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STUDENT-CENTRED INSTRUCTION IN SCIENCE AND TECHNOLOGY: A MODEL OF FACTORS AT ORGANIZATIONAL AND INDIVIDUAL LEVELS

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Abstract/Izvleček To achieve the goals of modern science and technology teaching, it is vital to organize student-centred instruction (SCI). The organization of SCI requires the teacher's ability to organize cognitively challenging teaching in a stimulating environment. The fundamental purpose of the study was to determine whether the teacher's organization of SCI was related to factors at the school level (organizational context) and factors at the individual level (individual context). We designed a model comprising four sets of factors. The results show a statistically significant correlation between SCI and all four sets of factors.

Keywords:
student-centred instruction; science and technology; four-factor model; professional development; stimulating environment.

Na učenca osredinjen pouk naravoslovja in tehnike: model dejavnikov na organizacijski in individualni ravni
Na učenca osredinjen pouk je bistvenega pomena za doseganje ciljev sodobnega pouka naravoslovja in tehnike. Organizacija takšnega pouka zahteva učiteljevo zmožnost oblikovanja kognitivno izzivalnega pouka v spodbudnem učnem okolju. Temeljni namen raziskave je bilo ugotoviti, ali je učiteljeva organizacija na učenca osredinjenega pouka povezana z dejavniki na ravni šole (organizacijski kontekst) in dejavniki na individualni ravni (individualni kontekst). Oblikovali smo model, ki vsebuje štiri sklope dejavnikov. Rezultati so pokazali statistično pomembno povezavo med poukom, naravnanim na učenca in vsemi štirimi sklopi dejavnikov.

Ključne besede:
pouk osredotočen na učenca; naravoslovje in tehnologija; model štirih dejavnikov; profesionalni razvoj; spodbudno okolje.

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Introduction

The goal of modern teaching in a knowledge society is to provide an in-depth understanding of basic concepts, media literacy, and facility in using advanced information technology, as well as to develop teamwork skills, social and communication skills, and independent lifelong learning skills. The outcome of education is the development of students' ability to use acquired and designed knowledge and skills in a variety of situations, as flexibly and creatively as possible (Dumont and Istance, 2013).

To achieve this goal, it is important to organize student-centred instruction (SCI), based on the didactic principle of comprehensive student activity. There are several terms for describing a student-centred approach to instruction, such as learner-centred instruction (Meece, 2003), learner-centred teaching (Soysal and Radmard, 2016; Du Plessis, 2020), student-directed learning (Zimmerman, 2002), and student-centred learning (Sin, 2015); these all originate in the assumption that students become deeply engaged in learning when teachers support students in generating their own strategies to solve cognitively challenging tasks and in constructing their own understanding of concepts (Talbert et. al., 2019). In this paper we chose the term SCI, because we define such instruction as a planned process in which learning and teaching are intertwined and in which student's and teacher's roles change places and complement one another according to the set learning goals.

Despite emphasizing the importance of SCI at the levels of education policy and practice, as noted by Talbert et. al. (2019), for the field of mathematics, very little research has been done to examine the relation between student-centred instructional practice in mathematics and adolescents' engagement in mathematics coursework.

In the effort to encourage the comprehensive development of the various individuals in a classroom, it is important to choose forms and methods of teaching and implementing didactic-methodological activities in line with clearly defined learning outcomes (Valenčič Zuljan and Kalin, 2020; Plešec Gasparič and Valenčič Zuljan, 2019). Good and Brophy (2003) point out that active learning occurs in situations where teaching is targeted, i.e. expressed through clear expectations to make decisions about the best methods and procedures for achieving optimal learning outcomes. Hattie (2018) states that a teacher's passion for evaluating the impact of their own teaching is a fundamental and critical lever for teaching excellence.

During the SCI process, it is necessary to become acquainted with students' prior knowledge, experiences, interests, needs, perceptions, attitudes, and motivations (Valenčič Zuljan, 2016). Thus, organized student-centred Science, Technology, Engineering, and Mathematics (STEM) instruction facilitates the transfer of knowledge about science and technology, while supporting critical thinking (Tamim and Grant, 2013; Zuljan and Valenčič Zuljan, 2015) and raising student motivation for, interest in, and positive attitudes about science and technology (Burris and Garton, 2007; Boddy et. al., 2003; Cotič et. al., 2018). It further enables the development of independent and creative individuals who can work together as a team and take responsibility for self-reflection as regards their own lifelong learning (El Hammoumi et. al., 2020).

In order to help students in modern teaching learn independently in the process of active learning, an environment must be provided in which teaching is characterised by a stimulating classroom atmosphere, where the teacher has positive attitudes towards students' success, shows interest in all students, uses scaffolding, and adapts learning activities to fit student abilities and interests (Good and Brophy, 2003; Wilen et. al., 2008). Valenčič Zuljan (2016) emphasizes the importance of teachers having high expectations of each student and explains that a good learning environment aims to encourage the mental and emotional activity of each student, i.e., establishing an atmosphere with many activities that require perseverance and hard work but are nonetheless achievable. Various studies confirm the importance of a quality classroom environment for student learning and of education quality for student motivation, positive attitudes towards learning and teaching, and student self-esteem (Arisoy et. al., 2007; Chionh and Fraser, 2009; Fraser, 2012; Good and Brophy, 2003; Mucherah, 2008; Pečjak et al., 2009; Valenčič Zuljan et al., 2012; Valenčič Zuljan, 2016; Vujičić et. al., 2020).

The teacher's role in SCI approaches is much more demanding than in the traditional way of teaching. Thus, it is not surprising that doubts, challenges, and questions arise concerning the time available to achieve outcomes (cover the curriculum), prepare students for successful external exams, create a positive classroom atmosphere, and maintain discipline, successful classroom management, and collegial acceptance (Boddy et al., 2003; Kazempour, 2009; Tamim and Grant, 2013; Vujičić at. al., 2020).

Research Problem and Research Questions

Teachers' professional activity – their motivation and didactic ability to create an atmosphere in which to encourage all students towards excellence in readiness for continuous professional development – is important for achieving modern student-centred STEM instruction goals. To encourage SCI in science and technology (both in the process of initial teacher education at the university level and later in teaching practice), it is important to understand what factors are associated with the teachers' organization of individual-centred instruction.

In this study, we were interested in whether the teachers' organization of SCI is related to factors at the school level (organizational context) and factors at the individual level (individual context). We designed a model of four sets of factors: 1) fostering an environment for student learning, 2) encouraging teachers' professional development, 3) teachers taking on a broader professional role, and 4) teachers' attitudes about professional development.

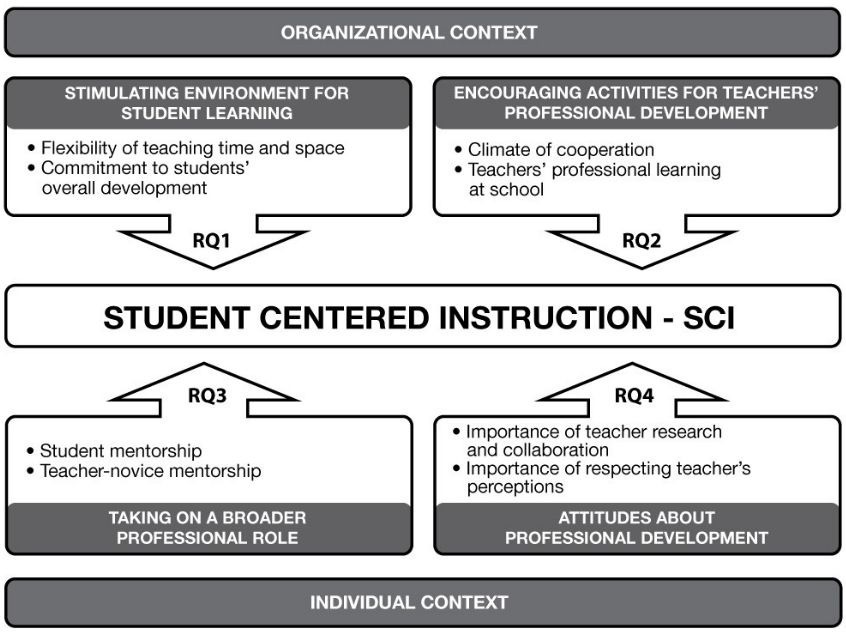

Figure 1. Research model.

In line with the research problem, research questions (RQs) were set that connect SCI with factors at the organizational level (first and second RQs) and at the individual level (third and fourth RQs).

Organizational context:
RQ1: Is there a statistically significant correlation between the teacher's organization of SCI and the elements of the school climate – a stimulating environment for student learning?
RQ2: Is there a statistically significant correlation between the teacher's organization of SCI and elements of the school climate – encouraging activities for teachers' professional development at school?

Individual-level context:
RQ3: Is there a statistically significant correlation between the teacher's organization of SCI and teacher characteristics in terms of broader professional engagement?
RQ4: Is there a statistically significant correlation between the teacher's organization of SCI and teachers' characteristics, namely their attitudes towards professional development?

Research methodology

Method
In our research, we used the quantitative pedagogical research approach and the causal, non-experimental method of educational research.

Sample
The study included 166 elementary school teachers from various elementary schools in the Republic of Slovenia, with 5 (3%) male and 162 (97%) female teachers. Of these, 7.1% (12) of teachers had worked up to 3 years, 5.39% (9) between 4 and 6 years, 28.74% (48) between 7 and 18 years, 35.32% (59) between 19 and 30, 22.75% (38) between 31 and 40, and 0.6% (1) provided no data.

Instrument and Procedures

Data were collected with six different scales developed as part of the project "Culture of Educational Institution as a Factor in Co-Construction of Knowledge". The Organization of SCI Scale comprised six items, which focused on student activity. Teachers assessed how often they organized classes in which the students observed independently, collected information, formulated hypotheses, carried out experiments, verified assumptions, analysed results, and drew conclusions (Table 1). A 5-point Likert scale (Never; Rarely; Sometimes; Often; Very Often) was used. The Cronbach alpha reliability coefficient was 0.831.

Table 1: Basic descriptive statistics

	N	**Min**	**Max**	**$\bar{x}$**	**Skew.**	**Kur.**
Teacher's organization of SCI	166	12	30	23.01	-.341	.145

The organizational context was measured with two scales: the Stimulating Environment for Student Learning Scale and the Encouraging Teachers' Professional Development Scale. The Stimulating Environment for Student Learning Scale contained the subscale Flexibility of Teaching Time and Space with three items, the Cronbach's alpha is 0.592, and for the subscale Commitment to the Overall Development and Learning of Each Individual with four items, the Cronbach's alpha is 0.751. The Encouraging Teachers' Professional Development Scale contains the subscale Climate of Cooperation among Teachers with four items, where the Cronbach's alpha is 0.744. For the subscale Encouraging Teachers' Professional Learning with two items, the Cronbach's alpha is 0.608. Teachers assessed individual items on a five-point scale regarding the extent to which the item applied to their school: 1– Strongly disagree; 2 - Disagree; 3 – Not sure; 4 – Agree; 5 – Strongly agree.

The context of the individual level (of an individual) was measured with two scales: the Taking on a Broader Professional Role Scale with two items, and the Teachers' Attitudes about Professional Development Scale with two items, where the Cronbach's alpha is 0.553. Teachers assessed individual items about attitudes on a five-point scale regarding the extent to which each item applied to them: 1– Strongly disagree; 2 - Disagree; 3 – Not sure; 4 – Agree; 5 – Strongly agree.

Data Analysis

Data were processed according to descriptive and inferential statistics. The correlation coefficient (r_s) and the Mann-Whitney U test for independent samples were used.

Research Results

Teachers' Organization of SCI and the Organizational Context

A stimulating environment for student learning and the encouragement of activities for teachers' professional development were assessed in the organizational context. Within the framework of a stimulating environment for student learning, we were interested in the elements of evaluating Flexibility of teaching time and space, and Commitment to the overall development of individuals.

SCI – Flexibility of Teaching Time and Space in School

According to Vujičić et. al., (2020), the spatial environment provides opportunities for connecting students with the content to be learned. This is achieved by defining the area of activity. The flexibility of teaching time and space in organizing SCI was measured with three elements (Table 2).

Table 2: Correlation coefficient (r_S) between SCI and assessing the flexibility of teaching time and space in the organizational context

SCI **Flexibility of teaching time and space in the school**	$\bar{x}$ s	r_S p N
1. It is possible to organize teaching time flexibly with a lesson that is not limited by the school bell.	3.40 1.16	.160* .021 163
2. The usable space outside the classroom is also adapted for teaching.	4.03 0.82	.145* .031 165
3. In the classroom, the chairs are arranged in such a way that it is possible to organize group work, and the environment is stimulating for two-way communication between the teacher and the students and between the students themselves.	4.21 0.78	.234** .001 166

Legend: * $p < .05$. ** $p < .01$.

An overview of the arithmetic means (Table 2) shows that the more frequently present items are associated with allowing space adaptation compared to the item associated with flexible teaching time organization. Among these three elements, the most prevalent is spatial organization in the classroom to enable the organization of various forms of work and encourage two-way communication ($\bar{x}$ = 4.21), followed by the use of space outside the classroom ($\bar{x}$ = 4.03). Slightly lower, but still with a high mean value ($\bar{x}$ = 3.40), is the possibility of flexible teaching time arrangements. Our research showed a statistically significant correlation between SCI and all three elements related to the flexibility of teaching time and space in school. Those teachers who organize SCI more often provide assessments that are statistically significantly higher, affirming that teachers in their school can flexibly organize time within a lesson that is not limited by the school bell (r_S = .160*, p = .021); to adapt the learning space in such a way that the layout of the desks enables the organization of various forms of work and cooperation of all teaching participants (r_S = .234**, p = .001); and to adapt and use the space outside the classroom (r_S = .145*, p = .031).

SCI and Teachers' Commitment to the Overall Development and Learning of Each Student

Schoolteachers' commitment to the development and learning of individuals was measured with four elements (Table 3).

Table 3: Correlation coefficient (r_S) between SCI and schoolteachers' commitment to the overall development and learning of each student

SCI **Schoolteachers' engagement with/commitment to the overall development and learning of each student**	$\bar{x}$ s	r_S p N
1. Excellence is encouraged – excellence of each individual.	4.23 0.72	.218** .003 164
2. Teachers highly value students' learning skills.	4.14 0.68	.227** .002 164
3. Encouragement of collaboration among students is an important goal for every teacher in our school.	4.26 0.72	.261** <.001 167
4. It is important for teachers in our school to encourage students to develop science and technical literacy.	3.93 0.73	.168** .016 163

Legend: ** $p < .01$.

Teachers rate the presence of all four elements relatively high. The review of arithmetic means shows that teachers assess that their colleagues encourage cooperation between students ($\bar{x}$ = 4.26), encourage excellence, i.e., individual excellence ($\bar{x}$ = 4.23) but also the students' skill in learning to learn ($\bar{x}$ = 4.23). The arithmetic mean value is slightly lower for the item "It is important for the teachers of our school to encourage students to develop science and technical literacy" ($\bar{x}$ = 3.93). According to Suprayoga and Valckei (2016), the stated context of the modern SCI process determines the application of strategies, diversity in learning activities, monitoring of students' individual needs, and achieving learning outcomes.

We found a statistically significant correlation between SCI and all four elements of staff commitment to the overall development and learning of each student. Teachers who more often organize SCI are statistically significantly more likely to assess that their school encourages student excellence (r_S = .218**, p = .005), cooperation among students (r_S = .261**, p = .001), student learning skills (r_S = .227**, p = .004), and the development of science and technical literacy (r_S = .168**, p = .003).

SCI and the Climate of Collaboration Among Teachers

The climate of cooperation in the organization was measured with four elements (Table 4).

Table 4: Correlation coefficient (r_S) between SCI and the climate of collaboration among teachers

SCI **Climate of collaboration among teachers**	$\bar{x}$ s	r_S p N
1. Teachers of different subjects carry out interdisciplinary teaching.	3.48 0.89	.195* .006 162
2. Teachers at our school can always count on the support and help of professional associates (school counselling services).	4.09 0.83	.189* .007 166
3. Pedagogical staff with varied profiles cooperate on an equal basis.	4.14 0.81	.171* .014 166
4. We have a clearly defined school vision, which is accepted by all school staff.	3.69 0.87	.133* .044 166

Legend: * p < .05.

The review of arithmetic means shows teachers assessing with high values that teachers at their school can always count on the support and help of professional associates ($\bar{x}$ = 4.09), and that various pedagogical staff members cooperate on an equal basis ($\bar{x}$ = 4.12). Somewhat lower arithmetic means were obtained for conducting interdisciplinary teaching ($\bar{x}$ = 3.48) and having a clearly defined school vision accepted by all school staff ($\bar{x}$ = 3.69). We found a statistically significant correlation between SCI and all four elements of collaboration among teachers. Teachers who more often organize SCI prove to be more statistically significantly appreciative of the support and help of professional associates who can always be counted on (r_S = .189*, p = .007), a clear school vision accepted by all school staff (r_S = .133*, p = .044), conducting interdisciplinary teaching (r_S = .195*, p = .006), and cooperation of pedagogical staff of various profiles within the team (r_S = .171*, p = 0.014).

SCI and Encouragement of Teachers' Professional Learning

The teacher's role in SCI approaches is much more demanding than traditional modes of teaching, so it is essential that teachers be encouraged to engage in professional development and enabled to do so in various ways. Supporting professional development, investing in learning, continuous professional development, and the research into personal practice become the main drivers of self-organizing processes comprising institutional development aimed at continuously changing student-centred educational practice. Encouraging teachers' professional learning was measured with two elements of the educational organization that teachers assessed, specifically how often these were made available (Table 5).

Table 5: Correlation coefficient (r_s) between SCI and encouraging teachers' professional learning

SCI **Encouraging teachers' professional learning**	$\bar{x}$ s	r_S p N
1. At our school, quality internal professional development is organized for teachers.	4.33 0.74	.186** .008 166
2. Teachers at our school are encouraged to participate in various forms of professional development outside school.	4.07 0.83	.195** .006 166

Legend: ** $p < .01$.

The results indicate that both elements for encouraging professional learning are highly present ($\bar{x}$ = 4.33 and $\bar{x}$ = 4.07) (Table 4). We found a statistically significant correlation between SCI and both elements for encouraging professional learning. Teachers who more often organize SCI assess as statistically significantly higher the potential for organized, quality, internal professional development at school (r_S = .186*, p = .008), as well as incentives for teacher participation in various forms of professional development outside the school (r_S = .195**, p = .006).

Teacher s' Organization of SCI and the Individual Context

In the individual context, teachers' broader professional activities were assessed; we measured these by their having taken on the role of mentor and by teachers' attitudes about professional development.

SCI and Taking on the Broader Professional Role of Mentor

Teachers' broader professional activities were measured through their mentoring of students in pedagogical practice, internships or student performances, and mentoring interns (over a period of three years) (Table 6).

We were interested in whether teachers who more often organize SCI invest more in professional mentoring activities. The variable of SCI is not normally distributed (Kolmogorov-Smirnov test for the variable of SCI Z = 0.131, 2p = <.001).

Table 6: Results of the Mann-Whitney U test that explored the differences in SCI and the teacher's role of mentor

SCI				**Test statistics**		
Broader professional role		***N***	**Mean Rank**	***U***	***Z***	***2p***
1. Mentoring students in pedagogical practice, during internships, or student performances.	no	38	59.04	1502.500	-3.34	.001
	yes	123	87.78			
2. Mentoring interns.	no	120	75.47	1704.000	-1.83	.067
	yes	35	91.31			

We can observe from Table 6 that teachers are more likely to mentor students than to mentor interns, which is understandable, given the extent of pedagogical practice. The Mann-Whitney U test for independent samples (Table 6) showed that teachers who organize SCI are statistically significantly more likely to take on the role of mentor to students (2p = .001).

No statistically significant differences were found between SCI and mentoring of interns ($2p = .067$), showing a correlation that is not statistically significant.

SCI and Teachers' Attitudes about Professional Development

Attitudes about group research on educational practice, which is the foundation for change and progress, and those about teachers' professional development – how to respect and change teachers' perceptions and beliefs – were measured with two items (Table 7).

Table 7: Correlation coefficient (r_S) between SCI and teachers' attitudes about professional development

SCI **Teachers' attitudes about professional development**	$\bar{x}$ s	r_S p N
Teachers' joint research of educational practice, different teams, and researchers is the foundation for changing pedagogical practice.	4.10 0.73	.265** <.001 165
Teachers' professional development should take account of and change teachers' perceptions and beliefs.	4.01 0.81	.103 .094 165

Legend: ** $p < .01$.

Table 7 shows that there is a statistically significant correlation between teachers' attitudes about joint research on teachers' educational practice, various teams, and researchers, which is the foundation for changing pedagogical practice and teachers' organization of SCI ($r_S = .265^{**}$, $p < .001$). However, we found no statistically significant differences between SCI and the attitudes of which teachers' professional development should take account to change teachers' perceptions and beliefs ($r_S = .103$, $p = .094$).

Discussion and conclusions

In order to achieve the goals of modern science and technology teaching, it is vital to organize SCI. The structure of teaching is important for the quality of the SCI process (Barron and Darling-Hammond, 2013). It is necessary for the teacher's professional ability to harmonize the planned outcomes with the manner of teaching; to respect students' interests and needs; to provide organizational support (e.g., setting clear expectations, managing instructional time and routines so that students have the maximum opportunity to learn) and instructional support (e.g., providing constructive feedback, using strategies to promote children's thinking and understanding of the content at a deeper and more complex level, and modelling) (Barron and Darling-Hammond, 2013; Downer et al., 2015; Martin and Rimm-Kaufman, 2015).

The purpose of the study was to evaluate the model of factors in SCI. The results of this study confirm the multi-factor model at the level of the context of the organization and at the individual level.

The results indicate a statistically significant correlation between SCI and all elements of a stimulating environment for student learning, both the flexibility of teaching time and space and the engagement of schoolteachers in the student's overall development.

The study has shown that teachers who organize SCI are more likely to report a statistically significant higher evaluation of the elements flexibility in teaching time and space in school. The importance of the spatial environment stems from its impact on student's academic, social, and emotional development, the learning process, and student perceptions of learning and school (Farmer et. al., 2011; Gest and Rodkin, 2011; Kutnick and Kington, 2005; Van den Berg et. al., 2012; Wannarka and Ruhl, 2008).

Encouraging individual excellence, development of students' science and technical literacy, facilitating the acquisition of learning skills in students, and the development of cooperation among students are important goals in SCI. The engagement of all teachers in the student's overall development is important for the success of such teaching. This is a demanding goal, and in order to be realized, teachers must have positive expectations of their students. They must also encourage students to achieve outcomes with the belief that even lofty goals can be achieved through diligent learning and effort (Wilen et. al., 2008).

For students to realize their potential, the teacher must offer various forms of scaffolding (Valenčič Zuljan, 2016), as well as respect for the didactic principle of differentiation and individualization (Valenčič Zuljan and Kalin, 2020). Our study has shown that teachers who organize SCI are more likely to record higher evaluations—to a statistically significant level--for all four elements of commitment to the overall development and learning of individuals: encouraging excellence in each student and cooperation among students, while encouraging student learning, and the development of science and technical literacy.

Several studies (Day et al., 2007) confirm the importance of collegial support and the support of principals for achieving excellence in teachers' professional work and professional development. The research established a statistically significant correlation between SCI and elements of cooperation between teachers. Those teachers who organize SCI more often report greater appreciation--on a statistically significant basis--for the collective support and assistance of professional associates who can be counted on at any time, with the indication that there is a clear school vision that is accepted by all school staff, and interdisciplinary classes are conducted with the teamwork of colleagues from different fields.

The goal of SCI should be continuous improvement of the teaching process, which includes the implementation of continuous professional learning even during the teaching and solving of collaborative problems to further improve professional development activities, providing opportunities to gain an understanding of theories aimed at improving student learning. It is precisely SCI that requires the teacher's competency to differentiate and individualize learning. It is a complex competency that develops, according to research findings, during later stages of teachers' professional development (Antoniou and Kyriakides, 2011, Pečar, 2018; Van den Lans et. al., 2017). Furthermore, it is important to emphasize that, in for teachers to have both a positive attitude towards SCI and the necessary didactic competencies for teaching, it is necessary to organize higher education for the teaching profession according to the model of SCI. Organized learning activities are thus needed in the later stages of teachers' professional careers (Plešec Gasparič et. al., 2020).

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