Razvoj modela računalno vođenoga učenja otkrivanjem korištenjem programa dinamične geometrije u nastavi matematike

Doktorski rad

dr. sc. Željka Dijanić

Sažetak:

Cilj je ovoga istraživanja razviti model računalno vođenoga učenja otkrivanjem u nastavi matematike koristeći program dinamične geometrije. Rad je teorijski utemeljen na teoriji radikalnog konstruktivizma (von Glasersfeld, 1995), teoriji učenja otkrivanjem (Bruner, 1961), Polyinoj strategiji rješavanja problema (Polyá, 1966) i Schoenfeldovom modelu rješavanja problema (Schoenfeld, 1985), pri čemu se kao ideja modela za e-učenje temeljeno na konstruktivističkom pristupu uzima konceptualni model e-učenja u prirodoslovlju (Elliott, Sweeney i Irving, 2009).

U istraživanju je sudjelovalo 15 učitelja matematike i 703 njihova učenika šestog, sedmog i osmog razreda iz dvanaest škola u deset županija Republike Hrvatske. Učitelji su suradničkim radom kreirali digitalne materijale za učenje u obliku interaktivnih apleta i objedinili ih u tri digitalna udžbenika, po jedan za svaki razred, koji obuhvaćaju po pet nastavnih jedinica iz matematike. Korišten je eksperimentalni nacrt s eksperimentalnom i kontrolnom skupinom kao skupinama za usporedbu, pri čemu je eksperimentalna skupina učenika učila po modelu računalno vođenoga učenja otkrivanjem, a kontrolna skupina učenika u tradicionalno organiziranoj nastavi. Prije provedbe eksperimenta učenici su pisali ispit predznanja i ispunili upitnike motivacije i stavova o učenju matematike s pomoću računalne tehnologije. Završna su se ispitivanja provodila na identičan način.

Ispitivane su varijable usvojenosti konceptualnog i proceduralnog znanja, motivacije učenika za učenje matematike i stavova učenika o samostalnom učenju matematike s pomoću računalne tehnologije. Analizom kovarijance utvrđen je utjecaj modela računalno vođenoga učenja otkrivanjem na te varijable, a dobiveni rezultati pokazuju statistički značajne razlike između skupina u korist učenika eksperimentalne skupine. Učenici koji su poučavani prema modelu računalno vođenoga učenja otkrivanjem postižu bolje rezultate u konceptualnom i proceduralnom znanju od učenika poučavanih u tradicionalnoj nastavi. Također se uočava poboljšanje intrinzične motivacije i interesa učenika za učenje matematike nakon intervencije, kao i pozitivan stav učenika i učitelja prema učenju matematike uporabom informacijsko-komunikacijske tehnologije.

Provedena je opširna kvalitativna analiza rasprava učitelja na forumu sustava za *online* učenje, analiza polustrukturiranog intervjua učitelja te analiza odgovora učenika na pitanja otvorenoga tipa, što im se svidjelo, odnosno nije svidjelo kada su učili po modelu računalno vođenoga učenja otkrivanjem. Dobiveni rezultati ukazuju na mnogostruke prednosti predloženoga modela učenja: individualiziran pristup svakom učeniku, aktivan rad svih učenika vlastitim tempom, mogućnost ponavljanja lekcije više puta ili vraćanje na prethodnu lekciju, istraživanje i samostalno otkrivanje novih spoznaja, vizualizacija matematičkih sadržaja, interaktivnost i dinamičnost digitalnih materijala, brza povratna informacija, lakše i zanimljivije učenje i vježbanje zadataka igrom. Neki od uočenih nedostataka učenja po tome modelu su: nesnalaženje pojedinih učenika u novom okruženju za učenje, nerazumijevanje uputa za rad, *brzanje* pojedinih učenika u proučavanju nastavnih materijala, kao i neprimjerenost tog modela učenja za usvajanje nastavnih sadržaja u kojima je naglasak na crtanju i geometrijskim konstrukcijama. Također se uočava važnost iskustva učitelja u poučavanju po tome modelu.

Razvoj tog teorijskog modela učenja doprinosi i znanstvenoj zajednici i zajednici praktičara. Model računalno vođenoga učenja otkrivanjem korištenjem programa dinamične geometrije ukazuje na mogućnosti primjene teorije konstruktivizma u matematičkom obrazovanju, kao i na potencijal računala i računalnog programa *GeoGebra* kao *scaffolding* potpore u učenju matematike. Rezultati tog istraživanja mogu pomoći dizajnerima digitalnih obrazovnih materijala i učiteljima matematike u kreiranju digitalnih nastavnih sadržaja (interaktivnih apleta) i planiranju nastavnih aktivnosti koje će pozitivno djelovati na izvedbu učenika i na motivaciju za učenje matematike. Predloženi model učenja znanstvenicima može poslužiti kao polazište za daljnja istraživanja uporabe računala i programa dinamične geometrije u nastavi matematike.

Ključne riječi: digitalni udžbenik, interaktivni aplet, konstruktivizam, konceptualno znanje, model učenja, motivacija, nastava matematike, proceduralno znanje, program dinamične geometrije, rješavanje problema, učenje otkrivanjem.

Development of the model of computer guided discovery learning by using dynamic geometry software in teaching mathematics

Doctoral thesis

Željka Dijanić, PhD

Abstract:

The modern mathematics teaching is focused on the student. Being an active participant in the teaching and learning process, he/she observes, investigates, asks questions, creates hypotheses, solves problems, cooperates with others, analyzes and evaluates his/her own work and the work of others. The teacher's role is to prepare appropriate activities for students, guide them in the learning process and encourage them to think. Computers and software specialized for mathematics learning, like dynamic geometry software, can help, especially as scaffolding support in doing some experiments and discovery learning.

The aim of the research is to develop computer-guided discovery learning model by using dynamic geometry software. The study is theoretically based on the radical constructivism learning theory (von Glasersfeld, 1995), the discovery learning theory (Bruner, 1961), Polyá's problems solving strategy (1966) and the problem solving model by Schoenfeld (1985). The idea for constructivist approached e-learning model is based on the conceptual model of e-learning in the natural sciences (Elliott, Sweeney and Irving, 2009).

The computer-guided discovery learning model progressively built during the research, consists three elements: (1) learning objects, (2) activities for students and (3) learning outcomes (Figure 0).

Learning objects are created like interactive applets in dynamic geometry software *GeoGebra* and made of a static and a dynamic part. The dynamic section includes the mathematical objects that can be moved so students could observe their interactivity and perform experimental work. The static section of applet contains instructions, questions, tasks, suggestions or help, which allow guiding student on his/her way to conclusion with minimal risk of failure. These interactive applets are organized in the digital textbook with chapters for each teaching unit and every applet has one of the following functions:

(1) Motivation applet, at the beginning of each teaching unit. Its main role is to present a problem or topic to the student and to motivate him/her for further work.

(2) Exploration applet; its role is to enable performing mathematical experiments to the student and help him/her discover new mathematical knowledge. There are one or more research cycles in each applet which stages are taken from Pólya's problem solving strategy: understanding the problem, devising a plan, carrying out the plan and looking back. At this learning stage the basic outcomes are to acquire conceptual knowledge and understand the basic ideas in mathematics.

(3) Training applet; its role is to enable students solve some math problems related to the topic. For additional students' motivation these applets include the elements of game and students' progress is encouraged by collecting points. The learning outcomes are to apply discovered skills in solving problems and acquire procedural knowledge.

(4) Additional contents; like interesting facts from the history of mathematics, some specific knowledge application in everyday life, extended mathematical contents for gifted pupils, additional teaching activities for students with less developed mathematical abilities, quizzes and the like.

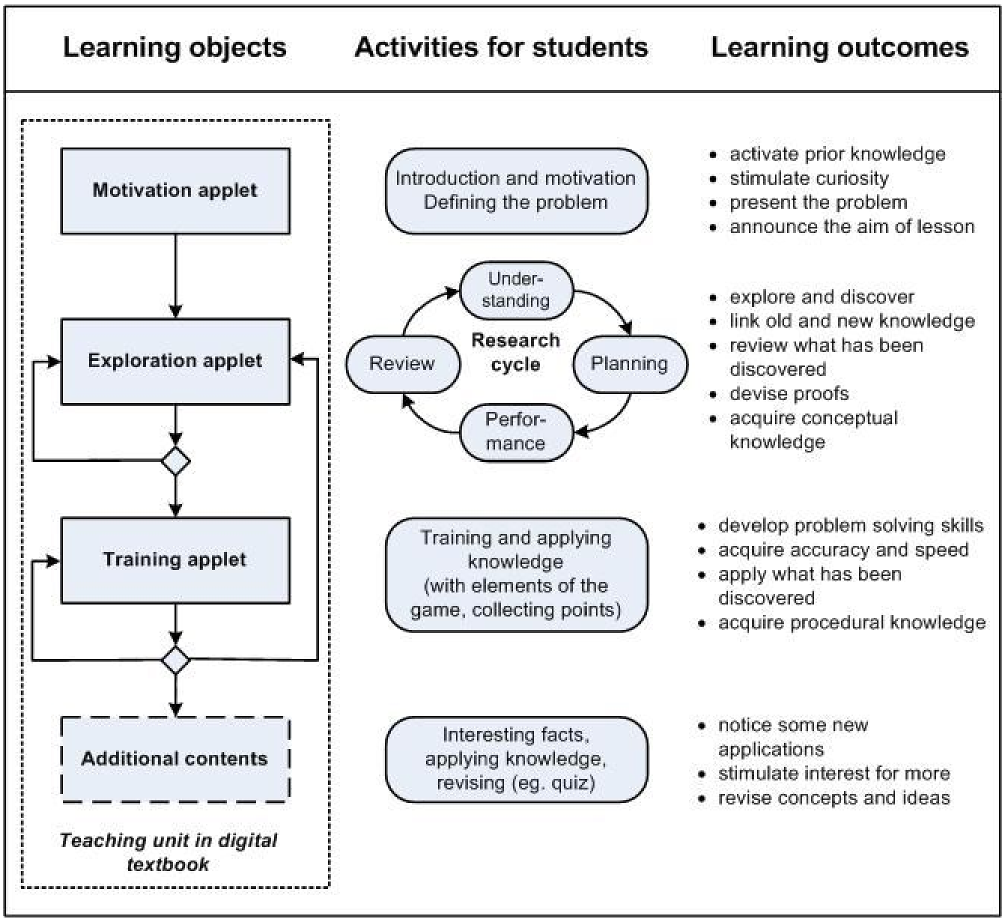

Figure 0. Scheme of the computer-guided discovery learning model

There were 15 mathematics teachers and 703 of their students from the sixth, seventh and eighth grades from twelve Croatian school participating in the research. Teachers collaboratively created digital learning materials in the form of interactive applets and made three digital textbooks of these materials, one for each grade, each including five lessons in mathematics. The experimental research plan with comparison groups was used, in which the experimental group of students was taught by the model of computer-guided discovery learning (as the intervention) and the control group of students was taught by teachers using traditional teaching methods. Before the experiment started, the students had taken the exams testing their prior knowledge in mathematics and completed the questionnaires of motivation and attitudes towards learning mathematics by using computer technology. The final examinations were conducted in the same way. The dependent variables studied in the research were conceptual and procedural knowledge, some aspects of students' motivation for learning mathematics and students' attitudes towards learning mathematics by using computer technology.

The teachers collaboratively created the lesson plans for both groups of students and also the exams for testing prior and final mathematics knowledge. Several questionnaires and some of their subscales were used for testing the motivation and attitudes: *Mathematics motivated strategies for learning questionnaire* (MMSLQ) (Liu & Lin, 2010), *Students' motivation towards science learning* (SMTSL) (Tuan, Chin & Shieh, 2005), *Mathematics and technology attitudes scale* (MTAS) (Pierce, Stacey & Barkatsas, 2005), *Predicting interest and achievement in learning exponential and logarithmic functions* (Rovan, Pavlin-Bernardić, Vlahović-Štetić & Šikić, 2014), *Attitudes to technology in mathematics learning questionnaire* (Fogarty, Cretchley, Harman, Ellerton & Konki, 2001) and *Attitudes to mathematics and technology in a computer learning environment* (Galbraith & Haines, 1998).

The covariance analysis determined the impact of the computer-guided discovery learning model on dependent variables, and the results have shown statistically significant differences between the groups in favor of the experimental group. If we look at the whole sample of students together, the students taught using the computer-guided discovery learning model accomplished better results in the conceptual (F=8.296; df=1/700; p<0.01) and procedural knowledge (F=9.173; df=1/700; p<0.01) than the students taught traditionally. If we look at the grades individually, such differences are detected only at the sixth-grade students for conceptual knowledge (F=5.608; df=1/238; p<0.05) and at the eighth-grade students for both conceptual (F=6.524; df=1/279; p<0.05) and procedural knowledge

(F=16.413; df=1/279; p<0.01), while there is no statistically significant difference between the groups of seventh-grade students.

Likewise, the results of the whole sample of students have shown statistically significant differences between the groups in favor of the experimental group for two tested motivational variables: intrinsic motivation (F=3.943; df=1/700; p<0.05) and students' interest for learning mathematics (F=9.564; df=1/700; p<0.01). There is no statistically significant difference for self-efficacy and mastery goals (in achievement goal theory). According to *Mathematics and technology attitudes scale* the results of the whole sample have shown statistically higher level of affective engagement in learning mathematics (F=5.771; df=1/700; p<0.05) for experimental group of students and no differences in the following variables: mathematics confidence, confidence with technology, attitude to learning mathematics with technology and behavioral engagement in learning mathematics. If we look at the grades individually, there are statistically significant differences between the groups in favor of the experimental group for following variables and grades: behavioral engagement in learning mathematics for sixth-grade students (F=6.356; df=1/238; p<0.05), mathematics confidence for eighth-grade students (F=9.103; df=1/279; p<0.01) and affective engagement in learning mathematics for eighth-grade students (F=11.543; df=1/279; p<0.01). The efficiency evaluation of learning mathematics by using ICT has shown statistically significant differences between the groups in favor of the experimental group: for the whole sample of students (F=20.651; df=1/700; p<0.01), for sixth-grade students (F=11.222; df=1/239; p<0.01), for eighth-grade students (F=7.100; df=1/280; p<0.01) and there is no difference between the groups of seventh-grade students.

Besides the quantitative analysis of students' results at exams and questionnaires, there was also the qualitative analysis of students' responses to open-ended questions of what they liked or did not like in the computer-guided discovery learning model. The students have pointed out the following advantages of the proposed learning model:

- the interactive tasks with quick feedback,
- the possibility of revising the lesson as many times as necessary,
- the exploration and discovery of new knowledge using a dynamic display of mathematical objects,
- easier, simpler, more interesting and funnier learning,
- visual display and animations,
- students do not have to write a lot in the notebooks.

Some students did not like discovery learning using interactive applets. They have noticed the following disadvantages of the proposed learning model:

- the educational contents are not explained well enough ,
- the instructions are difficult to understand,
- students prefer when their teacher explains them new knowledge,
- students do not write and draw in the notebooks.

Also, the extensive qualitative analysis of the teachers' discussions in the forum of learning management system *Moodle* was conducted, as well as the analysis of the semi-structured interview of the teachers. The results indicate multiple advantages of the proposed learning model:

- an individualized approach to each student,
- active work of all the students at their own pace,
- the possibility of revising the lesson several times or returning to the previous lesson, which certainly benefits the students with less developed mathematical abilities,
- the exploration and discovery of new knowledge for all the students,
- the visualization of mathematical contents, reasoning based on the visualization,
- the interactivity and dynamism of digital learning materials that enables experimental work,
- digital teaching materials are interesting, dynamic and motivating for students,
- quick feedback,
- solving problems through playing a game,
- additional contents for gifted pupils,
- students with disabilities can get more attention and help from the teacher (whereas others work independently).

The perceived deficiencies of using proposed discovery learning model in the class are:

- the disorientation of some students in the new learning environment,
- the lack of understanding the operating instructions, reading without understanding,
- some students rush through the learning material without proper reasoning,

- the lack of feedback to the teacher about the level of acquired mathematics knowledge for each student;
- the inadequacy of this learning model for lessons in which the drawing and the geometric constructions are the key features,
- some students have the feeling they are left to themselves,
- the problem with reading and understanding the operating instructions for students with disabilities, continuous need for teacher's help.

The importance of teacher's and students' experience in learning using this model has also been noted. This may be the possible reason why the results of seventh-grade students show no differences between the experimental and control group of students. The sixth-grade and eighth-grade teachers spent more time on explaining the rules and general students' tasks before discovery learning using these digital textbook and interactive applets.

The development of this theoretical learning model contributes to the scientific community and the community of practitioners. The model of computer-guided discovery learning by using dynamic geometry software indicates the possible applications of the constructivist theory in mathematics education, as well as the potential of computers and dynamic geometry software *GeoGebra* for scaffolding support in learning mathematics. The results of this research can help the designers of digital educational materials and the mathematics teachers in the reproduction of digital learning contents (like interactive applets) and in the planning students' learning activities that would have a positive effect on the students' performance and the motivation for learning mathematics. The proposed learning model can serve as a starting point for further research of using the computer and dynamic geometry software in teaching mathematics.

Keywords: digital textbook, interactive applet, constructivism, conceptual knowledge, learning model, motivation, teaching mathematics, procedural knowledge, dynamic geometry software, problem solving, discovery learning.