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DEVELOPMENT AND EVALUATION OF A COMPETENCE-BASED TEACHING PROCESS FOR SCIENCE AND TECHNOLOGY EDUCATION

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Abstract. *The quality of education is increasingly being measured less by the knowledge gained during schooling and more by the level of competence possessed by students at doing a particular job after completing their education. Target and process-planned curricula are being replaced more and more by competence-oriented curricula, especially in science and technology education, where competences, generally defined as the capability or the ability of an individual doing a job properly, are placed at the forefront. If competence is the desired criterion for educational quality, it can be easily established that suitable instruments and methods of measurement are needed for this kind of quality evaluation, which, however, are not yet available. Suitable instrumentation was developed in this study. Its use was demonstrated in the example of elementary education in Slovenia.*

Key words: *generic competences, students' skills, methods of teaching, triangulation.*

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Introduction

More and more countries are focusing on measuring and monitoring the quality of education. This holds true for Slovenia as well, where the Ministry of Education started reviewing and upgrading its educational policy between 2012 and 2013. It is clear that small corrections alone will not suffice, and that the entire education paradigm must be changed; it is also important to recognise that this cannot be done in one, simple step, but rather in the form of a long-term process.

One of the certain consequences of a non-competitive education system is high unemployment among the young, and the lowering of the general standard of living (Dumont, Istance, Benavides, 2010). These parameters are included in the regular reports made by international organisations such as UNESCO and OECD. Also, the Education for All (EFA) report "Regional overview: Central and Eastern Europe and Central Asia" emphasises the urgency in raising the competences needed for jobs in the 21st Century. Education and the method of schooling and studying do not provide the young with a competitive advantage, i.e. employability. Therefore, in todays society the young must be equipped with fundamental competences that are general in character (e.g. learning how to learn) and, thus, transferable between different areas. Skills and technical-vocational knowledge must be added to this (UNESCO, 2007). The results of the Progress in International Reading Literacy Study (PIRLS) suggest that the model of quality teaching is composed of three fundamental *dimensions*, with each of them being composed of 6 *elements*:

- *Intellectual dimension* (Elements: deep knowledge, deep understanding, problematic knowledge, higher-order thinking, metalanguage, substantive communication)
- *Learning environment* (Elements: explicit quality criteria, commit-

ment, high expectations, mutual support, students' self-control, student-teacher joint decisions), and
- *Making learning meaningful* (Elements: prior knowledge, cultural sophistication, knowledge integration, inclusion, narration).

In analysing and comparing different international studies, it is important to consider the fact that the differences in student performance across OECD member countries are explained by the following factors (UNESCO, 2008):

- 55% by student characteristics,
- 34% by environmental factors influence,
- 11% by differences between countries.

To analyse the current state of the educational system in Slovenia it makes sense to take into account, in addition to UNESCO's reports, some of the key international studies such as the Programme for International Student Assessment (PISA), International Computer and Information Literacy Study (ICILS), OECD's Teaching and Learning International Survey (TALIS), and the international survey *Health Behaviour In School-Aged Children,* conducted under the auspices of the OECD (HBSC).

Competency for 21st Century

The term "competency" first appeared in an article written by R.W. White (1959) in 1959 as a concept for performance motivation. Later, in 1970, Craig C. Lundberg (1970) defined the concept in "Planning the Executive Development Program". As it is quite a popular concept, there are many definitions about what competency could be. Generally, a competency is defined as the capability or the ability of an individual to do a job properly. It is a set of related but different sets of behaviour organised around an underlying construct, which we call the "*intent*". Competency includes the following elements:

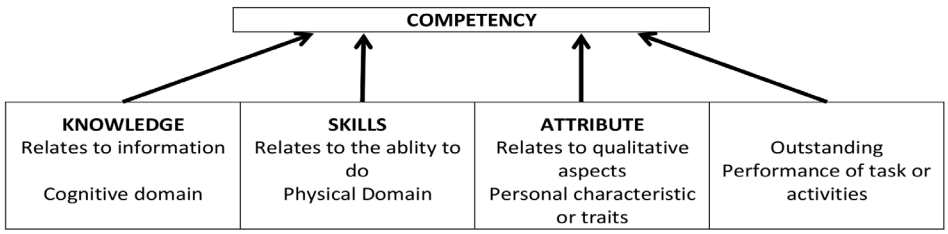

Figure 1: Elements of competency.

In accordance with this concept competence could also be called procedural and strategic skills. Thus, the authors Romainville, Coolahan, Weinert and Day defined competencies as the general capacity to act and the ability to perform tasks and activities based on knowledge, experience and values (Key Competencies, 2002). From numerous analyses and definitions of competencies it can be summarized that competencies are the skills, abilities, knowledge and experience of an individual to perform certain tasks and are a result of their personal development, mainly as a result of learning.

There is also great diversity regarding naming different competencies. Thus, the most frequent concepts are: key competencies, generic and subject-specific competencies. Generic competencies are those which an individual develops through typical approaches, procedures and strategies of educational work rather than with specific learning of a certain matter. The basis for the creation of a set of generic competencies was the Report of Mayer's Committee (1991). Generic competencies in the field of science, including technical science, are defined as competencies that the individual develops through the method of work rather than with the specific learning of a certain matter (Key Competencies Supplementary Statement for Engineering Technology, 2001).

Competency Development

Dreyfus and Dreyfus (1980) introduced a nomenclature for the levels of competence in competency development. The process of competency development is a lifelong series of doing and reflecting. As competencies apply to careers as well as jobs, lifelong competency development is linked with personal development as a management concept. The four general areas of competency are:

1. *Meaning Competency*: The person assessed must be able to identify with the purpose of the organisation or community and act from the preferred future in accordance with the values of the organisation or community.
2. *Relation Competency*: The ability to create and nurture connections with the stakeholders of the primary tasks must be shown.
3. *Learning Competency*: The person assessed must be able to create and look for situations that make it possible to experiment with the set of solutions that make it possible to complete the primary tasks and reflect on the experience.
4. *Change Competency*: The person assessed must be able to act in new ways when it will promote the purpose of the organisation or community and make the preferred future come to life.

The first two areas are particularly important in real working situations; therefore the focus will be on two competencies which are very important in schools, the learning and the change competency, with a special emphasis on skills from Figure 1. This entails the need for the following skills in today's schools, shown in Table 1 (Anderson, 2010).

Table 1. Competencies for the 21st century.

Competencies for the 21st Century				
Analytical skills	**Interpersonal skills**	**The ability of realizing**	**Information processing**	**Ability of changing/ learning**
Critical thinking	Communication/ Messaging	Initiative, self-regulation	Information literacy	Creativity/ innovation
Problem solving	Collaborating	Productivity, efficiency	Media literacy	Adaptability/ learning to learn
Decision-making	Leading and responsibility		Digital citizenship	Flexibility
Research and development			ICT procedure and concepts	

Every 21st Century skills implementation requires the development of *core subject knowledge* and understanding among all students. Those who can think critically and communicate effectively must build on a base of core academic subject knowledge. Within the context of core knowledge instruction, *students must also learn the essential skills for success in today's world, such as critical thinking, problem solving, communication and collaboration*. In the research presented, the development and evaluation of life and learning and innovation skills will be the subject of research attention.

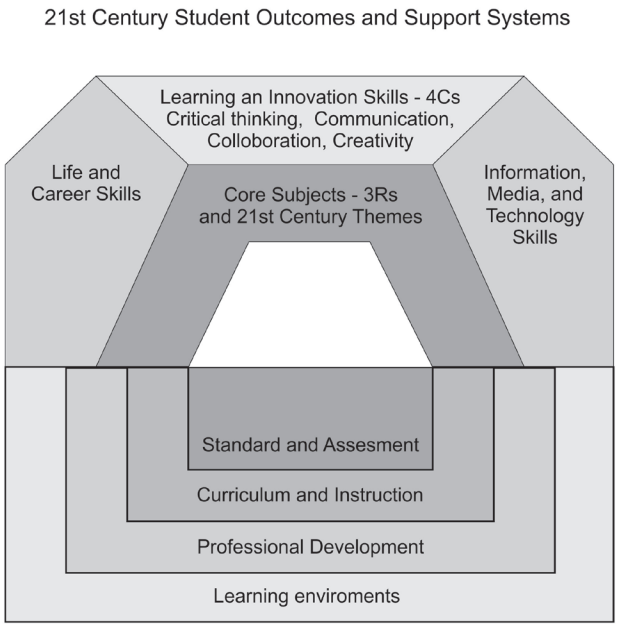

Figure 2: Students' outcome and support system.

Generic Competency

Generic competency is also known as object-independent and transversal or transferable competency, respectively. The creation of generic competencies depends on the specific area. When designing generic competencies in the field of science education, conceptual (content) and technical (design) aspects were considered; those were provided by the working group in order to identify basic concepts common to all natural science disciplines.

Skills as a part of generic competencies need to be developed throughout life, not just because of personal fulfilment and in order to actively engage with the society in which we live, but also so that we can be successful in a working world that is constantly changing. These are the most important factors in innovation, productivity and competitiveness (Figel, 2007).

In an educational process based on a competence-based curriculum, life and learning and innovation skills that influence the development of an individual generic competence are at the forefront. Students should therefore be able to use tools for the production, presentation and understanding of complex information, and have the ability to access, search and use internet-based services. They should also be able to use information and communications technology (ICT) to support critical thinking, creativity and innovation.

The generic competencies were the starting point for the observation and evaluation of students' skills in this study.

Teaching Methods to Support Competence-Based Teaching Process

Three types of learning based on research will probably prevail in competence-based teaching in the 21st Century: *project-based*, *problem-based* and *research-based* learning (Barron, et. all., 1998, Aber ek, 2012). These will provide students with more comprehensive learning in order to be able to use competences obtained in school (knowledge, skills etc.) for problem-solving in real life. Research-based approaches are important for nurturing communication, collaboration, creativity and critical thinking. It must be noted, however, that research-based learning is greatly dependent on well-structured assessment as regards defining learning tasks and the evaluation of learned content. *This will be discussed in detail later.* The success of research approaches is, of course, very much dependent on the knowledge and skills of those performing them. It is therefore not amiss out of place to note that all such reforms must include teacher training before they commence work in schools.

Problem of Research

In 1996, for the first time in the new state, Slovenia adopted an Elementary School Act and, on the basis of the concepts contained in The White Paper on Education in the Republic of Slovenia (1996), introduced comprehensive regulation at all levels of the educational system. In addition to the concept of knowledge, the concept of competence began to establish itself in the school environment, and was for the first time seen as *knowledge and skill*. The concept of competence has drawn attention to the complexity of knowledge, its entanglement with the disposition of the individual and the need to teach the use of skills (The White Paper, 2011).

Teaching on the basis of competencies should take place at all stages of the teaching process, from planning and implementation to evaluation, since this is the only way to achieve the objective of competent education - a comprehensive competent person. Competence diagnostics, through which teachers and students can find out to what degree an individual's competence is developed, plays a vital part, which lead to the development of a competitive model as a diagnostic instrument (Upheus, 2010). Evaluation and self-evaluation of performances provide a basis for the individual student's results (portfolio), which can also serve as an incentive for further work. "Instruments for self-evaluation, which are offered in some school textbooks, represent an important step towards the diagnosis of competences" (Hieber, Lenz, Stengelin, 2011: 3). As noted by R. Wesselink et. al., "the design of a competency-based curriculum, the design of the learning process and the design process of evaluation can be performed only when the concept of competencies is defined as clearly as possible. Another great trap is assessment, which is viewed as the Achilles heel of competency-based learning" (Wesselink, 2007: 39). Yet to be able to measure specific competencies they should be standardised so that they can be recognised and become measurable.

Knowledge and attitudes (according to Bloom's Cognitive and Affective Taxonomies (Bloom, 1956, Anderson, Krathwohl, 2001) can be measured with standardised tests. To assess knowledge in the field of technology, tests for the National Assessment of Knowledge are used in Slovenia and are the same for the entire country. Attitudes can also be assessed by using standardised procedures, such as the Thurstone, Likert (Judd, Smith, Kidder, 1991) or Bogardus scale (Miller, 1991). A problem in assessing skills arises when there are no standardised tests. With the introduction of a nine-year elementary school, the developers of the curriculum emphasised that the total grade should also reflect the grade in experimental work, i.e. assessment of skills, but in practice this proved to be extremely difficult, if not almost impossible. The most commonly stated reason for this was that the number of students to be assessed was too high. The problem also lay in the measurement methods and instruments, which should have been verified and uniform for a specific area and should also have enabled quick and objective assessment of students' skills. This study included the use of methods and instruments that enable suitable development and evaluation of students' skills.

Research Methodology

General Research Background

Special methods and instruments were developed for the evaluation of student competencies in this research. The methods and instruments developed can be further improved on the basis of the results obtained from the study. The research was performed in two consecutive school years, 2011/2012 and 2012/2013.

In the 2011/2012 school year the first study was carried out and was used to verify the basic measurement characteristics of the test and the selected instrument, the so-called recording form (see Table 2). The recording form was used by an external expert to grade (circle) the level of mastering a specific skill at both the lower and higher taxonomic levels. Students were divided into two groups, an experimental and a control group. Work in the experimental group was project-based and included problem-based and research-based lessons, an experiment and a technical analysis. Students drilled and practised specific skills before being assessed. In the control group the lessons were taught conventionally, with a teacher providing explanations and teaching in front of the classroom, and working with textbooks. There was no drilling of a specific skill. The study was performed in order to verify the validity, reliability, objectivity and sensitivity of the recording form. On the basis of this preliminary pilot study and a comprehensive analysis of the instruments used and the learning process it was established that the study could continue.

The second study was carried out in the 2012/2013 school year. In the experimental group the *method of teaching* was used as the experimental factor and *gender and initial assessment in natural science* (final grade in

Science and Technology in the 5th grade) as the non-experimental factor. In the control group *gender* and *final grade in Science and Technology in the 5th grade* were used as the non-experimental factor. No experimental factor was used since the lessons were taught in a traditional way.

At this stage of the study the emphasis was put on developing and assessing students' skills. The procedure was identical to that in the preceding stage. Among others, the main purpose of the study was also to establish whether project-based learning provides better conditions for developing students' skills than traditional instruction. The variables in the pedagogical experiment were:

- Independent variables: Gender, grade, experimental group, control group, taxonomic levels and teaching methods;
- Dependent variables: Initial state of skills at a lower taxonomic levels, initial state of skills at a higher taxonomic level, final state of skills at lower taxonomic levels, final balance of skills at a higher taxonomic level.

The data were computer processed using the SPSS 20,0 program for statistical analysis, at the descriptive and inferential statistics levels. The following procedures were used:

- frequency distributions (f, f%) of descriptive variables (gender and final grade);
- χ^2-test of the hypothesis of independence to test dependent associations between variables (according to gender and the final grade in Science and Technology);
- T-test for verifying hypotheses in smaller samples (progress dependent on gender and final grade).

Research Sample

During the 2011/2012 school year the study included 38 students from the 6th grade, aged between 10 and 11. They were randomly divided into two groups, the control group - CG (20 students) and the experimental group - EG (18 students). The research sample included approximately the same number of boys and girls.

The second study was carried out in the 2012/2013 school year. The study included 35 students from the 6th grade, aged between 10 and 11. They were randomly selected (regardless of their grade and gender) and divided into two groups, the experimental (17 students) and the control group (18 students). There were a third as many boys in the research sample as girls.

Instruments and Procedures

Content characteristics of the measurement instrument

A recording form (Table 2) was used for direct observation of students' skills in carrying out a specific task. The name of the generic competence was written in the form's title field. That was followed by a definition of the observed skill, how the skill was observed and what had to be taken into account. Mastery of specific skills was monitored and evaluated according to the criteria for each taxonomic level: knowledge, comprehension, application, analysis, synthesis and evaluation. These could be adapted to the individual subject and thematic area. The observer had to circle the degree of control, where 1 meant unsatisfactory, 2 satisfactory, 3 good, 4 fairly good and 5 very good mastery of the skill.

Table 2: Example of a recording form.

	Competence: ABILITY TO INTERPRET INFORMATION	
	SKILLS: • Presentation of information in a clear manner, correct use of professional terms; • Preparation and presentation of a project (work plan, seminar or poster).	
	HOW? Observe the skills of the particular student and circle the relevant level of skill mastery. Pay attention to whether the information is presented clearly and accurately, and whether the student had prepared the project independently.	
	CRITERION	**MASTERY OF SKILL**
LOWER LEVEL	In their presentation the student reviewed already known facts and concepts. The project was not elaborated on; other students could not discern the point.	1 2 3 4 5
	The student presented information in a clear way and reported independently using professional terms yet phrased in the student's own words. The project was elaborated on and summarised the essential points.	1 2 3 4 5
HIGHER LEVEL	The student analysed the information presented and provided argumentation for it. The project included all the key elements required.	1 2 3 4 5
	Key elements were connected in the presentation. The student independently formed clear conclusions that were correct and reliable. The student's own ideas were dominant. The student evaluated their project and suggested improvements.	1 2 3 4 5

Procedure

In this research were used two methods, triangulation method and qualitative educational research method. The purpose of triangulation in qualitative research is to increase the credibility and validity of the results (Bogdan, Biklen, 2006). In this case triangulation was used to observe the process and verify the students' attainment of skills. This ensured that the research situation could be observed from three perspectives: the teacher - the performer, student and observer. The observer was an expert in the field of technical education. The method of direct observation was used.

With the direct observation of skills - social, communication and working skills, we have determined the initial state of specific skills in the experimental and the control group:

- skills at lower taxonomic levels, and
- skills at higher taxonomic levels.

The following table (Table 3) shows students' skills that were developed and assessed at lower and higher taxonomic levels.

Table 3. Students' skills at lower and higher taxonomic levels.

SKILLS	COMPETENCE	LOWER LEVEL Student:	HIGHER LEVEL Student:
COMMUNICATION SKILLS	Ability to collect information	Information is collected using a previously presented method; only one source is used.	Electronic and written sources are used to search for information.
	Ability to analyse and organise information	The information is verified for accuracy and organised in previously presented structures.	The obtained information is verified and connected into a meaningful structure. The quality and validity of information are assessed.
	Ability to interpret	Information is provided in known contexts. Information is presented in a clear manner and independently.	Key elements are included in the presentation. Clear conclusions, which are correct and reliable, are formed independently. The student's own ideas are dominant. The student evaluates their presentation and suggests improvements.
	Ability to synthesize conclusions	The process of connecting data and forming conclusions is reviewed. Results are presented using only previously taught procedures.	Different types of graphs are used to present information; similarities and differences in each type are pointed out. Tables and graphs are modified/rearranged; their use is assessed.
	Ability to solve problems	Guidelines for achieving pre-set goals are considered and the results are verified using set criteria.	Student's own goals are set and the methods of achieving these goals are mastered. Own criteria for evaluation procedures are set and used, and own criteria for result evaluation are used.
	Verbal and written communication	Ability to describe the work procedure and to orally present their work/project.	Work/project's key elements - words are emphasised, and information is transmitted to other students in a clear, professional and logical manner.
SOCIAL SKILLS	Ability for independent and team work	Understanding of the task is demonstrated and a suitable group work method is selected. The student takes on a specific group role and understands that role.	The purpose and goals of the task are set, and how they will be realised is described. The roles, procedures and time-frames in the group are assessed on the basis of various aspects. Negotiating with other group members to set the goals that need to be verified and defined.
	Organisation and planning of work	The sequence of work procedures is reviewed and a proposed plan of the work is described.	Independent performance of procedures according to instructions, planning and organising work, finding key elements for good planning and work organisation. The student checks whether the work performed complies with the work planned, and assesses the individuals' work.
	Interpersonal interaction	Communication within the group is established and characteristics of that communication (frequent, rare) are explained; the student describes whether their ideas and opinions and suggestions by other group members were taken into consideration.	The similarities and differences of the proposals made by the group members' are presented and the reasons for the decisions made. The importance of collaboration and communication between members of the group and other groups is evaluated.
WORKING SKILLS	Transferring theory into practice	Workplaces, tools, machinery and equipment needed to implement the task are prepared.	The importance of the correct sequence of workplaces and the right use of tools, machinery and equipment is explained. A proposal is made for solutions regarding rationalisation of work places and procedures.
	Use of mathematical ideas and techniques	Guidelines for selecting ideas and techniques for specific tasks are observed. Mathematical knowledge is used in known circumstances.	The assumptions needed for the selection and use of mathematical ideas and techniques are recognised. Mathematical knowledge is adapted and used correctly in new circumstances. Problems are anticipated and measures taken to eliminate them.
	Adapting to new situations	Already known processing procedures are used with new material.	Processing procedures and tools for new material are selected, tested, and the most suitable procedures and tools are used.
	Concern for quality	Presented equipment is used for increased product quality.	Student's own equipment is made and used for greater product quality, and suggestions are made for improvement.
	Safety at work	Safety equipment is used when working with tools and machinery; the student understands the importance of quick and correct action in the event of danger.	Devices, machines and tools are used safely; quick and correct action is taken in the event of danger or risk. The efficiency of safety equipment is verified.

In the experimental group project-based learning (PBL) was used. The training and demonstration of certain skills were conducted. Students trained in *all three* specific skills. In the control group, a frontal teaching method was used, e.g. conversation, demonstration and work with texts. There was no training in specific types of skills.

The instrument and measurement methodologies developed enabled the optimisation of the learning process; different methods of work were assessed depending on the given objectives with a focus on students' working, communication and social skills.

Results of the Research

a) *Gender and final grade in Science and Technology (hereinafter S&T) in the 5th grade*[1].

At the beginning, the homogeneity of the control and the experimental group had to be verified. The difference between both groups in gender and in final grade in S&T in the 5th grade was examined, as shown in Tables 4 and 5.

Table 4. Student gender in the experimental and control groups.

			Group		Total
			Experimental (EG)	Control (CG)	
Student gender	Boys	No.	11	12	23
		%	64.7	66.7	65.7
	Girls	No.	6	6	12
		%	35.3	33.3	34.3
Total		No.	17	18	35
		%	100.0	100.0	100.0
$p = 0.903$ $\chi^2 = 0.015$					

It was established that there was no statistically significant difference between the experimental (EG) and the control group (CG) as regards gender ($P = 0.903$, $\chi^2 = 0.015$). The same was true for the final grade in S&T since the experimental group's average grade was 4.11 and the control group's 4.00 ($P = 0.891$, $\chi^2 = 0.23$), as shown in more detail in Table 5. Consequently, the composition of both groups was statistically appropriate.

b) *Initial state of the experimental and the control group*

Whether the didactic approach (work forms and methods) affected the development of skills as part of the students' generic competences was also considered. Therefore, the mastery of skills before the start of the experiment had to be examined. The following analysis shows the initial level of students' mastery of a specific skill for the lower (Table 6) and the higher taxonomic levels (Table 7). Students' skills were divided into three groups: social, communication and working skills, as shown in Table 3.

1 S&T - Science and technology is a subject in the 5th grade of elementary school that includes topics from natural sciences and technology.

Table 5. Final grade in S&T in the 5th grade.

Student gender				Group		Total
				EG	CG	
Boys	Final grade in S&T	C	No.	5	5	10
			%	45.5	41.7	43.5
		B	No.	5	5	10
			%	45.5	41.7	43.5
		A	No.	1	2	3
			%	9.1	16.7	13.0
	Total		No.	11	12	23
			%	100.0	100.0	100.0
Girls	Final grade in S&T	C	No.	0	1	1
			%	0.0	16.7	8.3
		B	No.	0	1	1
			%	0.0	16.7	8.3
		A	No.	6	4	10
			%	100.0	66.7	83.3
	Total		No.	6	6	12
			%	100.0	100.0	100.0
Total	Final grade in S&T	C	No.	5	6	11
			%	29.4	33.3	31.4
		B	No.	5	6	11
			%	29.4	33.3	31.4
		A	No.	7	6	13
			%	41.2	33.3	37.1
	Total		No.	17	18	35
			%	100.0	100.0	100.0
$p = 0.891$ $\chi^2 = 0.23$						

Table 6. Initial state of skill mastery - lower level.

GROUP		Arithmetic mean	Standard deviation	Test for difference of means		Test for homogeneity of variants	
SKILLS		$\bar{x}$	s	Boys	Girls	Boys	Girls
SOCIAL	EG	3.470	0.750				
	CG	3.324	0.735				
COMMUNICATION	EG	2.269	0.643	0.470	0.473	0.353	0.657
	CG	2.115	0.552				
WORKING	EG	3.447	0.605				
	CG	3.300	0.593				

Table 7. Initial state of skill mastery - higher level.

GROUP		Arithmetic mean	Standard deviation	Test for difference of means		Test for homogeneity of variants	
SKILLS		$\bar{x}$	s	Boys	Girls	Boys	Girls
SOCIAL	EG	2.921	0.740				
	CG	2.675	0.788				
COMMUNICATION	EG	1.509	0.535	0.499	0.284	0.318	0.577
	CG	1.370	0.490				
WORKING	EG	2.388	0.719				
	CG	2.133	0.665				

The test for difference of arithmetic means showed the students' mastery of communication skills (written and oral communication) at the lower and at the higher level to be the poorest; however, the analysis showed that there was no significant difference between skill mastery at the lower and higher level between the experimental and control group (Boys = 0.470, Girls = 0.473 – lower level, Boys = 0.499 Girls = 0.284 - higher level).

Figure 3 shows the level of mastery of a specific skill at the lower and the higher level. The level of students' skill mastery is represented by an ordinate encompassing values from 1 to 5, where 1 means unsatisfactory, 1.5 - 2 satisfactory, 2.5 - 3 good, 3.5 - 4 quite good and 4.5 - 5 very good. The most problems arose in the field of written and oral communication due to poor vocabulary and poor use of standard language.

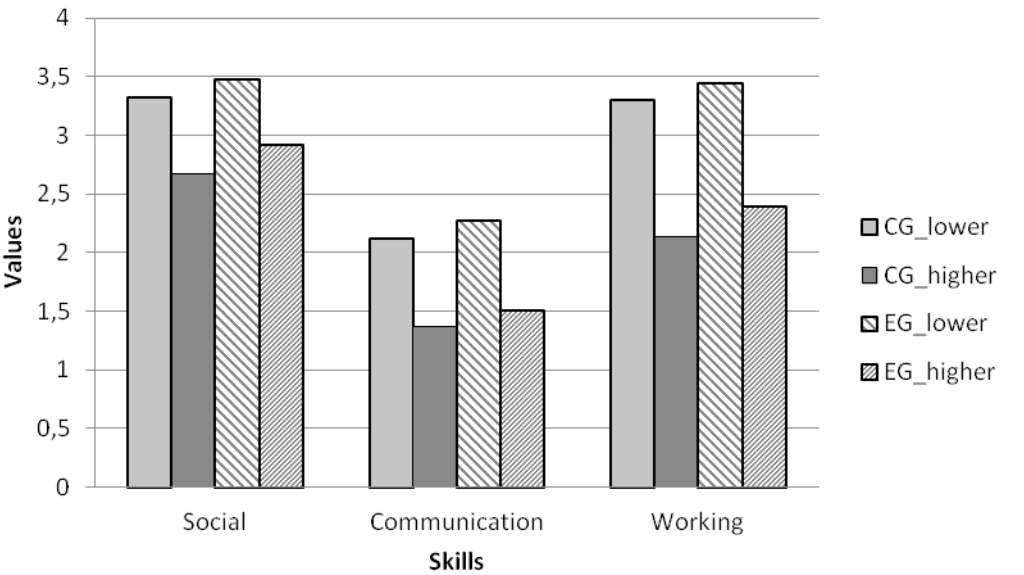

Figure 3: Comparison of students' skills at lower and higher taxonomic levels.

c) *Final state of the experimental and control group*

As mentioned already the main focus of this study was skill mastery at the end of the experiment, i.e. students' progress in social, communication and working skills. Only after this had been established, could the question of whether project work enables greater development and progress in skill mastery than teaching focused on frontal instruction with explanations and text work be answered.

Table 8. Final state of skill mastery - lower level.

GROUP		Arithmetic mean	Standard deviation	Test for difference of means		Test for homogeneity of variants	
SKILLS		$\bar{x}$	s	Boys	Girls	Boys	Girls
SOCIAL	EG	4.686	0.411				
	CG	4.055	0.588				
COMMUNICATION	EG	4.024	0.853				
	CG	2.944	0.596	3.476	0.001	3.704	0.063
WORKING	EG	4.566	0.356				
	CG	4.037	0.494				

The test for difference of means (Table 8) showed that there was a significant difference between the control and the experimental group in students' skill mastery (social, communication and working) at the lower level (Boys = 3.476; Girls = 0.001). The most progress was made in communication skills.

Table 9. Final state of skill mastery - higher level.

GROUP		Arithmetic mean	Standard deviation	Test for difference of means		Test for homogeneity of variants	
SKILLS		$\bar{x}$	s	Boys	Girls	Boys	Girls
SOCIAL	EG	4.156	0.791				
	CG	2.592	0.754				
COMMUNICATION	EG	3.039	1.159	5.231 5.231	0.000	13.173	0.001
	CG	1.472	0.537				
WORKING	EG	3.647	0.631				
	CG	2.902	2.445				

The test for difference of means (Table 9) again showed a significant difference between the control and the experimental group (B = 5.231; G = 0.000). Again, the most progress was made in communication and social skills.

d) *Progress in skill mastery with regard to gender*

Table 10. Progress in skill mastery with regard to gender.

GROUP		Arithmetic mean	Standard deviation	Test for difference of means		Test for homogeneity of variants	
SKILLS		$\bar{x}$	s	Boys	Girls	Boys	Girls
SKILLS - INITIAL STATE	Boys	2.212	0.376	0.769	0.000	0.278	0.602
	Girls	2.982	0.559				
SKILLS - FINAL STATE	Boys	3.171	0.669	0.991	0.000	0.278	0.602
	Girls	4.162	0.655				

It had been assumed that the most progress in skill development would be made by girls. The test for difference of means (Table 10) showed that there was a significant difference in skill mastery progress with regard to student gender (Boys = 0,991; Girls = 0,000). This confirmed the assumption that progress is also dependent on gender. Girls achieved greater progress in skill mastery than boys. The difference between the initial and final state was 0.959 for boys and 1.18 for girls.

e) *Progress in skill mastery with regard to final grade in S&T*

An assumption was also made that progress in skill mastery would be greater for those students whose final grade in S&T was higher. The test for difference of means (Table 11) showed that there was a significant difference in skill mastery progress with regard to final grade (Boys = 13.654; Girls = 0,000). This confirmed the expectation that progress in skill mastery is also dependent on the final grade. For students whose final grade was a C progress made was 0.922, for students with a B it was 0.955 and for those with an A it was 1.196.

Table 11. Progress in skill mastery with regard to final grade.

FINAL GRADE		Arithmetic mean	Standard deviation	Test for difference of means	
		$\bar{x}$	s	Boys	Girls
SKILL - INITIAL STATE	C	2.045	0.192		
	B	2.282	0.308	18.994	0.000
	A	3.005	0.563		
SKILL - FINAL STATE	C	2.967	0.496	13.654	0.000
	B	3.237	0.605		
	A	4.201	0.701		

An assumption was also made that progress in skill mastery would be greater for those students whose final grade in S&T was higher. The test for difference of means (Table 11) showed that there was a significant difference in skill mastery progress with regard to final grade (Boys = 13.654; Girls = 0,000). This confirmed the expectation that progress in skill mastery is also dependent on the final grade. For students whose final grade was a C progress made was 0.922, for students with a B it was 0.955 and for those with an A it was 1.196.

The students' combined progress in social, communication and working skills was also of interest. The level of students' skill mastery is represented by an ordinate encompassing values from 1 to 5, where 1 means unsatisfactory, 1.5-2 satisfactory, 2.5-3 good, 3.5-4 quite good and 4.5-5 very good. As has already been established (at the lower and higher levels), the most progress was made in communication skills, and the progress was greater in the experimental group than in the control group (Figure 4). Thus, a conclusion can be made that the teaching approach influences skill development in students.

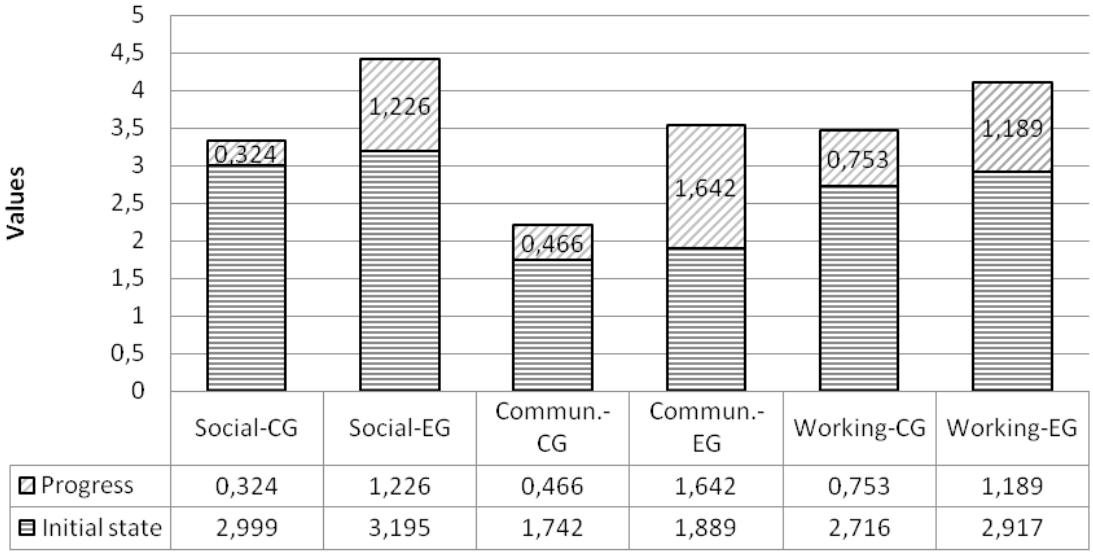

Figure 4: Progress in skill mastery with regard to group.

The effect size (d) was measured by deducting the average transfer grade in the control group from the average transfer grade in the experimental group. This was then divided by the combined standard deviation. According to Cohen, the effect size of +0.8 is large, +0.5 medium and +0.2 small, which is why planning principles with effect size 0.8 or more are of particular interest.

Table 12. Effect size.

		Average Value			
		Control group (CG)	Experimental group (EG)	Combined standard deviation	Result
SOCIAL SKILLS	Lower level	4.055	4.686	0.999	0.63
	Higher level	2.892	4.156	1.546	0.81
COMMUNICATION SKILLS	Lower level	2.944	4.024	1.450	0.74
	Higher level	2.472	3.039	1.696	0.33
WORKING SKILLS	Lower level	4.034	4.566	0.850	0.62
	Higher level	2.902	3.647	3.076	0.24
Average Value		3.216	4.019		

Discussion

Planning lessons well is very important for the teacher since this is the only way to achieve the desired progress in students (Cohen, 1988). This research mainly focused on developing and evaluating students' skills in the frame of four generic competences. A large part of lesson planning is knowing all the generic competences and the specifics of each individual competence, especially which strategies, methods and types of lessons are being planned, since they fundamentally affect the development of a certain skill or competence. To sum up all the major findings presented in the research:

1. The results show that, after the experiment, the mastery of skills at a lower and higher taxonomic level for a single generic competence is higher in students of the experimental group and mostly in learning and problem solving, interpretation, and verbal and written communication, where the appreciation is mostly due to successful methods of work.
2. Boys and girls were, at a lower taxonomic level, the most proficient in social skills and the least proficient in communication skills. Boys achieved the most progress in mastering social and communication skills and girls in mastering working skills.
3. From the calculated effect size (d) (Table 12), it can be concluded that the most progress in students' skills was achieved in developing social and communication skills at a higher taxonomic level. A moderate effect was achieved in the field of working skills at a higher taxonomic level.
4. It was proven that in project work that is based on problem-based and research-based lessons (active students), better results were achieved in developing students' skills than with frontal work (students are passive listeners).

The relatively good result presented in Table 12 was surprising since the measured effect confirmed that greater development of students' skills can be achieved by using PBL. The control group's average value was 3.216, while that of the experimental group was 4.019. The most progress in skill mastery was achieved in developing social skills at a higher level, and in communication and working skills at a lower level, as had also been expected.

That project based learning (PBL), which encompasses problem-based lessons, experimental and research work, and has a very strong effect on students' process knowledge and indirectly on developing skills, is also proven by John Hattie's results, who sieved through 900 results of meta-analysis, that included 52,600 studies and 240,000 students (Hattie, 2013). He established that PBL have a strong effect (above 0.60) on the students' achievement and also on cooperative learning, developing vocabulary, teaching learning strategies, solving problems and students' prior achievements (prior knowledge). These are also the elements that we planned when implementing lessons and research.

Conclusions

The results showed that project-based learning as a modern teaching method and part of the competence-based curriculum offers optimum development of students' knowledge and skills. Progress depends on the gender and the preliminary score of the student. Not only is it important to develop certain skills i.e. competences, but one also needs to have suitable tools to test them. On the bases of Bloom's, Simpson's and Dave's taxonomy for all three fields, cognitive, affective and psychomotor, the research developed a unified taxonomy (UTC – Unified Taxonomy of Competences) where acquired skills/competences in every field at a lower and higher taxonomic level are defined. For this purpose, an instrument for measuring students' skills/competences was developed.

The research was carefully planned, because it took place in a classroom with randomly chosen students in the presence of experts from the technical and pedagogical-didactical fields. A pilot study was carried out beforehand under the same conditions and where the students were of the same age. The developed instrumentation allowed evaluation of initial mastery of skills at both taxonomical levels, evaluation of final state and following the progress in mastering skills at both taxonomical levels.

It is obvious that the results of the research will be of great help to teachers, as the instrumentation developed along with the measurement methodology will help improve the quality of examination and evaluation of students' skills, not only in Science and Technology, but also in other areas of education, and not only in Slovenian schools, but also worldwide. The results and findings of this research could also have an impact on the consideration of amending the regulations on examination and assessment of knowledge in elementary school and integrating an assessment of student skills.

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