Self-efficacy, creativity and proactive behaviour for innovative science and technology education

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ABSTRACT: Innovative pedagogies can improve teaching and learning in the 21st Century. The proactive behaviour of science and technology pre-service teachers in providing high quality education is the focus in this article. 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 proactive behaviour. By applying social-cognitive and situational strength theory, the self-efficacy, creative potential and the proactive personality of the students were analysed. Self-efficacy has a strong impact on proactive behaviour, especially when it is nurtured through mastery goal-oriented tasks. Creativity mediates proactive behaviour. Some factors affecting creative potential are not well developed. This is because of constraints in the pre-service teacher education science and technology curriculum, combined with a lack of systems thinking. These findings have implications for contemporary education and for the redefinition of education to enhance innovation in the classroom.

INTRODUCTION

Pedagogy, as teaching, is multifaceted and complex. It affects the strategic orientation of modern societies to improve the economy by reducing the gap between education system outcomes and labour market needs [1]. It combines theory and practice, ways of thinking and of implementing learning [2]. A better understanding of innovative pedagogies is required to address contemporary educational challenges, and improve teachers' professional competences and behaviour [3].

The behaviour of the teacher in guiding learning in the classroom should be based on the acquisition by students of: a) knowledge (disciplinary, interdisciplinary, epistemic and procedural); b) skills (cognitive and metacognitive, social, emotional, psychological and practical); and c) attitudes and values (personal, local, social and global) [2][4].

Pre-service teacher education programmes must strive to incorporate the most appropriate methods and content, because the acquisition of disciplinary knowledge and skills is no longer sufficient to meet the complex requirements of teaching [5-7]. Students need to apply a wide range of knowledge and skills, imparted through a set of values and attitudes, in unfamiliar and evolving circumstances where innovative behaviour is required.

The competencies required for innovative teaching can be nurtured during training and beyond. In this way, pre-service teachers can work more efficiently and be more motivated, more creative, and develop a positive attitude towards science and technology (S&T) in the lead-up to commencing service, while they actively participate in a creative, social and collaborative environment that enables them to utilise and further develop their metacognitive and psychomotor skills [5].

The primary goal of high-quality pre-service teacher education should be the development of proactive behaviour for innovative performance in the classroom that reflects a proactive personality in identifying and solving problems identified in different environments [3]. Moreover, proactive behaviour might help teachers, both pre-service and later in service, to implement a new educational design that improves various elements, such as:

1) the educational design itself;
2) the school as an institution;
3) the students' competencies;
4) the teachers' own competencies.

Pre-service teachers present an important element in the process of transferring knowledge and skills between education and practice to assist in identifying the factors influencing proactive behaviour and professional development [6-8].

In the past decade, there have been several attempts to modernise education and to optimise student learning of S&T subjects [3][6-11], but studies are rare of pre-service teachers' practice from the perspective of occupational self-efficacy, proactive behaviour and creativity in the learning of S&T.

THEORETICAL BACKGROUND

Teachers are designers of the learning environment. Innovative pedagogy should [2]:

1) reflect teacher professionalism;
2) map the content of innovation;
3) promote the natural learning inclination of students towards creativity, critical thinking, collaboration, inquiry, problem-solving;
4) plan for student-centred education;
5) provide organisational support and networks;
6) align with teacher experience and skills;
7) provide domain specifics for innovative learning;
8) provide contemporary holistic assessment frameworks.

Bandura developed a model of triadic reciprocal causation between cognition, environment and behaviour, where the relationship between cognition and behaviour is moderated by self-efficacy [12]. Self-efficacy determines whether a reaction to stimuli is positive or negative based on abilities and experiences [12]. A combination of cognitive, social, emotional and behavioural sub-skills is required for effective functioning [12].

Self-efficacy can influence motivation, interest in a subject, academic performance [12], satisfaction of basic psychological needs and proactive behaviour as a proximal variable [3], especially when social cognitive theory is applied to innovation learning [13]. Moreover, self-efficacy plays an important role in predicting a teacher's level of creativity, especially student-centred approaches to learning. On the other hand, a level of self-efficacy can be reduced with a *trial and error* approach to S&T subjects [13].

Creativity as a higher cognitive skill plays an important role in S&T education, and graduates who possess this skill are most valuable in the global market and the economy [14]. Amabile offers a definition of creativity relevant to S&T education:

> *A product or a response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic* [15].

A creative person is able to produce a wide range of ideas, processes or products that are novel, original, unexpected, imaginative or useful, as well as recognising limitations and constraints [14][15]. Creativity plays a significant role in problem-solving, where students can muster their experiences in the context of social cognitive theory, and therefore create a strong sense of efficacy [13]. Creative students may have a higher level of self-efficacy based on previous success in a subject, and this can also influence their innovative performance [3]. In contrast, those who demand more information feel less useful and less creative if tasks are not well designed [15][16].

The S&T activities in laboratories or workshops entail not only creative ability, but also analytical and practical skills. Critical thinking is important for learning [17], especially for knowledge transfer, and the application of problem-seeking and problem-solving skills to problem definition particularly for novel problems. Self-efficacy, creativity and critical thinking are important attributes for pre-service teachers when generating, developing, applying, promoting and modifying ideas. This can be attributed to a proactive personality, which is an antecedent of proactive behaviour [3].

Proactive behaviour can be seen as the human response to changes and challenges in social, economic and the natural environment, as well as being closely linked to new technologies [3][5]. Thus, a proactive pre-service S&T teacher will be able to adapt existing educational aids or experiments to the new situation, create new educational products, new educational technologies, as well as redesign existing curricula, and hence redefine it for the innovative pedagogy of the 21st Century. Proactive pre-service S&T teachers will be proficient in systems thinking, able to master goals, and collaborate in physical and virtual networks [5].

The purpose of this study is to gain insight into the individual's perception of self-efficacy, directly and indirectly, contributing to proactive behaviour in the context of the social cognitive model.

The study addressed the following research questions (RQ1 to RQ3):

RQ1: What is the relationship between pre-service teachers' self-efficacy and their creative potential?
RQ2: What is the relationship between pre-service teachers' creative potential and their proactive behaviour?
RQ3: Does pre-service teachers' self-efficacy predict their proactive behaviour?

METHODOLOGY

Conceptual Framework

For this study, a conceptual framework was drawn from the socio-cognitive theory of Bandura [12]. Reciprocal interactions between cognition, environment and behaviour determine students taught behaviour at task performance. As a result, students develop beliefs about their expected outcomes and develop perceptions about their own efficacy. The students' beliefs in their capacity for organisation and conducting activities to achieve desirable learning outcomes can moderate the relationship between cognition and behaviour; thus, students can evaluate how their abilities match the demands of the tasks. In S&T laboratories situational strength affects students' behaviour to complete tasks [18]. Moreover, laboratory work in engineering is normally supported by information communication technology to search, capture, analyse, present data and visualise results, which can promote situational strength more than in less technology intensive classrooms [9]. Socio-cognitive theory was combined with the theory of situational strength to predict the pattern of direct and indirect interactions (Figure 1).

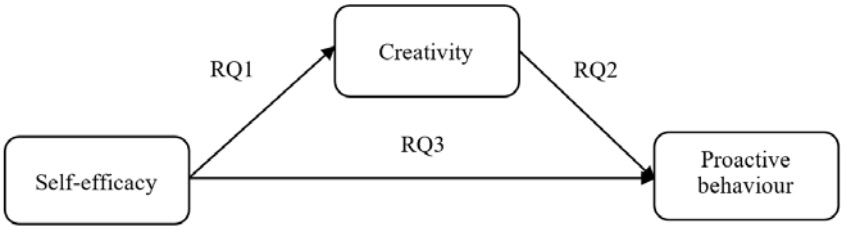

Figure 1: Relationships among the research questions (RQs).

Situational strength might significantly affect students' behaviour where the laboratory work-related responsibilities and requirements are easy to understand, and are compatible with each other. Moreover, there are several limitations to working in an S&T laboratory, where students cannot express their creativity and carry out their own experiments; individuals are limited to promoting measures to reduce negative outcomes and/or increase the likelihood of positive outcomes [18]. Teaching S&T does not encourage teachers to use autonomy-supportive approaches that would improve learning outcomes [8].

Sample

The study sample consisted of 140 pre-service S&T teachers from the University of Ljubljana, Slovenia, during the two consecutive academic years 2018/19 and 2019/20. The sample included more females (n = 123, 87.9%) than males (n = 17, 12.1%), and was 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. The students were informed of the purpose of the study.

Instruments

The pre-service teachers' self-efficacy was self-assessed using a 5-point Likert scale (1 - not very like me to 5 - very like me). A questionnaire titled *Self-efficacy and me* was constructed [19] and included sections on *feeling efficient* (eight items), *making an effort* (five items), and a new construct of *showing stability/being flexible* (three items) in the context of Bandura's theoretical concepts framed in social cognitive theory [12]. All the sections of the questionnaire are reliable based on Cronbach's alpha coefficient (*feeling efficient*: $\alpha = 0.76$, *making an effort* $\alpha = 0.74$, *showing stability/being flexible* $\alpha = 0.78$).

The pre-service teachers' creative potential was measured through the test for creative thinking-drawing production (TCT-DP) [20]. The students' level of achievement in terms of drawing production was assessed based on 14 criteria [20], and the maximum possible score on the test was 72. The TCT-DP test proved highly reliable, with Cronbach's $\alpha = 0.86$.

The level of proactive behaviour was assessed on a 5-point Likert scale (1 - strongly disagree to 5 - strongly agree) with a questionnaire called *Action and me*. The construct of proactive behaviour consisted of five items, where Cronbach's α reliability was high at $\alpha = 0.89$.

Procedure and Data Analysis

A paper and pencil method was used for the two questionnaires and the test. Students participated in the study during real-world classroom sessions throughout a study day, and were briefed about the research and ethical considerations, before completing the questionnaires and validation tasks in class.

The data were analysed with IBM SPSS (v.25). The reliability of tests was measured with Cronbach's alpha coefficient. Descriptive statistics were used to present the student's basic information, mean scores and standard deviations of

dependent variables; and multiple regression analysis to find significant relationships between groups. Exploratory factor analysis was used to identify factors in creative potential measured with TCT-DP to provide factors for multiple regression analysis.

RESULTS AND DISCUSSION

One hundred and forty pre-service S&T teachers were involved in this study. There were more male than female students, which is typical of pedagogical study programmes.

Pre-service S&T teachers' basic descriptive data are shown in Table 1. Self-efficacy and proactive behaviour results are reported on questioners' subscales. Pre-service S&T teachers reported above-average self-efficacy in all subscales, while self-reported proactive behaviour is slightly above the average.

Results of creative potential were obtained with assessment of creative drawing on 14 criteria. These criteria constitute a whole TCT-DP construct based on Urban [20]: 1) continuation; 2) completion; 3) new elements; 4) connections-graphic; 5) connections-thematic; 6) boundary breaking - fragment dependent; 7) boundary breaking - fragment independent; 8) perspective; 9) humour and affectivity; 10) unconventionality - material manipulation; 11) unconventionality - abstract/surrealistic elements; 12) unconventionality - signs and symbols; 13) unconventionality - non-stereotypical use of given elements/fragments; and 14) speed of drawing.

To find a valid structure of creative potential factors, an exploratory factor analysis was applied. A Kaiser-Meyer-Olkin sampling adequacy test of the TCT-DP was $0.80 > 0.5$, and Bartlett's test of sphericity was significant ($p = 0.00 < 0.05$). Principal component analysis (PCA) as an extraction method with oblique rotation of TCT-DP data revealed 13 criteria with communalities $h^2 > 0.60$. The criteria of *unconventionality: material manipulation* had $h^2 = 0.24 < 0.6$, which points to a validity problem and was excluded from the further analysis [21].

On the first run of PCA, the total variance of the TCT-DP factors was 73.42%; which means at least 50% of the variance could be explained by common factors, which is considered to be reasonable [21]. When Kaiser's criterion was applied to the TCT-DP, four factors had eigenvalues > 1.00 in the first run PCA. For the purpose of the study only loadings > 0.5 were considered, and they were obtained in a pattern matrix as product of Oblimin with Kaiser normalisation [21]. Creativity factors 1-4 with loadings > 0.5 expressed with a mean value are shown in Table 1.

Table 1: Descriptive statistics for subscales measuring pre-service teachers' self-efficacy, proactive behaviour and creativity in total and on factors of creativity obtained with PCA ($n = 140$).

Instrument subscales	Minimum value	Maximum value	Mean [/]	SD [/]	95% Confidence interval	
					Lower bound	Upper bound
Feeling efficient	2.00	5.00	3.96	0.55	3.86	4.05
Making an effort	2.60	5.00	4.43	0.53	4.34	4.52
Showing stability/being flexible	1.00	5.00	4.01	0.72	3.88	4.13
Proactive behaviour	1.80	5.00	3.78	0.70	3.66	3.90
Creative potential in total	7.00	61.00	37.20	10.19	35.49	38.90
Creativity factor 1	0.00	24.00	18.97	4.35	18.24	19.69
Creativity factor 2	0.00	9.00	2.15	2.24	1.77	2.55
Creativity factor 3	0.00	12.00	1.24	3.01	0.73	1.74
Creativity factor 4	4.00	24.00	14.72	4.38	13.99	15.46

Creativity factor 1 aggregates scores for the following five criteria: *continuation, completion, unconventionality: surrealistic/abstract elements, unconventionality: not-stereotypical elements,* and *speed.* Fulfilling criteria of *continuation* and *completion* points to basic fragment dependent usage, while *unconventionality* reflected in *surrealistic/abstract elements* and *not-stereotypical completion of existing fragments* reveals students' ability for visualisation and representation, thus creating a broad picture.

Creativity factor 2 includes two criteria: *humour and affectivity,* and *unconventionality: signs and symbols.* Scores on these two criteria might revel students' ability for empathising, which can be most useful at user design tasks.

Creativity factor 3 includes two criteria: *boundary breaking: fragment dependent, and independent.* This factor points to risk-taking ability in pre-service teachers.

Creativity factor 4 includes four criteria: *new elements, connections graphic, connections thematic* and *use of perspective.* This factor could reflect ability to create composition and novelties.

The present study was an attempt to seek answers to RQ1-RQ3. A complex theoretical model was created, in which a linear relationship was proposed between the variables/factors studied at each level of the model. The regression model predicts relationships with a standardised 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. Shown in Figure 2 is a summary of the multiple regression analyses with significant β values ($p < 0.05$).

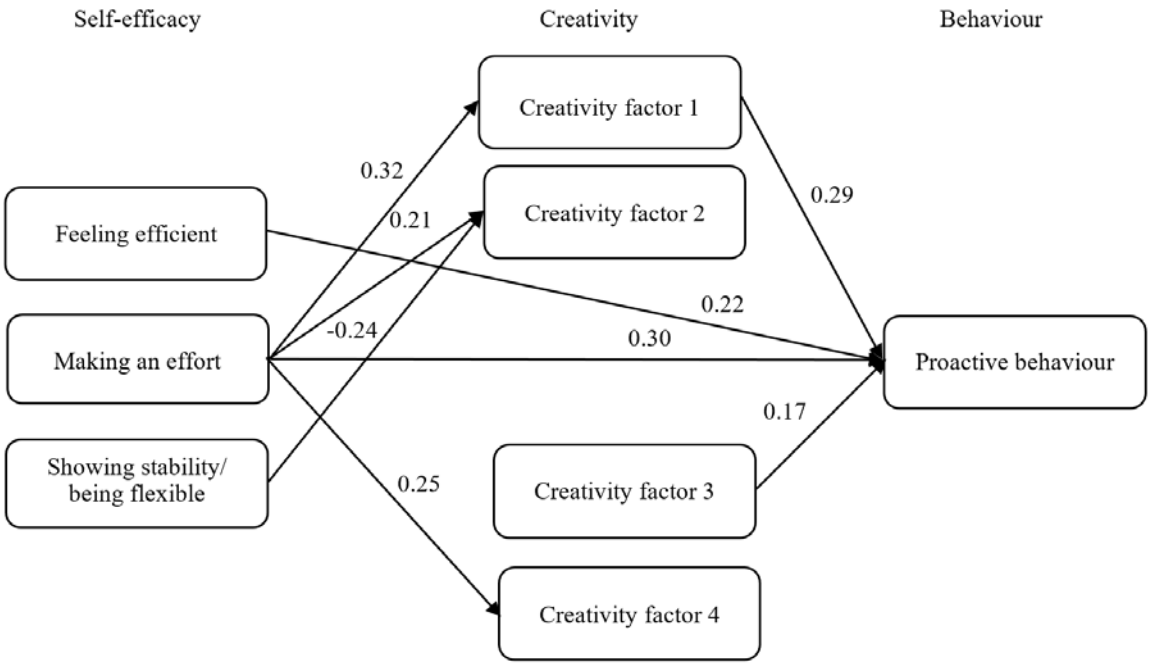

Figure 2: A model showing the relationships among self-efficacy, creative factors, and proactive behaviour with significant ($p < 0.05$) standardised regression coefficients ($n = 140$).

Pre-service S&T teachers' self-efficacy was found to be a significant predictor of their creativity and of proactive behaviour. A belief that ability can increase with effort significantly predicts proactive behaviour (β = 0.30), creative performance regarding students' ability for visualisation, representation and making basic designs using constraints and rules (β = 0.32). Students' beliefs that hard work pays off can be useful at problem identification and definition, using empathy and symbolic language in the sense of diagrams and representations (β = 0.21). Their belief in their ability to meet specific goals and/or expectations significantly predicted their proactive behaviour (β = 0.22). It was also found that students' perception of their stability and flexibility, while performing S&T tasks might decrease their creative ability in the emotional component and the use of symbolic language (β = -0.24).

Situational strength might decrease creative potential due to tasks completed without failure, i.e. students just follow rules for correct work to decrease the likelihood of negative outcomes and increase the likelihood for positive learning outcomes, as argued by Meyer et al [18]. More predictive value in both creativity and proactive behaviour can be achieved with more authentic tasks, where students can take advantage of risk-taking and are required to apply, more frequently, different knowledge, skills and developed attitudes toward S&T, so as to cope with diverse situations [13][22].

Pre-service S&T teachers' proactive behaviour was found to be an important factor driving their innovative behaviour. Proactive behaviour is largely affected by students' ability to use available fragments, which are modified with abstract or surrealistic elements and completed in a new, not-stereotypical way, as a response to S&T challenges or problems (β = 0.29). Proactive behaviour is also affected by students' ability to take risks in laboratory work, design work or at other S&T activities (β = 0.17), which is highly correlated with creativity, as measured by the TCT-DP test (β = 0.49).

Creativity factor 2, which has *humour and affectivity*, and *unconventionality: signs and symbols* does not have significant predictive value for proactive behaviour, and similarly for creativity factor 4, where ability for creating composition and novelties does not affect proactive behaviour, and is much affected by situational strength that confirms the theoretical concept of Meyer et al [18].

The laboratory work is compatible with that which allows students to work, taking into account constraints and limitations. Experimentation in a science laboratory obeys strict rules and planned procedures, so as not to make mistakes, while work in technology and engineering workshops is oriented to make products by well-prepared design considering all constraints and limitations, e.g. material, economic factors, time and engineering processes.

Creativity factors 2 and 4 in proactive behaviour needed for effective teaching of S&T imply the application of information and communication technology, not just plug and play as a black box [11], discussing possible misconceptions and relating them to real-world cases [7]. Creativity factor 4 implies more teacher-autonomy approaches to problem-solving, such as in design-based work and thinking [16].

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 [22].

CONCLUSIONS

The findings suggest that self-efficacy, perceived control over learning of S&T and creative thinking skills are needed in collaborative innovation processes. Pre-service S&T teachers' self-efficacy was found to be an important predictor in proactive behaviour, especially when it is moderated with creativity. Pre-service S&T teachers who believe that their ability increases with effort are task-oriented and more likely to be engaged with higher cognitive tasks, while those with repeated negative mastery experiences were more likely to experience a decrease in self-efficacy.

Cognitive flexibility was found to be an important prerequisite for pre-service S&T teachers' proactive behaviour in the context of innovative pedagogy. Moreover, it could be that a lack of originality in students' projects, a weak problem definition, no proper feedback and time pressure can suppress creativity. A systems thinking approach to problem-solving and decision-making can increase the predictive strength of factors affecting proactive behaviour.

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