. S&T teacher education programs must stress developing pre-service teachers' innovative behaviour and not just emphasize developing disciplinary knowledge and skills. It has been also established that self-regulation ability of pre-service teachers was low and consequently an ability for knowledge and skills transfer that help students increase understanding of the content, support long-term constructive and creative endeavours.

Pre-service S&T teachers' innovative behaviour can be nurtured during their training using various motivational constructs including satisfaction of their needs, articulation of their occupational self-efficacy, self-initiated development, acquisition of interdisciplinary knowledge and skills, creative real-life problem solving, development of flexibility and stability, systems thinking, goal orientation, support through collaborative learning and interactive feedback, transfer of positive experiences, networking, teamwork, scaffolded learning, and the development of making skills.

Teachers who have developed innovative behaviour will find it easier to implement any educational design in their work. Moreover, teachers with a heightened capacity for innovation are expected to be able to design and redefine their teaching/learning environments and/or transdisciplinary teaching, enabling students to achieve a wide range of learning outcomes in S&T at higher cognitive levels, thereby obtaining a high-quality education. Additionally, these teachers' innovative behaviour and learning environments will facilitate students' development of innovative behaviour at a young age, which will enhance productivity growth and value creation in the future.

In S&T teacher education program at the University of Ljubljana, a large majority of the sample presents female students. Thus, gender differences were not explored in this study and hiring more male pre-service teachers could improve students' interest in S&T, and greater emphasis should be placed on developing technology-based concepts, engineering design, and practices. Owing more diversity in students, greater transfer of team learning and greater perceived control over learning of S&T activities can be established.

The development of innovative competencies requires special treatment, including measuring the impact of innovative behaviour. The instruments used in this study are complex, and a larger sample size is required to achieve greater accuracy. Further research studies should explore the critical knowledge, skills and attitudes needed to directly or indirectly influence positive proactivity and creativity within the social-cognitive theory supported with an activity theory of technology supported learning.

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