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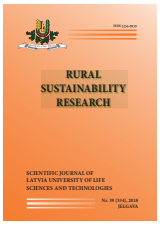

A Constructivist Approach to the Teaching of Mathematics to Boost Competences Needed for Sustainable Development

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Abstract. The constructivist approach is based on the idea that knowledge can never be passed from one person to another. The only way to acquire knowledge is to create or construct them. The constructivist approach changes also the role of the teacher in the educational process, the task of them is to organize the environment so that the student himself can construct the cognitive forms that teacher wants to give him. In the paper, the nature of the constructivist approach is identified, different aspects regarding mathematics education are analysed as well as the potential impact on the development of mathematical competences in the context of sustainable development is discussed. The study process and learning methods appropriate to constructivist approach also were studied. In order to illustrate the need for a constructivist approach in mathematics education, the survey of students from Latvia University of Life Science and Technologies (LLU) and Riga Technical University (RTU) were carried out, the results of which proved that mathematics learning at universities has to be changed. The current study proved that the constructivist approach radically changes the process of teaching and learning mathematics, connecting it with daily life, rather than teaching only abstract formulas and using a creative approach to mathematical tasks solving. This study shows that using constructivist approach to the teaching of mathematics, the competences needed for sustainable development are boosted.
Key words: constructivism, mathematics, sustainable development.

Introduction

At present, sustainable development and environmental issues are key issues for the development of society, because they raise different challenges which are shaping prospects for quality of life in the future. Education is one of the factors contributing to the sustainable development of society as well as contributes to the development of the competencies needed for sustainable development of every member of society. Education for sustainable development (ESD) teaches individuals how to make decisions that consider the long-term future of the economy, ecology and equity of all communities (UNESCO, 2008). Higher education has a particular responsibility and role to play by equipping learners with capabilities they need to take on different challenges (David, 2004). Through their pivotal and influential role in society, universities are key stakeholders in achieving a sustainable future (Cortese, 2003). That is why universities have to focus on the learning that supports sustainable development and building capacity compatible with sustainable development.

It should be noted that mathematics has a special role to increase the capacity of the university in preparation of new professionals in line with the development trends of society as well as getting competencies for living and working in the changing world with focus on employment and sustainable socio-economic development, as well as seeing mathematics as an instrument to tackle environmental challenges. Complex problem solving, critical thinking, creativity, decision making, cognitive flexibility – these are the competences most often referred to as a key element of sustainable development, and they can be developed through mathematical education. According to Serve (1957), mathematics develops logical thinking that includes the ability to think deductively, ability to abstract, generalize, classify, ability to think, analyse and criticize. Mathematics is considered as a unique way of interpreting human thoughts.

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In spite of the above mentioned, several studies have shown that the quality of the mathematics studies is decreasing and the level of students' preparation and knowledge is getting worse. There are several factors that influence the development of mathematics education, including the structure of study programs, learning environment and pedagogical approaches to teaching mathematics. It is well known that in recent years several universities have reduced the time allocated to mathematics studies, but the content has remained unchanged or even increased. Therefore, the situation is that teaching of mathematics consists mainly of transmitting of main concepts to students focusing on task-solving techniques. Traditional teaching involves the passive transmission of abstract, symbolic and existing mathematical structures to students, thus forcing them to adopt thinking structures developed by others which do not motivate students to get better results. In turn, students are interested in explaining in detail how the particular mathematical calculation techniques are applied in real life context.

Based on various pedagogical studies, it is believed that the constructivist approach radically changes the process of teaching and learning mathematics, connecting it with daily life, rather than teaching only abstract formulas and using a creative approach to mathematical tasks solving. Thus, the aim of this study was to identify the nature of the constructivist approach, to discuss the potential impact on the development of mathematical competences in the context of sustainable development as well as study process and learning methods appropriate to constructivist approach. In order to illustrate the need for a constructivist approach in mathematics education, the aim was also to identify students' views on the organization of the current mathematical study process and approaches, used in the development of competences.

Materials and Methods

The problem has been approached by analysing and evaluating the scientific literature for the development of the methodological basis of this study. Constructivist ideas in pedagogy have evolved since the 17th century, based on the philosophers of that time, who believed that a person can understand only what he had constructed himself. In his turn, I. Kant considered that knowledge depends on the interactions between the environment and person's internal properties, and the person himself organizes and interprets his own experience. The idea of constructivism is based on the fact that the human brain does not directly reflect the external world, but constructs its experience and life in cognitive and emotional processes in the social context as subjective ideas and concepts. In accordance with Jonassen (1991), the reality available to a person is the reality created by him which is determined by the person's ability to gain this experience. The present world exists independently of the person, it is not directly perceivable, recognizable or taught. Experience does not come from perception, but in the activity of the person himself (Jonassen, 1991).

Constructivist ideas are also found in several works including ideas of theorists *Dewey*, Piaget, Vygotsky, Candy, Driver, Merizow, Boud etc. However, constructivism as a theory was officially recognized in the early 1990s. It should be noted that mathematics education is more influenced by Piaget, Vygotsky, and von Glasersfeld ideas.

Piaget's works had a great influence on mathematics education. Piaget's ideas were considered a new field in mathematics education, which encouraged the development of cognitive knowledge. According to the Piaget's theory of cognitive development, it is not possible to provide information which will be immediately understood and used, but the students themselves build their knowledge as a result of assimilation and accommodation processes (Piaget, 1977). According to Piaget, all knowledge is constructed and the instrument of construction includes cognitive structures that themselves are products of continued construction. That characterizes constructivism as cognitive position. Piaget theories describe the structures of mind, focusing on in the human mind, how a person assimilates information and adjusts or does not adapt it to the one he knows.

In accordance with Glasersfeld (1987), perceiving is always an active making rather than a passive receiving. He claimed that knowledge is not passively received but actively built up by the cognizing subject and knowledge is the result of a self-organized cognitive process. The function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality. Creating own, internal reality, however, with changing internal or external constraints, challenges to try and / or adapt new experiences (Glasersfeld, 1989).

The Russian psychologist Vygotsky emphasizes the importance of the social environment in cognitive development as well as culture and people as the most important factors in the development of an individual. He proved that an individual cannot develop without interacting with the environment (Vygotsky, 1978). Constructive processes are particularly strong in group conditions, where each individual has a sense of the complex social interactions in which he is included. Vygotsky considered that knowledge starts at the social level, and only then it becomes individual knowledge (Vygotsky, 1978).

With regard to constructivism in higher education, there are five aspects that have recently emerged from the basic ideas mentioned above (Bognar, Gajger, & Civic, 2015):

1) Learning is a process of interaction between what we know and what we still need to learn. In the learning process the previous knowledge and students cognitive structure have to be taken into account;
2) Learning is a social process – "is not in leads, but in relations between people";
3) Learning is situational process, i.e., "participation in certain social and cultural circumstances";
4) Learning is a metacognitive process which "includes the understanding of the skills and strategies that enable successful resolutions of the problems, and to use these skills and strategies in order to learn effectively";
5) Learning is based on the students' activity and autonomy.

These aspects are taken into account in empirical study creating questionnaire to identify students' views on the organization of the current mathematical study process and approaches used in the development of competences. The research included a survey of students from Latvia University of Life Science and Technologies (LLU) and Riga Technical University (RTU). The survey questionnaire included several diagnostic blocks: information about the respondent, assessment of mathematical knowledge, skills and competences, teaching mathematics at university, mathematical learning experience, mathematical potential values, and proposals to be taught in mathematics at the university. The questionnaire also included questions whether students saw the need for mathematical knowledge in today's labour market conditions. This paper analyses students' answers to questions related to mathematical learning experiences, the teaching of mathematics at a university and approaches used in the development of competences.

Questionnaire included different types of questions. Respondents were required to evaluate the expressions by expressing their approval or disapproval on a 4-stage (diagnostic blocks: "Teaching mathematics at university", "Mathematical competence") or the 5th-stage (Diagnostic Block: "Potential mathematical values") Likert scale. Other question types were also asked in the questionnaire – questions with indicated answers and an open question.

The survey was attended by 699 respondents by completing the electronic questionnaire, available at http://www.iipc.lv/surv/index.php/393736/lang-lv. 269 questionnaires were completely completed, and used as the basis for this study.

Results and Discussion

To implement constructivist approach, it should be designed, implemented, and then guided through the process of collaboration and interaction between students, so that learning is constructed by the group, rather than just the individual (Fernando *et al.,* 2005). Constructivism assumes that learning is a social process where individuals learn through interacting with other people (Pritchard & Woollard, 2010). Different studies show that learning is an active process in which an individual continues new knowledge and understanding based on existing experience of choosing and transforming information.

However, the answers of the students surveyed indicate that the situation in the mathematical studies of Latvian universities is the opposite. Knowledge is still passed as a lecture using teaching methods. In addition, lectures take place in large groups. The skills of the tasks solving, given during the lectures are trained in practical works. Learning more correlates with repeating of a rule, algorithm solving examples, not with deeper understanding of mathematics. Pursuing of the conformity of the methods of teaching/learning of mathematics with a student's expectations, the process of learning could be more involving, interesting.

Several responses to the open question: "What should be taught in mathematics at the university and how exactly should this be done to promote mathematical competency building?" point to the need to link mathematics studies with the calculations that are actually used in a particular specialty, rather than teaching the most difficult solution possible, a kind that never needs to be used in reality. According to Vygotsky, an individual learns better if the content and process of learning correspond to his "closest development zone" and he can solve the problem with the support of experienced people and cooperation with other people (Vygotsky, 1986).

Various suggestions for improving mathematics education at universities come from the student survey. Students from both universities claim that:

1) Enhancement of the link between teaching of mathematics and practice: The lecturers should explain examples of real life where a particular teaching substance is used. It makes it easier to perceive and understand the mathematics concepts differently, but the question arises whether it is necessary.
2) Increase students' motivation: before starting to learn a particular branch of mathematics, first of all, it would be useful to know how it can be applied in practice in a particular specialisation. It would encourage students' interest and would make the process of learning easier.

3) Lecturers should be more interested in the application of mathematics in the particular area of science.
4) Learning should be directed towards understanding: It is necessary to strive to teach a person to understand mathematics, but not just teach him/her in order to make him know formulas without an opportunity to learn how to apply them in the real life.
5) Links between mathematics and other subjects. Students pay attention to the need to demonstrate the connection of higher mathematics with other study subjects and applications in them, for example, in physics, in order to calculate different values – centres of gravity for the body, non-standard volumes, fields, etc., in construction – building material loading loads, etc. calculations.
6) Students also see the need for mathematical knowledge in everyday life, such as interest bills (for example, when buying something at a discount), calculation of the area (when building a house or arranging a garden), etc. It proves that the formulas and their explanations alone are not enough to be concerned with the environment and the chosen future profession to create an interest in students with practical examples in life / profession, thus motivating them to succeed in math and competence development.

According to the theory of constructivism, the study process includes the following components (Parsons, Hinson, & Sardo-Brow, 2002):

a) A student creates knowledge himself with the meaning that they themselves have to find.
b) This means understanding both the whole and individual parts. Understanding interconnections must be found in the learning process.
c) Motivation is an essential learning indicator
d) Self-directed learning is a process.

Several studies have shown that motivation is a key element of successful teaching and learning. It depends on the needs of the individual's personal interest, depending on the results and practical application abilities. According to a study by Havighurst (1972) on the relation between different life cycles and educational needs, at the age of 18-30, education is usually linked to career prospects and employment prospects. Mathematics is an area that needs to be as knowledgeable as possible so that an individual can successfully pursue his or her career.

However, in this study, only 54.7% perceive the need for mathematical knowledge in today's labour market conditions, while 18.2% of respondents deny the connection between mathematical knowledge and employment, which undeniably reduces student motivation for achieving good results. An average 56% of respondents agree or even strongly agree to the statement "Mathematical thinking helps solving life and professional problems", 44% of them have the opposite opinion. 68% of total respondents agree to the statement "People who understand mathematics will easily deal with tasks that require thinking". Only 33% of students from computer sciences and information technologies specialties see the role of mathematical thinking in solving various problems.

In constructivism, the goal of learning is to develop a critical thinking personality as a social change maker. In accordance with Cobb (1988), there are two major goals for mathematics:

1) The student should develop mathematical structures which are more complex, abstract, and powerful and they are increasingly able to solve a wide variety of meaningful problems.
2) The students should become autonomous and self-motivated in their mathematical activity. The students have to believe that mathematics is a way of thinking about problems.

The impact of the constructivist approach on the development of mathematical competences in the context of sustainable development can be seen from different aspects. The most important that constructivist approach gives preeminent value to the development of students' personal mathematical ideas and students are encouraged to use their own methods for solving problems. Through interaction with mathematical tasks and other students, the student's own intuitive mathematical thinking gradually becomes more abstract and powerful (Clements & Battista, 2009). Constructivism theory is based on the idea that people construct their own knowledge through their personal experience. The effectiveness of constructivism is that it prepares students for problem solving in complex environment (Shuman, 1996).

According to Gibbs (1992), university students are assumed to be self-directed in their studies and activities provide them opportunities of hands-on practices for learning and interpreting it. They develop their own understanding of learning, its meaning according to the context, and the ways to acquiring it.

The use of Vygotsky (1978) ideas based constructivism develops confidence, respect for others, etiquettes and social skills among learners. Constructivism offers students opportunities of cooperative and collaborative learning.

The constructivist approach assumes that the more effective it becomes, the more repeated it is doing. It consists of various forms and activities, including

cooperative learning, learning experience, problem-based learning and teaching research (Hussain & Sultan, 2010). It is based on the active involvement of students and their interaction with the creation of new knowledge. Critical thinking, problem-solving approach and analytical skills are the most important skills that are developed in the process of mathematics education and are also the cornerstones of sustainability. Equipped with such abilities and skills, the student creates new knowledge based on their past experience and involvement in the learning process (Li, 2001). Constructivism means understanding both the whole world and individual parts. Understanding interconnections must be found in the learning process.

The constructivist approach changes the role of a teacher in mathematics education from an instructor to a leader or facilitator. As knowledge can never be passed from one person to another the only way to gain knowledge is to either create or construct the same. Consequently, the teacher's task is to change the environment of the pupil so that the pupil himself can construct the cognitive forms that the teacher wants to give him. According to Bruner (1986), in the constructivism, a teacher, offering appropriate tasks and opportunities for dialogue, guides the focus of students' attention, thus unobtrusively directing their learning. In accordance with the constructivist approach, the role of a lecturer changes from the knowledge provider to the organization of a teaching assistant. The teacher (Parsons, Hinson,& Sardo-Brow, 2002):

1) Encourages students to learn the information themselves.
2) Encourages students to further learn what they are interested in.
3) Helps students explore the topic themselves.
4) Seeks to make students more aware of some topics.
5) Motivates, uses the interests of students.

Educational environments should be structured to cause students to develop more powerful thinking teaching and classroom environment change if you accept that students must construct their own knowledge (Clements, Battista, 2009). Students' individual differences also have to be taken into account.

Summarizing the findings in this study and taking into account the author's experience in teaching mathematics, it is necessary to give preference to learning methods that require constructive answers - projects, summaries, multi-task tasks, all that can reveal conceptual understanding better than tests or short answer tasks and the most important problem solving - methods based on the development of mathematical imagination, creativity, heuristic thinking, etc.

Conclusions

1. The greatest influence on constructivist approach in mathematics education comes from Piaget, Vygotsky and Glasersfeld who characterize constructivism as cognitive position and also admit that social interaction and knowledge is self-organized cognitive process.
2. Different studies prove that learning is an active process in which an individual continues to acquire new knowledge and understanding based on existing experience of choosing and transforming information.
3. The LLU and RTU students' survey shows that mathematics is taught in a dry and boring manner. Based on the survey results, it is necessary to provide as much theoretical knowledge and proof as to form mathematical logics and teach the deeper structure of math, and then solve tasks of applicable nature.
4. The impact of the constructivist approach on the development of mathematical competences in the context of sustainable development can be seen from different aspects including critical thinking, problem-solving approach, analytical skills as well as confidence, respect for others, etiquettes and social skills among learners.
5. There are different methods of approach to constructivist approaches – problem and project based, corporative and collaborative methods. Also, experiential and inquiry learning as well as research and discovery learning as main methods in mathematics education in the context of sustainable development are recommended.
6. Taking into account empirical study results as well as findings from reviewing scientific literature and other information sources in connection with the author's experience in teaching mathematics, using constructivist approach in teaching of mathematics, the competences needed for sustainable development are boosted.

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