Teacher Education to Promote Constructivist Use of ICT: Study of a Logo-based Project

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Abstract

In the frame of a training course for future teachers, an ICT-enhanced project, based on a Logo learning environment and inspired from a constructivist education philosophy, was undertaken aiming at familiarizing students with the use of computer as a tool that can trigger constructivist learning and helping them to adopt an exploratory and constructivist teaching practice.

The training methodology applied in the training course focused on the trainees' self-activity and active engagement in lab exploratory activities. The common feature of the training activities was not the programming language but the so-called "Logo spirit", a constructivist spirit of action and learning. Through such a process, it was expected that student-teachers would gain personal experiences of exploratory and constructivist learning and would be able to inspire into their future students the same educational spirit.

Student-teachers were asked to give instructions to their turtle to draw regular polygons and a circle using movement commands. They were encouraged, before they give instructions to the Logo turtle to draw a geometrical figure, to analyse the problem and to think about the instructions. Very often student work resulted in unexpected wrong figures on the screen. So students had the opportunity to recognise their errors and to try again. This process was repeated several times until students reached the expected result. They were encouraged to try several solutions and keep trying until they succeed, to work with self-action and autonomy and finally to be questioned about the educational value of those activities.

- The evaluation of the project was based on
- Teacher-students´ achievement on the tasks as it was recorded on their work sheets.
- A 5-point Likert scale measuring the degree to which students agreed or disagreed with statements regarding the interest and the educational usefulness of the learning experience they had working on the tasks.
- Answers and explanations on open questions given in written form asking them to detect and mention any positive educational issues they had found in that method and to think of and report similar methods for teaching their school subjects
- Two case-studies: two teacher-students were encouraged to implement the same activities in their school class with their students and report results and experiences.

The evaluation results indicated a positive impact on the students in terms of familiarization with the spirit of the proposed methodology and of understanding the potential of ICT for constructivist learning. The evidence coming from the two course participants, who applied and evaluated the methodology in a school class, provided encouraging indications that the students became capable of applying the methodology they had learnt in real classroom settings.

Keywords

constructivist pedagogy; teacher education; Logo; problem solving

Introduction

This study was based on two premises. The first concerns the implementation of the ICT-enhanced constructivist learning today in classroom. The second refers to the emerging need for the appropriate teacher education and professional development as a presupposition for the implementation of constructivist innovation in classrooms.

Computer technology and the constructivism paradigm

There is wide consensus in education that learning is no longer seen simply as the result of a transmission of knowledge. Nowadays pedagogical strategies employed in the current ICT-based learning are linked to *constructivism* paradigm. According to constructivism, knowledge is considered to be socially and individually constructed; learning is the acquisition of meaningful competences in a realistic context; learning is advanced through interactive and authentic experiences that dovetail with the interests of the student and through active learning. So the focus is on the development of a suitable environment for constructing knowledge rather than for its transfer.

In such an environment the use of ICT can trigger constructivist innovation in the classroom contributing to the realisation of meaningful authentic, active-reflective and problem-based learning, a method that challenges students to "learn how to learn"; students seek solutions to real world problems, which, based on an ICT framework, are used to engage their curiosity and initiate learning, leading so to critical and analytical thinking.

The constructivist education philosophy aims at a school where students learn how to learn, in a learner-centered environment with emphasis on learning through discovery and exploration and on experiences in the development of problem-solving strategies (diSessa et al 1995).

The emerging need for teacher education in ICT-enhanced constructivist learning

ICT-enhanced constructivist classroom practices, however, demand that teachers play a new role. This means that opportunities, like exposure to a number of critical examples and experience in designing ICT-based activities and integrating them in their classroom practice in constructivist ways are of great priority. The aim is to convince teachers for the potentiality of ICT as constructivist learning tool through their own personal experience. For this reason the development and implementation of appropriate courses is very important for the teachers' professional development and crucial for the success of innovative approaches using ICT.

Teachers need to go beyond traditional approaches (Bhattacharya and Richards, 2001) and become acquainted with new methods in order to get a clear understanding of the educational functionality of technological tools in their educational practices. The approaches to staff training include the need for awareness of the advantages and possible difficulties of the proposed methods for school learning and usage of settings and tools for training similar to those expected to be used in classrooms in the sense of learning by doing and applying the new knowledge in real learning contexts.

Designing ICT-enhanced constructivist learning

Under the pre-mentioned theoretical framework, appropriate ICT-enhanced activities, critical examples and strategies that can be applied both in teacher training courses and in students' teaching to trigger constructivist innovation, have been integrated in the curriculum of the courses offered by the Educational Technology Lab at the School of Pedagogical and Technological Education (ASPETE) in Patras (Greece). Course participants, who are future teachers, are provided opportunities to examine how ICT can be used to promote a constructivist, learner-centered approach to learning.

Using a Logo environment as tool for constructivist learning

Logo is one of the ICT tools used among others in the training activities. Logo was selected because it is not only a dynamic programming language but also a valuable problem solving tool and a general mind tool. It is adjustable to student cognitive structures and offers micro worlds, simulations, open problem solving environment, diagnosis of student own errors, control and autonomy of their learning, spontaneous reflection, and development of self-knowledge (Papert 1980, Noss 1987, Hoyles και Sutherland 1989).

As the students programme the computer, they teach the machine to think and through this process they also discover the patterns of their own personal thinking (Papert 1980). Logo in general supports constructivist learning and the use of computer as a tool for the development of intellectual skills. So, Logo is used as a tool that can trigger constructivist learning in classroom. The objective of training activities with Logo is mainly to help teachers to recognise its educational value and to adopt corresponding teaching methods in their future classroom.

The training methodology

Basic constructivist conceptions are presented and discussed with the trainees before and concurrently with the lab activities focusing on Papert's theoretical work and especially on *Mindstorms* (Papet 1980), which is given to the trainees among other resources. The training methodology applied in our training course focuses on the trainees' self-activity and active engagement in lab exploratory activities. The common feature of the training activities is not the programming language but the so-called "Logo spirit", a constructivist spirit of action and learning (Papert 1980). Through such a process, it is expected that student-teachers will gain personal experiences of exploratory and constructivist learning and will be able to inspire into their future students the same educational spirit.

Student-teachers are asked to work on problem solving with self-action and autonomy and to be questioned about the educational value of those activities. They are encouraged, before they give instructions to the Logo turtle to draw a geometrical figure, to analyse the problem and to think about the instructions. Very often student work results in unexpected wrong situations on the screen. So students have the opportunity to recognise their errors and to try again. This process is repeated several times until students reach the expected result. This way, learning turns out to be a personal "adventure" of knowledge construction.

The study

In the frame of the evaluation of our courses, a study was undertaken during the 2nd semester of academic year 2005 to examine their impact on student-teachers. A part of that study which monitored and evaluated some representative Logo-based training tasks is reported in this paper including evaluation data and results.

The sample

57 student-teachers participated in the training activities. They had already finished their studies in a university (most of them in technical disciplines) and were attending a pedagogical course of two semesters in the School of Pedagogical and Technological Education (Patras, Greece) in order to qualify for teaching in the corresponding discipline in secondary education. The training activities were developed during the 2nd semester (2005). So, students had already been taught, among other pedagogical subjects, theories of learning, including constructivism. None of them had any previous experience in using Logo but they were comparatively ICT-literate.

The training tasks

First of all, students had the opportunity during one teaching session to familiarise themselves with the command centre of MicroworlsPro (Logo Computers Systems Inc) and the basic Logo movement commands. In a next session a worksheet that presented the tasks assigned to the students with the necessary instructions was handed over to students. There was no other help given to them except technical advice when it was needed.

In those tasks students were asked to give instructions to their turtle to draw regular (meaning identical sided and identical cornered) polygons using four movement commands: *forward, back, right, left.* They could try several solutions, and they were encouraged to keep trying until they succeed. The exact tasks were the following:

Task 1: write instructions for the turtle to draw a regular square.

Task 2: continue with a regular triangle

Task 3: can you invent a command to help you make the previous polygons easier and quicker to draw?

After the end of task 3 the command *repeat* was introduced and we showed to the students how to use it:

- $\text{repeat}_{\text{space}}\text{n[Commmand1}_{\text{space}}\text{Argument1}_{\text{space}}\text{Commmand2}_{\text{space}}\text{Argument2}_{\text{space}}$ etc. ...]

They were asked to try this new command on the triangle and the square and to write their commands in a table.

Task 4: Continue for drawing the next regular polygons (Pentagon, Hexagon, Octagon, Nonagon, Decagon) using the command *repeat*. Write your commands in a table.

Task 5: Now try a circle. Notice and use the previous “sides-angle” pattern.

Task 6: Look at your whole work. Can you see a relationship between the *Sides* and the *Angle* numbers? Can you write a theory that says how many degrees need to be turned to complete the polygon so that your turtle returns to its original heading?

After the end of the tasks a discussion was organised in the class where the expected solutions and answers were presented and the entire student work was commented.

The evaluation instruments

The evaluation of the project was based on

- Teacher-students´ achievement on the tasks as it was recorded on their work sheets.
- A 5-point Likert scale measuring the degree to which students agreed or disagreed with 4 statements (2 positive, 2 negative) indicated in table 7 regarding the interest and the educational usefulness of the learning experience they had working on the tasks.
- Answers and explanations on open questions given in written form asking them to detect and mention any positive educational issues they had found in this method and to think of and report similar methods for teaching their school subjects

Two case-studies: two teacher-students were encouraged to implement the same activities in their school class with their students and report results and experiences.

Results and discussion

- The evaluation data collected with the instruments mentioned above are presented on the following tables and commented shortly.

Students’ achievement in the tasks

- The first task appeared a rather easy one for the students. Almost all of them after only few trials gave the right instructions to the Logo turtle to draw a square with dimensions of their own choice using mostly the set of commands *forward 100 right 90* (4 times).

results	Frequency	Percent %
failure	02	03.5
Success	55	96.5
Total	57	100.0

Table 1. Students' achievement in task 1: drawing a square

- The 2nd task proved more difficult compared to the first one. The students tested several methods before they were able to write a set of commands to draw a regular triangle. The main difficulty they encountered was identified in the estimation of the right angle. Most of them, knowing that in the regular triangle each angle is 60 degrees, started trying this angle. This choice, unexpectedly for them, didn't result in a triangle. They needed to repeat their effort several times in order to find that the angle of the turtle's turn should be different from that of the triangle.

results	Frequency	Percent
failure	9	15.8
success	48	84.2
Total	57	100.0

Table 2. Students' achievement in task 2: drawing a triangle

- Some of them were observed to put themselves in the turtle's position trying to find the right turn (120 degrees). The lesson learned from this unexpected initial failure was that all of us (including children), need to concretise a problematic situation in order to reach a solution. The computer screen proved such a tool for the concretisation of abstract notions. What the students watched on the screen was just a visualisation of their own thought. So they had the opportunity to re-assess their own initial thinking and to correct their mistakes.

answer	Frequency	Percent
"repeat"	09	15.8
"square-triangle"	08	14.0
No clear answer	07	12.3
other	05	08.8
No answer	28	49.1
Total	57	100.0

Table 3. Students' answers in task 3: inventing a command

- The invention of a command that would help them to make the triangle and the square easier and quicker to draw was proved a difficult task. Only a few students found the expected command *repeat*, although almost all of them had already used the repetition of movement commands in the previous two tasks. 8 students answered suggesting the names of the wanted polygons ("square-triangle"). These answers are interesting because they might be interpreted as suggestions for relevant routines drawing immediately the corresponding polygons and could be exploited as a good opportunity for an educator to introduce the Logo processes.

results	Frequency	Percent
failure	01	01.8
success	40	70.2
partial success	16	28.1
Total	57	100.0

Table 4. Students' achievement in task 4: drawing the next polygons

- The students continued with the next polygons using the new command *repeat* and writing their commands in a table indicating the number of sides and the angle of turtle's turn for each polygon. The majority succeeded in drawing the polygons but there was a significant percentage of those who drew some polygons successfully but failed in others. Once again the main difficulty was encountered in the angle. The same instance mentioned above of students' testing different methods was observed in this task too.

results	Frequency	Percent
failure	04	07.0
success	37	64.9
A new polygon with more sides	11	19.3
More than one circle	01	01.8
missing	04	07.0
Total	57	100.0

Table 5. Students' achievement in task 5: drawing a circle

- The final drawing asked by the students was the circle. The great majority of students continued to draw polygons with a continuously increasing number of sides and a decreasing angle. These efforts were resulting in polygons gradually approaching the circle in the term of a polygon with an unlimited number of sides. Some efforts stopped in a new polygon having simply more sides than the previous ones failing in seeing the "sides and angle" pattern indicated on the table where the number of sides and angles had been recorded. But the majority of the students could exploit that table and identified the relationship between the numbers of sides and angle. This relationship guided them to draw the circle using a command like the following: *Repeat 360 [forward [step] right 1]*.
- Finally students were asked to look at their whole work and write a theory saying how many degrees need to be turned by their turtle in order to complete the polygon and to return to its original heading. Not surprisingly, the number of students who could identify the wanted theory was identical to that of students who succeeded in drawing the circle. It is obvious that the identification of the "sides and angle" pattern was crucial for the successful fulfilment of the previous circle-drawing task.

results	Frequency	Percent
No answer	11	19.3
Angle x sides = 360 degrees	37	64.9
Faulty	5	08.8

missing	4	07.0
total	57	100.0

Table 6. Students' answers in task 6: concluding a theory

- The observation of student work and behaviour during the tasks showed that the tasks attracted the attention and interest of the great majority and in some cases students worked enthusiastically. Scenes of celebrations were observed in some cases in which students had achieved, after several unsuccessful trials, to instruct their turtle to draw the expected polygon (and especially the circle) on their screen. We also noticed the insistence of some others on continuing to experiment on a task even after the end of the given session.

Students' opinions on the interest and the educational usefulness of the tasks.

In my opinion these activities with Logo were…	Agree	Rather agree	No opinion	Rather disagree	Disagree
An interesting learning experience	90.6	09.4	00.0	00.0	00.0
Boring	02.2	00.0	00.0	11.1	86.7
No useful	08.9	08.9	11.1	22.2	48.9
Helped me to think of similar activities for my teaching subjects	52.1	20.8	14.6	06.3	06.2

Table 7. Percentage % of students' opinions on the interest and usefulness of the tasks (N=57)

Students were also asked to evaluate in writing the entire project regarding the interest and the educational usefulness of the learning experience they had working on the tasks. The evaluation results (table 7) indicate that almost all the students agreed with the statement that the entire project was an interesting and far from boring learning experience. The great majority (a total of 71.1%) agreed or rather agreed that the Logo activities were useful and helpful regarding their possible transfer to other school subjects (a total of 72.9%). There were a low percentage of students, who although they found the activities interesting, were not convinced of their usefulness in an educational context, possibly due to the subject of the activities that is the construction of geometrical drawings, which perhaps made it difficult for some students coming from different disciplines to transfer the educational meaning into their school subjects.

Answers and explanations to open questions

- In order to examine in more depth the impact that our project had on students, we asked them, if they had agreed (or rather agreed) on the 1st and 4th statements of the table 7 (concerning the interest and usefulness of the tasks) to think about and answer in writing the following two open questions:
- Question 1: What positive educational issues did you find, if any, in this method? Explain your opinion shortly.
- Question 2: Can you think of similar methods for teaching your school subjects? If yes, please describe shortly.

Categories of answers *(This method …)*	frequency
offers creative learning	6
is attractive and interesting for students	5
promotes learning through discovery	5
facilitates the understanding of concepts concerned	5
offers active role for students	4
exploits students' mistakes	2
develops students' imagination	2
cultivates intellectual skills	1
provides motives for learning	1
concretises abstract notions	1
is useful as exercise but only after teacher's presentation of concepts concerned	3
no clear answer	5

Table 8. Positive educational issues identified by students (open question 1) (N=22)

- 22 students answered each of the two open questions. The answers to question 1 were analysed and categorised qualitatively according to the educational issue mentioned by students. The resulted categories are presented shortly on the table 8 (most of the students mentioned features belonging to more than one category). The majority of them (14/22) could identify and mention several constructivist issues belonging to or approaching constructivist ideas ("offers creative learning", "active role for students", "exploits student faults" etc). They seemed to have been influenced and understood the educational meaning of the activities. This was more obvious in the following characteristic answers and explanations:
  - "…the student is involved in a process that requires deep thought and use of his intelligence in order to reach a solution".
  - "…The student observes his/her errors and is able to correct them".
  - "…In this way student constructs the knowledge through personal work instead of simply receiving information from a teacher"
  - "…Children can approach geometrical concepts in a more free, playful way"
  - "…Students don't simply watch the computer screen, they are active, they use their imagination and cultivate their creativity"
  - "… It helps students to put themselves in the turtle's position"
- Five students failed to mention any precise educational features and answered in very general and unclear terms. Three others re-confirmed that the method was useful and interesting but they would prefer the traditional method of lecture before the application of the method. As one of them explained "…we should present the subject on the blackboard and then apply this method for better understanding".

In the words of another one from the same group:

- "First, I would present the theory to the students and the formula angle=360/sides to help them understand the rationale of this method and then

I would ask them to apply it… this work would be done faster if there was a library with ready drawings on the screen and students were asked to do only changes in parameters"

- This kind of answers indicates, in our opinion, a misunderstanding of the pedagogic rationale of our project and implies persistence with the traditional model of the teacher-guided instruction of the new concepts instead of the proposed knowledge construction by students themselves.

Categories of answers	frequency
Creation and use of simulations	7
Engineering drawings	7
Other programming techniques	2
Not applied in my subject	4
No clear answer	2

Table 9. Similar methods for teaching school subjects mentioned by students (open question 2) (N=22)

- Answering to the 2nd open question, the majority of students (16/22) suggested a method that could be implemented in their own school subject and described it more or less sufficiently. Students' answers were categorised according to the method suggested and they were heavily influenced, as it was expected, by their discipline. So, the engineering students suggested different engineering drawings and the informatics students other programming techniques. Seven other students suggested different kinds of simulations to be created by school-students in a way very similar to that they had followed in our project. There were four students (economics and sociology graduates) who answered that they couldn't imagine any applications of the method in their school lessons. As one of them put it "in social sciences this method does not help the transfer of concepts to pupils".

Evaluation of two case studies

- Two teacher-students were encouraged to apply the same activities in their school class with their students and to report in writing evaluation results and experiences.
- **Case study 1:** The first teacher-student (teacher of informatics at secondary school level) was initially very sceptical about the implementation of Logo activities in his school class. He was used to teaching informatics in a traditional teacher-centered way with emphasis on lectures, blackboard presentations, and drill and practice exercises on computers. He accepted to test the logo-based activities (the same ones he had already done) with his school-students at a lower secondary school, where he was working on a temporary base. 16 students from grade 3 (age 14) followed the activities.
- According to the report he wrote after the end of those lessons (Stoyannopoulos, 2005) he needed one teaching period (45 minutes) to familiarise students with the Logo command centre and the movement commands mentioned above. Students, introduced to programming for the first time, learned how to use the movement commands fast, although they encountered difficulties with the arguments of the commands. A difficulty appeared in the beginning of the tasks: "there was a student anxiety focusing more on finding the correct solution than on working freely and creatively, due to a tendency to seek high marks". This point indicates that the teacher-student seems to have realised the necessity for the so-called "Logo spirit" to be present in the Logo activities, a spirit very different from the traditional mark-oriented one that is dominant in the class (a well known situation in Greek secondary education).

- Gradually the logo activities succeeded to attract the students' interest and most of the students through a test and error practice achieved sufficient results. As he mentions "the sides and angle model played a significant role for the successful drawing of the circle by some student groups". He concludes that the overall activity acted very positively for student learning and that "the traditional teaching approaches cannot help students in the development of an algorithmic way of thinking… It is very important for students to be engaged in problem solving in a creative, not mechanistic way working collaboratively in the class…" These last points imply a remarkable shift from his initial scepticism to a more positive attitude to the "Logo spirit" indicating a positive effect that the previous training had on him.
- **Case study 2:** The second student-teacher who accepted to implement the Logo activities was also an informatics teacher in a higher secondary school (student age 16). He had shown great interest in the training sessions and accepted enthusiastically to work with his students on the same tasks. According to his report (Theodorides, 2005), his students after an initial frustration, showed great interest in that work and great commitment to their tasks. Most of them reached sufficiently good results. He explains the initial student frustration noting that "they were engaged in an exploratory way of learning very different from what they were used to so far".
- Evaluating his students' work he notes that "students participated actively in the whole learning process", "it was very productive for students to watch their errors on the screen after a wrong instruction to the turtle… it allowed them to retry another set of instructions and so on… it was like playing with the turtle". He observed that "what students liked more in these lessons was the opportunity they had to work with autonomy, to make decisions and act on them without having to listen passively to lectures". He concludes that "it was a self-regulating process for students facilitating learning through exploration and discovery".
- Similarly to the first one, this case study indicates that our student-teacher succeeded in implementing in his classroom the same activities he had followed during his training in a constructivist way. He seems through his report to recognize in his students' reactions and behaviour in the classroom some of the expected outcomes of the learning approach (very similar to those observed in the training class). He also seems to appreciate this kind of learning as exploratory, self-regulating and different from the teaching methods he used to follow till then.

Conclusions

- The inferences drawn from the data reported in this paper indicate that the inclusion of ICT-based problem solving in the teacher training curricula in a constructivist way helped student-teachers to recognise its pedagogical potential for school learning. Although there were some failures in the students' work and misunderstandings were noticed in a few cases, the whole project seems to have had a significant impact on the majority. This impact included familiarisation of the students with the constructivist learning spirit and concrete personal experience of an exploratory and constructivist learning that can inspire their future teaching methodology and convinced them to use computer as a constructivist learning tool.
- The added educational value of this project concerns not only the advancement of the teachers' technological culture but also (and more importantly) the development of a constructivist pedagogy that can be applied with computers as learning tools in real classrooms. The evidence coming from the two course participants, who applied and evaluated the methodology in classroom with positive results, provided encouraging indications that students became capable of applying the methodology they had learnt in real classroom settings. The monitoring of a long-term impact on student-teachers' future teaching praxis could be subject of further investigation.

Finally, the evidence offered by this project argues that the integration of ICT in teacher education can play an important role to introduce constructivist innovation in teaching and learning. We concur with Becker and Riel (2000) that if we want our schools to offer creative problem-solving and constructivist, independent thinking, the most effective way to achieve these goals may be to design a teacher education system where teachers are encouraged to be creative problem solvers in the design of learning environments for their students.

References

Becker, H.J. and Riel, M.M. (2000) *Teacher professional engagement and costructivist-compatible computer use.* Available online at http://www.crito.uci.edu/tlc/findings/report_7/text.html (accessed 10 October 2006).

Bhattacharya, M. and Richards, C. (2001) *Innovative Course Design as Action Research: Instructional Technology for Teacher Education*. In Proceedings of Society for Information Technology and Teacher Education International Conference (Chesapeake, VA: AACE). Edited by C. Crawford et al. pp.1052-1057

diSessa, A., Hoyles, C., Noss, R.and Edwards, L. (1995) *Computers and Exploratory Learning: setting the scene*. In Computers and Exploratory Learning, A.A.diSessa, C.Hoyles and R.Noss (eds.), NATO ASI Series, 146, 1-14

Hoyles, C. and Sutherland, R. (1989) *Logo Mathematics in the Classroom,* Routledge, London.

Noss, R. (1987) *How do Children do Mathematics with Logo?* Journal of Computer Assisted Learning, 1, 2-12

Papert, S. (1980) *Mindstorms*. Basic Books, New York.

Stoyannopoulos S. (2005) *Development of basic programming skills from C grade students using MicroworldsPro environment.* Dissertation, School of Pedagogical and Technological Education, Patras.

Theodorides, A. (2005) *Logo as a tool to understand processes and variables in programming,* Dissertation, School of Pedagogical and Technological Education, Patras.