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Efficiency of learning environment using GeoGebra when calculus contents are learned in collaborative groups

Djurdjica Takači [a,*], Gordana Stankov [b], Ivana Milanovic [c]

[a] University of Novi Sad, Faculty of Science, Serbia
[b] Subotica Tech – College of Applied Sciences, Subotica, Serbia
[c] High School Isidora Sekulić, Novi Sad, Serbia

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ABSTRACT

In this paper we present a modern approach of teaching mathematics based on the computer supported collaborative learning (CSCL) of calculus contents. The collaborative learning was used in calculus course at the University of Novi Sad, Serbia, for examining functions and drawing their graphs. In 2012 the authors decided to improve the collaborative learning introducing *GeoGebra* application. Small four member groups were formed by using Kagan's (1994) principles. Two groups of students, the experimental, and the control one were observed. The students in the experimental group learned with the help of *GeoGebra*, and the students in the control group learned without using *GeoGebra*.

Comparison between those two groups of the first year calculus students, regarding their way of learning and the results achieved, is described below. Before the students' collaborative learning, they were tested with a pre-test and their knowledge necessary for examining functions was verified. The pre-test showed that there was no significant statistical difference between the experimental and the control group. The experimental group worked with the help of the computer and the control one without it. After the collaborative learning, the students were tested with a test (colloquium) and the results of the experimental group were significantly better than the results of students in the control group. At the end of the course the students did their exams (post-test), and the results of the experimental group were significantly better than the results of students in the control group.

Some students from the experimental group had to answer questions in an interview related to the use of *GeoGebra* during their collaborative learning. In order to see the students' difficulties in solving problems, students in the experimental group were asked to cross out incorrect parts of solutions, not to erase them. The teachers reviewed the students' tasks done during the collaborative learning and after that the students who had corrected their mistakes were invited for an interview about using *GeoGebra* for overcoming their difficulties. Based on the students' results in the tests, answers in the questionnaire and in the interview, it can be concluded that *GeoGebra* has enabled an easier learning of this material. The *GeoGebra* package enables the students to check whether each step in the process of solving a task was correctly done or not. The results of our research show that *GeoGebra* can help those students having insufficient knowledge (necessary for solving those tasks) to improve it.

We can say that our research shows that the students' learning achievement in examining functions and drawing their graphs is better when they use *GeoGebra*, working in collaborative groups than without using it. Also, *GeoGebra* enables creation of effective learning environment for examining functions and drawing their graphs.

* Corresponding author.
E-mail address: djtak@dmi.uns.ac.rs (D. Takači).

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1. Introduction

The crucial agent for the effective organization and development of a knowledge based society is people's knowledge and skills. The wide spread use of information and communication technologies (ICT) is at the same time cause and result of the development of such a society. One of the main aims of education is to enable students to participate actively in this society. Kim (2002) quotes precisely some of the aims of the educational development. According to Kim (2002, p. 144) education should develop into "… one that is search- and discovery-centered, emphasizing creativity and initiative, and valuing interaction and collaboration." These aims are more easily obtained if students at educational institutions use ICT and for achieving these goals, better pedagogical methods should be developed (Allegra, Chifari, & Ottaviano, 2001; Manenova, Skutil, & Zikl, 2010; Valtonen et al., 2014; Viamonte, 2010).

Even today, learning by using personal computers is considered a solitary activity, although during classes at educational institutions, a pair, or a small group of students work on a single computer. Some of the reasons for this is either a limited number of computers available, or different skill levels of handling some programs by students, where they depend on the help of one another. Keeping Kim's suggested aims in mind for the development of education, the above stated situation, as well as using internet in the process of education, can be a good basis for a successful application of collaborative learning and its research. This way CSCL emerged as a field of learning science in 1990s (Crook, 1994; Koschmann, 1996; O'Malley, 1995). Nowadays CSCL is regarded as one of the most advanced tools for improving teaching and learning (with the help of ICT) (Figueira-Sampaio, Ferreira dos Santos, & Carrijo, 2009; Garcia, 2013; Gomez, Wu, & Passerini, 2010).

In this paper, the process of computer supported collaborative learning during the course Mathematics I, or calculus course, for the first year students, majoring in physics, chemistry, and informatics, at the University of Novi Sad, is analyzed. The content of the course is similar to almost all calculus courses. The students are supposed to do all calculations as determining the derivatives, their zeroes, limits, asymptotes, and so on, and then to draw the graph of the function. It is well known that many students have difficulties with the calculus contents, in particular examining functions (Takači, Pešić, & Tatar, 2006; Tall, 2009, 2011; Tall & Vinner, 1981).

We structured our paper in the following way:

In Section 2 the theoretical approach and the literature review of the constructivism, collaborative and cooperative learning with the accent on computer (GeoGebra) environment are presented.

In Section 3 the methods of forming the experimental, the control and the collaborative groups are explained. The research process of the students' tasks are presented.

In Section 4 the analysis of the tasks done in experimental groups are analyzed with the regard to the mistakes that students made during their collaborative learning with the computer.

In Section 5 the statistical analysis of the results of students achievement on the test and the post-test is given. In general it is shown that students in the experimental group have much better results than the students in the control group.

In Section 6 the conclusion of our research is presented.

2. Computer supported collaborative learning

According to Stahl, Koschmann, and Suthers (2006, p. 1) "Computer-supported collaborative learning (CSCL) is an emerging branch of the learning science connected with studying how people learn together with the help of computers." Also Miyake (2007, p. 248) says: "Current CSCL (Computer Supported Collaborative Learning) research has seen some consensus in regarding as a social process, where each individual participant, or learner, is responsible for creating his or her own knowledge through social interaction with human beings by interaction with physical objects in everyday situations".

As the CSCL is the base of our research, in this section we present it together with its relating notions. Results of cooperative and collaborative scientific research have contributed a great deal to the development of CSCL (Wang, Wu, Kinshuk, Chen, & Spector, 2013; Zurita & Nussbaum, 2004). That is why we present collaborative and cooperative learning and discuss the relationship between them. A special highlight is given to the crucial role of the usage of the computer in CSCL, particularly in learning calculus. This section starts with reviewing the constructivism as it is the theory of learning on which collaborative learning, cooperative learning and CSCL are based.

2.1. Constructivism

According to constructivist learning theory, the learner's mind actively creates knowledge in its own way and does not passively adopt it from the outside (Bordner, 1986; von Glasersfeld, 1995). In the process of learning, the learner creates meaning of new ideas and information, connecting them with his existing knowledge. Often he has to adapt his existing knowledge to accommodate the new experience. During the learning activities that follow, the individual develops his knowledge and it becomes more complex, more sophisticated over the time.

Although the construction of knowledge is an individual activity, the learners realize it through interaction and collaboration with other people. The students explore their learning environment, conduct and monitor their own learning and are responsible for it. In this process explanations of thoughts and discussions among students are of crucial importance (Iran-Nejad, 1995; Naylor & Keogh, 1999; Sjoberg, 2010; Taber, 2011).

At the same time the teacher acts as a facilitator and guide. He structures learning environment to facilitate the students' learning. He requires from students to analyze, encourages their initiative, uses different interactive materials and suggests students to use them, encourages students' dialogs, suggests students to ask different questions the teacher and one another and seeks elaboration of students' initial responses. Teacher also initiates discussion after engaging students in experiences that point out the contradictions to students' knowledge (Brooks & Brooks, 1993; Dogru & Kalender, 2007; Tobin & Tippins, 1993).

The constructivist learning is most effective when the students compare and share their ideas with others and also the social interaction is best in small groups (Good & Brophy, 1994). Knowing that, many teachers have begun to organize learning according to the constructivist