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TRANSDISCIPLINARY APPROACH OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS EDUCATION

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Abstract. *At the end of 20th century and especially in this century the education field is undergoing a significant change not only as a result of technological innovations but also pedagogical innovations on the bases of artificial intelligence (AI), cognitive science and neuroscience. What interested us was the attitude of students and teachers towards these changes. In the research the participating students were arranged in two groups, the control group (CG), where conventional lessons were carried out and the experimental group (EG), in which teachers used a transdisciplinary cognitive neuroeducation model. The performance data for the both groups was acquired via questionnaire adopted from TIMSS research. The teachers' attitude towards these changes was mostly monitored via qualitative research.*

As is appa*rent from the results, a positive shift can be seen in the students' attitude towards school. And this positive attitude towards school can create in students the suitable motivation, which is the first and most important step towards quality knowledge. A positive shift was also made in the minds of the teachers.*

Key words: *artificial intelligence, cognitive science, cognitive neuroeducation model, multidisciplinarity, neuroscience, transdisciplinary model.*

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Introduction

In the last decade much research was done in the field of education that predicted the crucial changes in the educational systems. To state a few: Innovative learning: key elements for developing creative classrooms in Europe (Bocconi, Kampylis, in Punie, 2012, Dumont, Istance, Benavides, 2010)), Education for all; Global monitoring report: Education for all by 2015, will we make it? (UNESCO, 2008), Creating effective teaching and learning environments: first results from TALIS (OECD, 2009), Understanding the Brain: The Birth of Learning Science (OECD, 2007), Bringing a 1-to-1 Program to Life (Microsoft Partners in Learning, 2010). And certainly a number of other researches: PISA, UNESCO, EU commissions, PIRLS, ICILS, TAUS, HBSC... All these researches show that the space of education is drastically changing, that it requires new paradigms and approaches to teaching, especially while introducing new technologies. And actually, in the field of education many innovative shifts have been made.

A brief overview of these shifts shows three phases of innovation and modernization of the education:

1. *Technological phase* – when schools are equipped with computerized-technological equipment.
2. *Content phase* – when intensively encouraged creation and preparation of modern e-learning materials are created.
3. *Methodological phase* – when society started to understand that in order to elevate the quality of education it is simply not enough to technologically equip the schools and adjust some learning contents "in some way" to new technological possibilities but that they have to completely change the concepts and paradigms of teaching in a planned and systematic way.

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Modern information and communication technology presents an opportunity for greater effectiveness and equality in education. It is well known from literature, that only a few of the statements that say that the use of new technologies allows for a wholesome transformation of learning are convincingly supported by research. The prime reason for this is that these claims are most often followed by "technology focused" instead of "learning focused" teaching approach. (OECD, 2013) This is why, if educational policy makers wish to develop a society of equal opportunities, they must use new and effective approaches to teaching and educating. This means that educational policy needs a change in the way pedagogical practice is conducted, mostly in the paradigms of teaching (Flogie, Dolenc, Aberšek, 2015).

New Paradigm: From Interdisciplinarity to Transdisciplinarity

In ancient Greece, knowledge was not strictly bound to the knowledge of the individual discipline and then leading scholars were able to devote freely to various in this scientific area. The influence of reductionism that began with Aristoteles and continued intensively until the end of the previous Millennium has created many of individual disciplines with precisely defined boundaries and methods of work (Bregant, Stožer, Cerkvenik, 2010).

In the field of education, we have in recent decades, defended in particular the multidisciplinary approaches, which argument that each discipline is allowed a high degree of autonomy and basically precluded any possibility of creating something new. This can be nicely seen in the introduction of the discipline of science, for example in the Slovene schools, which from the starting point of the subject Natural science strictly divided between three basic disciplines of physics, chemistry and biology. Such an approach, however, is no longer involved in the philosophy of competences and competence-based curricula that are an irresistible trend of the development of education worldwide. It is not enough that students are given knowledge and skills, but they also need to have the experience of how to use them, and must be given the tools with which they can solve problems in their daily lives. Students need to be given the basic and generic competencies (Pešakovič, Flogie, Aberšek, 2014); they however do not focus on the individual scientific disciplines, but mainly on their integration on their *fusion* in concrete life situation with the concrete objective of this moment. This means that the field of paradigm of education needs to rise to a higher level. The process of teaching/learning needs to be observed transdisciplinary, which in our case means exploration of a relevant issue or problem in education in such a way that it integrates the perspectives of multiple disciplines in order to connect new knowledge and deeper understanding to real life experiences.

Transdisciplinarity

Transdisciplinarity could include integration (better fusion) of many disciplines and the incidence of new subsidiary discipline. The model uses transdisciplinary approach pointing out that each area is independent of the other; they have their own tools for analysis. As a separate discipline becomes more mature, the walls between them grow, making the differences become less logical. To be able to skip these boundaries, these walls between disciplines, a certain kind of dynamic meta-structures need to be created, combining the structures of the old disciplines and the creation of new parts of the disciplines. The current status of neurosciences, cognitive science psychology, artificial intelligence and education is a fine example of such a division between the disciplines.

Transdisciplinary Cognitive Neuroscience Paradigm

Researchers Suarez-Orozco and Satin-Bajaj believe that when disciplines reach maturity, a dynamic meta-structure is needed which facilitates merging and new divisions of disciplines. Under such a meta-structure, the disciplines propel the evolution of knowledge, but adapt themselves when sufficient driving forces emerge to provoke their adaptation (as cited in OECD, 2007, p. 133). Hirsch Hadorn and others are of the opinion that in the case of neuroscience, cognitive science and education, the more comprehensive understanding of learning is a compelling driving force as it is critical to broader goals such as sustainable economic growth, societal cohesion, and personal development (as cited in OECD, 2007, p. 133).

The current state of neuroscience, cognitive science and education provides a good illustration of the shortcomings of disciplinary separation (Aberšek, 2013). On learning, recent advances in neuroscience and cognitive science have produced powerful insights while educational research has accumulated a substantial knowledge base (Aberšek, Borstner, Bregant, 2014a, 2014b). Researchers Nicolescu and Stavinschi believe that neuroscientific perspective on learning adds a new important dimension to the study of learning in education, and educational knowledge could help direct neuroscience research towards more relevant areas (Nicolescu, Stavinschi, 2007). Because both fields are well-developed, however, they have deeply-rooted disciplinary cultures with field-specific methods and language which make it extremely difficult for experts from one field to use the knowledge from the other (as cited in OECD, 2007, p. 132). In Figure 1 proposal for fusing neuroscience, cognitive science, education and other relevant disciplines, and creating a new trans-disciplinary field would connect work on learning across the intellectual walls dividing disciplines is shown (Flogie, Dolenc, Aberšek, 2015).

Various mentioned researchers in implementing transdisciplinarity mostly stress the importance of connecting education with neuroscience. However, the hereby presented model stresses the demand that such a model needs to be wider, more complex and that a transdisciplinary model needs to: for the most part, include also the latest results from cognitive science, especially in the recent decades due to rapid development in the field of information and communication technology, artificial intelligence (AI) and the use of the AI methods in the process of modern education. Thus, the model was named "cognitive neuroeducation" and it stresses two important premises:

- it is true that in learning and teaching one must begin with neuroscience and take into account the way the human brain acquires and processes information,
- however, one must in doing so also take into account the possibility of creating suitable learning environments.

However, in doing so one must not perceive the process of education partially, from the individual field's point of view, and also not multidisciplinary, where on one side their mutual interaction is taken into account but at the same time it allows that each constituent component has its own method of operating and its own vocabulary but one needs to create common and unified methods of operating and a common vocabulary. Only in such a way a common and unified way of educating can be developed while at the same time allowing experts from different fields to understand each other. Thus, making it the beginning of a new era in the educational theory as a newly created uniform theory for the 21st Century.

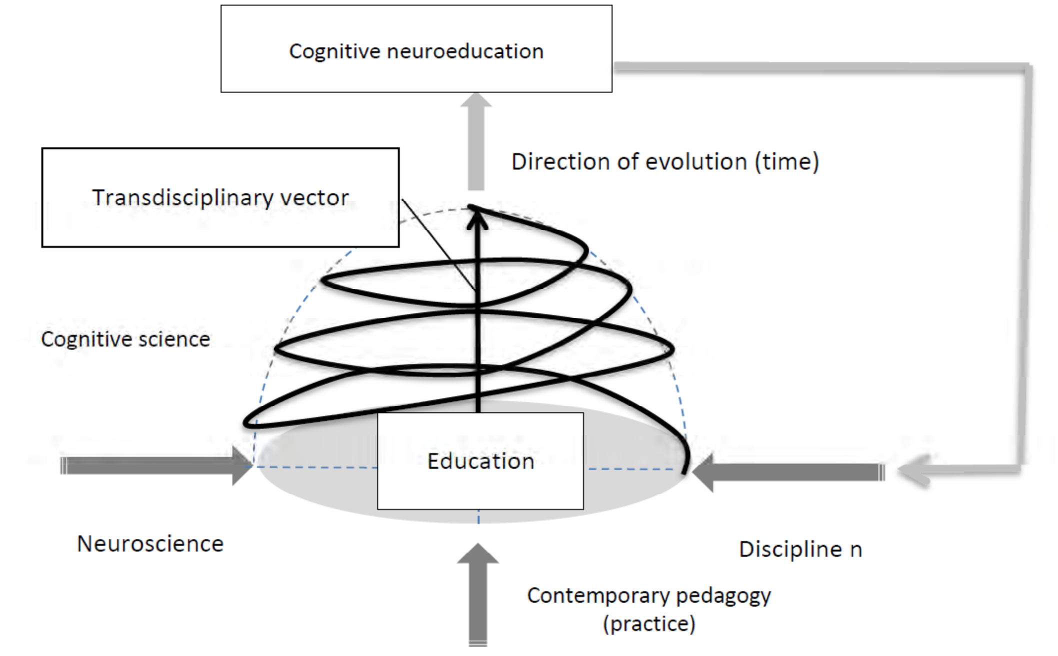

Figure 1: Birth of the new discipline: Cognitive neuroeducation (Flogie, Dolenc, Aberšek, 2015).

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Cognitive neuroeducation is generating valuable new knowledge to inform educational policy and practice, while using AI methods and suitable learning technology. In many questions, neuroscience builds on the conclusions of existing knowledge and everyday observation but its important contribution is in enabling the move from correlation to causation – understanding the mechanisms behind familiar patterns – to help identify effective solutions (Hirsch Hadorn, et. al, 2008). However, the results of neuroscience and their inclusion in the process of education does not suffice, because it does not take into account a sufficient number of effects and possibilities.

A somewhat more detailed explanation of the basic idea shown in Figure 1 is presented in Figure 2. As previously mentioned, the mission of education needs to be perceived as complex, because within the contents, methods of work, learning environments and the organization of these activities is constantly intertwining.

In Figure 2 organizational needs are marked with O1-O4 and levels of activities from P1-P6. The education's mission needs to be to experience what has been learned in the qualitative shift in knowledge from declarative towards experiential knowledge, and from knowledge in the wide sense of the word towards suitable competences. What is meant by experience in this context is the change in all forms of long-term memory, which means changing and adapting:

- *Declarative memory*, memorizing data, information and knowledge in the narrow meaning of the word,
- *Procedural memory*, memorizing procedures, such as problem solving, critical judgement, co-operation and team-work, all in all different skills and competences and
- *Episodic memory*, integrating all types of knowledge and procedures into a concluded whole, therefore one's own experience.

These types of changes need to be addressed systematically and according to systems theory (Bertalanffy, 1976) and total productivity management (TPM) (Phusavat, 2013), a commonly known procedure from industrial practice, which was used ever since the early seventies of the former century (TPM). This principle in connection to education started to be used at the turn of the century, mostly with the 21 step system (Microsoft Partners in Learning, 2010), which was an attempt to transfer 21 keys (Kobayashi, 1995) into schooling practice. In these innovations it is also worth mentioning the multidimensional method (Bocconi, Kampylis, Punie, 2012).

This kind of a systematic approach needs to have, in the process of education, for its basis the acquired experiences from the students and be in accordance with the assigned pedagogical goals. The presented research focuses mainly on the influences of learning environments (introduction of ICT and AI based learning materials) on reaching the assigned pedagogical goals and on experiencing what has been learned while abiding by integrative methods (cognitive neuroeducation) on learning and teaching. *The thing of interest will be the result of introducing innovative method and the opinions of learners concerning this process.*

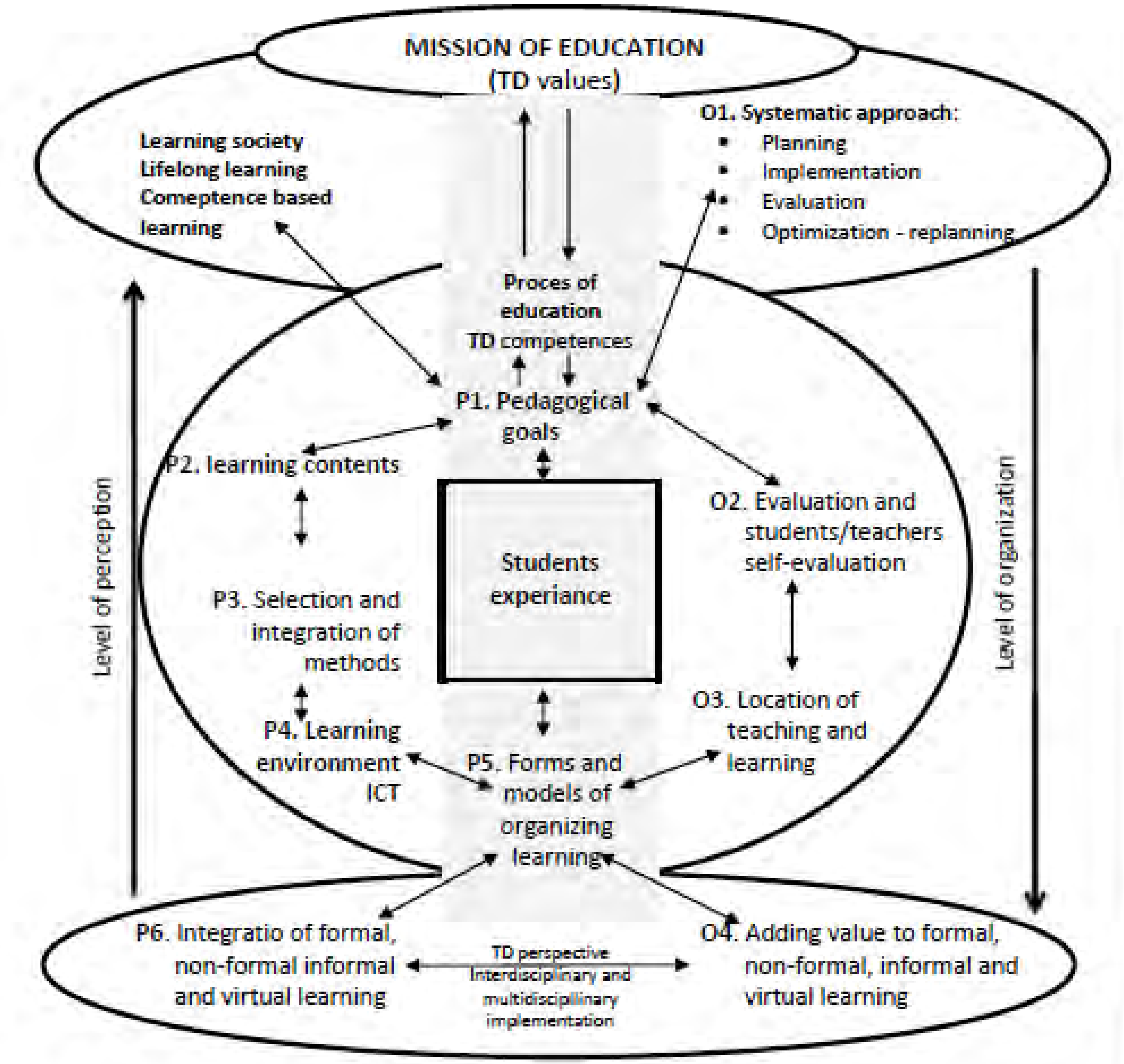

Figure 2: Transdisciplinary model of changes in education.

The key for implementing such a model of teaching is teacher's planning. It must be based on three levels:

- Level 1: Desired Results
  - Plan of required time
  - Plan of Required Technology
  - Plan of Content Standards
  - Over-arching Essential Question (Transdisciplinary) and essential questions. They can *be unit specific* questions which focus attention on the important objectives of the project or *content questions* lead to fundamental and specific answers.

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- Level 2: Determine Acceptable Evidence
  - Determine acceptable evidence of understanding (Student learning goals).
  - Plan for information, media, technology and resources.

- Level 3: Plan learning experiences and instruction
  - Plan instructional activities that address the learning objectives
  - Plan for information, media and technology and resources
  - Plan of the whole procedure: steps in the task – based on lesson plan versus responsibilities.

In this research the transformation of such transdisciplinary *cognitive neuroeducation* model into practice will be observed and evaluated in the classroom.

Methodology of Research

General Background of the Research

The general aim of the research was to create and evaluate a new educational paradigm (transdisciplinary model), innovative curriculums; ones that are based on modern transdisciplinary pedagogic model, which support individualization and differentiation of lessons while using modern informational and communicational technology side by side to student friendly smart (intelligent) e-materials. At the same time the research also focused on the i.e. competences of the 21st Century (global communication, cooperative work, constructive problem solving, critical thinking and developing of creative expression) in all participants (students and teachers) (Pešakovič, 2014). The presented article originates from a transdisciplinary model, seen in Figure 2 and focuses only on organizational needs and the use of the Systematical approach (according to Figure 2, O1) in accordance to P5, forms and models of organizing learning in P4 - learning environment. The research focused mostly on the effect of ICT on the attitude of students towards school and the attitude of teachers towards recommended changes, as a key factor for the overall success.

The presented research was carried out within the framework of the project Innovative Pedagogy 1:1 in the light of 21st century competencies (Aberšek, Flogie, verc, 2015). The research lasted for two years and was carried out in nine elementary and secondary schools in different regions. All modern scientific findings were tested and evaluated there and later upgraded in individual segments, mostly where the gap between theoretical findings and practical findings was too wide. The results of some concluding findings are given in continuation.

Research Methods and Procedures

The aim of the empirical research is the evaluation of influence of presented transdisciplinary approach (Aberšek, Flogie, Dolenc, 2015) on the attitude of students and teacher towards school. Firstly, transdisciplinary model of *cognitive neuroeducation* was designed and developed. Individualized contents and e-materials, which comprise of various topics suitable for different levels of knowledge are prepared as example for intelligent tutoring system TECH8 (Dolenc, Aberšek, 2015). The evaluation of the finding from students was carried out with the help of the same questionnaires that were used in TIMSS research. The results were analyzed with the help of the SSSP statistical tools. The attitude of teacher concerning the proposed changes was monitored with the help of qualitative methods of research (Aberšek, Flogie, verc, 2015).

The research was presented with two key questions, crucial for the success of the project:

1. What is the usefulness and friendliness of modern approaches, according to students' opinion or is it possible to achieve better motivational results in student with the proposed approach?
2. How do teachers perceive the proposed approaches to teaching?

In the research two groups of students that participated were arranged as follows:

- *The control group*, where conventional lessons were carried out
- *The experimental group,* in which teachers used a transdisciplinary cognitive neuroeducation model.

The performance data for the control group and the experimental group was acquired via questionnaire. In the control group (CG), after the TIMSS summative assessment students also fulfil questionnaire. The questionnaire was identical to that for the experimental group (EG).

Participants and Sample Selection

In the research transdisciplinary cognitive neuroeducational model was tested in the 7th, 8th and 9th grade (experimental group) in 10 randomly chosen lower secondary schools (suburban and urban). From all students (approx. 2000 students) the simple random sample (SRS) of 100 students has been used from these schools participated in the research, so all subsets of the frame are given an equal probability. The simple random sample (SRS) has been used, while this minimizes bias and simplifies analysis of results.

The group was fairly gender homogenous and was composed of 42 girls and 58 boys. In the research however, the only valid answers were considered, thus the number of participants varies between 87 and 88. Transdisciplinary cognitive neuroeducational model was tested in real classroom environment. Also 20 teachers participated in a qualitative research.

For the control group the analyzed data from TIMSS (TIMSS, 2011) research was used. 4373 students from 450 lower secondary schools in Slovenia (suburban and urban) participated in the research. All these students are representatives of conventional (traditional) teaching/learning model.

Data Analysis

Quantitative data in the experimental and control group was collected, reviewed and rated by a group of experts in the field of educational science. Quantitative data collected in the experimental group was analyzed according to the following phases, or by: encoding, defining and organizing the data and interpreting the results. Data from TIMSS research was collected, evaluated and statistically processed by the Educational Research. Qualitative data from teacher was collected mostly via interviews between specific training and with the help of assessment questionnaires.

Results of Research

Table 3 shows summarized the results of researching the students' attitude towards school as a whole and especially their attitude towards natural science subjects such as Mathematics and Physics.

Table 3. The general attitude of students towards school.

Questions	Group	N	Mean	SD	t	Sig. (2-tailed) p
Do you like school?	EG	88	2.40	0.92	0.608	0.67
	CG	4383	2.36	0.89		
Do you like school if you know that lessons will be active with use of ICT?	EG	88	2.58	0.89	0.475	0.02
	CG	4383	2.36	0.89		
I fill comfortable (safe) at school.	EG	88	2.95	0.86	0.639	0.001
	CG	4386	2.24	0.83		
I feel affiliation to my school	EG	88	2.81	0.99	0.096	0.001
	CG	4373	2.24	0.91		
Do you like Mathematics (General)	EG	97	2.54	1.04	0.003	0.001
	CG	4387	2.17	0.91		
I like Physics (General)	EG	97	2.16	0.99	0.244	0.75
	CG	4335	2.13	0.94		

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Means in Table 3 show that there are differences between students from the experimental group (EG) and the control group (CG) concerning the question if they like attending school, where students from the EG have a more positive attitude towards school and they also feel more comfortable and safe. The difference in the average is even greater if the students know that the class will be held by using the "innovative" approach and by using modern teaching technologies. Means also show a positive trend in the EG towards school affiliation and a positive trend in the popularity of Mathematics, partially also Physics. A smaller difference in Physics is probably due to the fact that even at classical lessons quite a lot of experimental methods of work are used, which are harder to substitute with suitable methods in connection to using ICT. However, it is alarming that results in both groups are fairly poor, which show that there are problems in teaching this subject.

The homogeneity of variance as assessed by Levene's Test for Equality of Variances was confirmed. Therefore, an independent t-test was run on the data as well as 95% confidence intervals (CI) for the mean difference. It was found that students from both groups equally like to attend school and that there were no significant differences between groups (t (0.403) =0.608, p=0.67). It was also found that there were statistically significant differences between groups in whether the students like going to school more when they know the lessons will be held in the innovative way (t(2.325)=0.475, p=0.02), feeling comfortable (safe) at school (t(7.743)=0.639, p=0.001), fill affiliation to their school (t(5,382)=0,096, p=0.001) and liking mathematics (t(3.242)=0.003, p=0.001). However, there were no significant differences between groups in liking physics (t (0.299) =0.244, p=0.75).

If solely the students' attitude in EG towards Mathematics and Physics is looked in detail, the following results are reached, as seen in Table 4 and 5.

Table 4. The attitude of students of EG towards mathematics.

Claim	Answers				N	Mean	SD
	Not at all	Moderate	Much	Very much			
I like mathematics	19 (19%)	30 (31%)	26 (27%)	23 (23%)	98	2.5	1.1
I like learning mathematics.	31 (31%)	31 (31%)	26 (26%)	11 (11%)	99	2.2	1.0
I am usually successful in mathematics.	8 (8%)	20 (21%)	46 (47%)	23 (24%)	97	2.9	0.9
Mathematics lessons are usually carried out in an innovative manner, because the teacher uses different ICT supported methods.	6 (6%)	34 (34%)	45 (45%)	14 (14%)	99	2.7	0.8

Table 5. The attitude of students of EG towards physics.

Claim	Answer				N	Mean	SD
	Not at all	Moderate	Much	Very much			
I like physics.	29 (30%)	32 (33%)	26 (27%)	11 (11%)	98	2.2	1.0
I like learning physics.	38 (39%)	37 (38%)	17 (17%)	6 (6%)	98	1.9	0.9
I am usually successful in physics.	11 (11%)	31 (32%)	42 (43%)	13 (13%)	97	2.6	0.9
Physics lessons are usually carried out in an innovative manner, because the teacher uses different ICT supported methods.	11 (11%)	31 (32%)	48 (49%)	7 (7%)	97	2.5	0.8

The comparison of results from Table 3 and 4, or 5 for the subject of Physics and Mathematics, shows slight differences. These originate from the fact that in Table 3 only one simple question is asked: "Do you like mathematics or physics?" without any additional clarifications of instructions, because of this the students answered according to their current feeling. However, in Table 4 and 5 this question was better stated, because it was divided into several claims, which more thoroughly explained the question, making it possible for the students to understand the meaning better. By doing so, they had an additional opportunity for deliberation, resulting in a somewhat higher average rate (M=2.575 for mathematics and M=2.3 for physics) and a somewhat lower standard deviation (SD = 0.95 for mathematics and 0.9 for physics).

Discussion

The presented research shows, that there are differences between students from the experimental group and the control group concerning the question if they like attending school, where students from the EG have a more positive attitude towards school and they also feel more comfortable and safe. It also shows a positive trend in the EG towards school affiliation and a positive trend in the popularity of Mathematics, partially also Physics. The interpreted results of the comparison of the results from Table 3 and 4, or 5 for the subject of Physics and Mathematics, also show slight differences. These differences mainly originate from the fact that in Table 3 only one simple question is asked, however, in Tables 4 and 5 questions were better stated and divided into several claims, which make it possible for the students to better understand the meaning.

If these results are compared to other similar research worldwide (Currie, Zanotti, Morgan, Currie, de Lazio, Roberts, Sendal, Smith, Barkenov, 2012, Halász, Michel, 2011, Malerba, Vonortas, Breschi, Lorenzo, 2006) or own (Dolenc, Aberšek, 2015, Kordigel Aberšek, Dolenc, Kovačič, 2015, Pešakovič, Flogie, Aberšek, 2014, Hus, Kordigel Aberšek, 2011), one can see that the reached results are lower. In the majority of worldwide research the results were mostly reached under "laboratory" conditions, in newly built and well equipped schools, where the teachers were chosen, prepared and motivated. Likewise, in our, previously done pilot studies, we worked with chosen teachers, who were properly trained and well-motivated. Also, the contents and e-material was properly developed and tested, and pilot studies were carried out only on one subject within a limited scope. But in this research it is alarming, that the results in both groups are fairly poor, which shows that there are problems in teaching these subjects.

What were the circumstances in the presented research and why were the results poorer? As previously mentioned, in the research ten average schools participated, which were fairly different in size. Similarly the teachers chosen were the ones that taught at these schools. As was later seen, in smaller schools the headmasters could not choose teachers that taught in the selected department. In the following Table 6 the reasons why individual teacher joined the research are given. Only 4% are the initiators of the project (mainly headmasters and vice headmasters) and 29% participate according to his/her will. But 54% are without any motivation to do different and to learn new methods of teaching. So only 1/3 of teachers joined voluntarily, all others were in one way or another "forced" to cooperate what definitely influence the final results.

Table 6. Involvement of teachers in the projects (%).

As the initiator of the project	4
According to my will	29
At the initiative of colleagues	12
I had no choice	13
At the initiative of school management	41

The assigned teachers were expected to carry out at least 30% of their lessons by using innovative teaching approaches (transdisciplinary model) with the use of ICT (not necessarily for the duration of the whole teaching hour) which required a completely different way of teaching, a drastic shift in the "mind-set", interconnecting teachers with similar topics (multidisciplinarity), individualization and differentiation of leaning, constructivist approach to teaching; where the process of teaching and learning (way) is as important as the knowledge itself (goal). Also, the organization of the teaching environment was fundamentally changed, modern teaching technology was implemented in lessons that encouraged modern ways of teaching, problem-based approach, investigative approach and research approach. All of these things resulted in the need to form new knowledge for the teachers, which required of them to distance themselves from total control of the learning process. Although everyone involved in the research knew that including modern technologies (ICT) will not by itself bring forth any change in teaching and

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learning and that it may even become a hindrance if the teachers were occupied solely with teaching technology (and technological problems), they were still mostly worried by the technology. Thus, when training teachers it was specifically stressed that after implementing new tools there also always needs to be time for didactic reflection and looking for balance between the approach that is technology orientated and the approach that is student and teaching with technology orientated, where technology is only to offer assistance to teaching.

A combination of different forms of training teachers has worked pretty well. The analysis of the evaluation questionnaire after the trainings were concluded showed that the teachers, while for the most part liking the trainings, have understood them differently. Their observations and comments were included in planning and implementing further trainings. Many contents, where they did not see a direct and immediate correlation with their work in the class (e.g. Digital literacy in international research PISA), were rejected as ballast and waste of time. The most difficult thing to do was to follow through with their request for more substantial examples of good practice for concrete subjects from the Slovene curricula – many, at least in the beginning, were having problems realizing that they are *the ones* that need to be active and are sometimes the ones to prepare examples of implementing innovative pedagogy for actual space in the Slovene school.

In short, even when training teachers, the one being taught (in this case the teacher) and his or her experiences need to be put in the center of the educational process. It seems that in schools where they will continue using implementation of innovative pedagogy there will soon come a shift in training teachers from using tools towards topics on pedagogy and didactics. This, of course, is a process, which requires time and cannot be concluded in the duration of any project. To sum up, from what was said, the key factor for initiating changes in the field of education is the teacher, who needs to be:

- properly trained
- suitably equipped and familiar with opportunities and limitations of technology, and
- at the same time motivating, which can happen only when he without fear controls the learning process. While doing so he must also focus on what is most important, *teaching*, and must master technology on the level of routine, basically not to lose energy on with *what* he will teach, but concentrate on *how to teach*, thus maximizing the effect of the process.

However, one must take into account that one is pilot studies, where all parameters can be immediately adjusted, making it possible to achieve good results and the other are studies carried out under real-life situations, in this case real learning environments.

Conclusions

New discoveries in the field of developmental artificial intelligence (AI), cognitive science and neuroscience hold a great promise for improving current teaching methods and learning process at all. At the end of the previous and especially in this millennium the education landscape is undergoing significant change as a result of technological innovations but also scientifically educational innovations on the base of AI cognitive and neuroscience. The changes in the way education is implemented and in the way students learn are witnessing. While the conventional setting of the classroom will continue to form the bedrock of education systems, it will be enhanced by the integration of new tools and pedagogies, and it will be complemented by many more online AI based learning opportunities. Yet there remains a significant gap between the scientific discoveries that could improve our education system and the application of this knowledge. It needs to be known of the fact that on one side there are discoveries and pilot research where all the parameters can be adjusted regularly making it possible to achieve better results and that on the other are research that are carried out under real-life conditions, in our case real learning environments.

It is obvious, that teachers are the main actors in delivering proposed innovative pedagogical changes and most responsible for success in the learning process. New technologies and associated innovative pedagogies require a very different skill-set from more conventional teaching, and this places additional pressures on the teaching staff. Teaching staff are not all technology experts and in many cases, they have not received any form of pedagogical training at all. They need specific training, guidance and support (as in presented project) if they have to deliver quality teaching. This is especially true as the integration of these new modes of teaching is resulting in a changing role for teachers, from *knowledge transmitters* and experts in a particular subject to *mentors and facilitators of critical thinking*.

One of the possible steps in this direction is also implementation of presented transdisciplinary model according to figure 2 in the educational process. It is certain that in schools where they implement innovative pedagogy they see improvement not only in students but also in their teachers' qualifications. In these schools a lot has been done, mainly on levels of perception P1-P6 (due to external influence, see figure 2) and not enough on organization and organizational needs O1-O4 (Figure 2), which mostly depended on individual schools and their inner motivation. Especially concerning the organization of education there will have to be done in future a lot more, mostly by raising awareness and appropriate training. However, as is apparent from the results of the research presented in tables 3, 4 and 5 there are visible positive shifts in the students' attitude towards school. Such positive attitude may in students create suitable motivation, which is the first and most important step on the path towards more quality knowledge.

Similarly, when educating teachers, the one being taught (in this case the teacher) and his experiences need to be put in the center of the educational process. It seems that in schools where they will continue using implementation of innovative pedagogy there will soon come a shift in training teachers from using tools towards topics on pedagogy and didactics. This of course is a process, which requires time and cannot be concluded in the duration of any project.

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