

Integrating HOTS Activities with GeoGebra in Pre-Service Teachers' Preparation

Wajeeh Daher, Nimer Baya'a

Abstract—High Order Thinking Skills (HOTS) are suggested today as essential for the cognitive development of students and as preparing them for real life skills. Teachers are encouraged to use HOTS activities in the classroom to help their students develop higher order skills and deep thinking. So it is essential to prepare pre-service teachers to write and use HOTS activities for their students. This paper describes a model for integrating HOTS activities with GeoGebra in pre-service teachers' preparation. This model describes four aspects of HOTS activities and working with them: activity components, preparation procedure, strategies and processes used in writing a HOTS activity and types of the HOTS activities. In addition, the paper describes the pre-service teachers' difficulties in preparing and working with HOTS activities, as well as their perceptions regarding the use of these activities and GeoGebra in the mathematics classroom. The paper also describes the contribution of a HOTS activity to pupils' learning of mathematics, where this HOTS activity was prepared and taught by one pre-service teacher.

Keywords—Higher order thinking, HOTS activities, pre-service teachers, teachers' preparation.

I. INTRODUCTION

THE present paper describes an experiment with 12 pre-service teachers in their third year of study, who specialize in mathematics and technology teaching in the middle school. The participating pre-service teachers were part of a program for students who excelled in their secondary school study. In the frame of this program, the pre-service teachers are requested to perform a special personal project in their third year of training. In the academic year 2013-2014, the project involved activities that put emphasis on higher order thinking skills (HOTS). The pre-service teachers, collaborating with their training in-service teachers and their pedagogical supervisors, built mathematical activities that emphasized higher order thinking skills, and afterwards these pre-service teachers taught these activities to grade 9 students in the frame of their practical training. The pre-service teachers brought their laptops to the classroom and used a mobile overhead projector to present the activities to the pupils who investigated them with GeoGebra. So, technology was an essential tool in the pupils' hands to work with HOTS activities. The pupils' investigation process was composed of: working with GeoGebra, searching for mathematical relations, putting and verifying conjectures, and justifying them.

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II. LITERATURE REVIEW

Higher order thinking takes place in the higher levels of the hierarchy of cognitive behavior [1], where the most widely accepted hierarchy of cognitive processing is Bloom's Taxonomy. This taxonomy consists of six levels: knowledge, comprehension, application, analysis, synthesis and evaluation. Another and related hierarchical taxonomy can be found in [2] who developed a similar taxonomy for cognitive behavior, consisting of four levels: remembering, processing, creating, and evaluating. The relation of these two taxonomies to lower and higher order thinking skills is described in Fig. 1 [3].

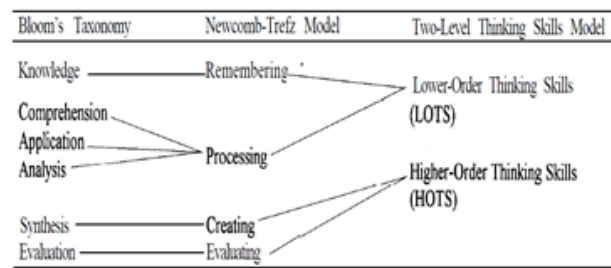


Fig. 1 A comparison of Bloom's taxonomy, Newcomb-Trefz learning model and two levels of thinking skills [3]

Mathematics educators and mathematics education researchers have been interested in HOTS in the mathematics classroom. Being so, they have studied different aspects of integrating HOTS in this classroom. [4] studied US state's effort to incorporate higher order thinking on its Algebra I End-of-Course tests. The results showed that few Algebra I test items from 1998 and 2001 were found to assess higher-order thinking, while Algebra I test items written in 2007 were found to be more cognitively complex. [5] studied how using activities developed using Bloom's taxonomy influences students' achievement. She found that the mean of the posttest scores in mathematics for the experimental group in which the teachers developed lessons using Bloom's Taxonomy were significantly higher than the mean of the group which used textbook bound instruction. Moreover, the experimental group yielded significant gains as measured by the difference between the pretest and posttest scores. These results indicate the added value from lessons emphasizing different cognitive levels' activities. So we intended to prepare our pre-service teachers in using HOTS activities in the mathematics classroom. This would result in deeper learning of mathematics by the middle school pupils who our pre-service teachers will teach in the training schools and as future

teachers of mathematics. Doing so, we assumed that both basic and higher-order thinking skills are important for the learning of middle school students, and it is not necessary to emphasize higher-order thinking while leaving basic skills [6].

Our experiment in preparing mathematics pre-service teachers to write and teach HOTS activities is described below.

III. THE EXPERIMENT AND ITS FOUR PRINCIPLES

The objectives of the projects, developed in the reported experiment, depended on four principles. First, HOTS activities would support the professional development of the pre-service mathematics teachers and prepare them to use such activities in the classroom as future mathematics teachers. Second, engaging with HOTS activities would enhance the pre-service teachers as learners of mathematics and give them new approaches when coming to work with mathematical problems. As a consequence of the previous two principles, we expected that the pre-service teachers who engage in developing mathematical activities based on higher order thinking skills would value these activities as promoting students' mathematical learning and thinking.

The third principle is related to encouraging the pre-service teachers to be innovators. We assumed that working with HOTS activities, with the supervision of their pedagogical supervisors, the pre-service teachers experience being innovators, and, as a result, they are encouraged to become innovative teachers in their future work in schools. The fourth principle is related to the use of technology in performing the HOTS activities. We assumed that technology assists students in developing higher order thinking skills. This assistance is due to the ability of students who use technology to manipulate mathematical objects, observe the results of this manipulation and, as a result, conjecture mathematical relations. This made us suggest GeoGebra, a free mathematics software, to our pre-service teachers to make it a tool with which HOTS activities are carried out.

Deciding upon the four principles, we came to decide upon the training process that we would follow to support our pre-service teachers, becoming ready to use HOTS activities in the mathematics classroom. To carry out the preparation process, we utilized a document of the ministry of education about using HOTS activities in the schools. We also introduced GeoGebra to our pre-service teachers, and encouraged them to write HOTS activities that utilizes GeoGebra, and collaborate with the training in-service teachers to carry out these activities in the mathematics classroom. Our preparation process is described in detail below.

IV. PRE-SERVICE TEACHERS' PREPARATION PROCESS

To prepare the pre-service teachers to use the HOTS activities in the classroom, we followed the following process:

- a. Introducing a document of Ministry of Education, which details the higher order cognitive skills that in-service teachers are expected to encourage their pupils to use.
- b. Presenting examples of mathematical questions that encourage the use of a specific higher order cognitive skill among pupils.
- c. Teaching GeoGebra and requiring the pre-service teachers to construct applets using GeoGebra.
- d. Presenting examples of applets built in GeoGebra to be used by the pupils to carry out an activity based in higher order thinking skills.
- e. Requesting the pre-service teachers to prepare questions that encourage the use of a specific higher order cognitive skill among pupils.
- f. Asking the pre-service teachers to prepare a worksheet of questions and instructions on a specific subject in intermediate level mathematics based on an existing applet or an applet that they constructed, and categorize the questions in the worksheet according to the various higher order cognitive skills.
- g. Presenting the model suggested by the writers of the article clarified with various examples of mathematical activities.
- h. Requesting the pre-service teachers to collaborate with their in-service mathematics teacher trainers to prepare activities according to the suggested model, and apply them with their pupils in the training school.

V. THE SUGGESTED MODEL FOR INTEGRATING HOTS ACTIVITIES

To guarantee the assimilation of higher order thinking skills among middle school mathematics pupils, we developed a model for integrating HOTS activities with GeoGebra in pre-service teachers' preparation. This model describes four aspects of HOTS activities and working with them: activity components, preparation procedure, strategies and processes used in writing a HOTS activity and types of the HOTS activities.

A. The Activity Components

Our suggested model describes six components that students should include when writing a HOTS activity:

- a. Description of the activity that the pre-service teacher plans to carry out with the help of the applet. This description should include the mathematical concepts and/or relations that the student plans to investigate or construct, and the learning actions that should be performed to arrive at the mathematical concepts and/or relations through working with the applet and discussing the findings.
- b. Pedagogical instructions for the teacher, including description of the educational environment, and the roles of the teacher and pupils in this environment.
- c. Technical description of the GeoGebra applet used in the activity (directions how to use the applet).
- d. Link to the GeoGebra applet in the GeoGebra Tube, where they need to upload the applet to.
- e. A worksheet detailing the questions to be asked when performing the activity with the pupils.

- f. A table that categorizes the questions in the activity according to the various higher order cognitive skills, and description of expected pupils' mathematical answers (correct and wrong answers) to each question, accompanied with instructions to the teacher of possible responses and actions according to the pupil's answers.

B. The Procedure of Preparing a HOTS Activity

The procedure of preparing a HOTS activity includes six steps: write a HOTS activity, reflect on it, rewrite it, implement it in the classroom, reflect on the implementation, and rewrite the activity.

C. Strategies and Processes Used in Writing a HOTS Activity

The pre-service teachers were also introduced to the relation between the strategy used in a HOTS activity and the processes included in it. These strategies included problem solving, planning, exploring, taking decisions, construction of concepts, analyzing, and discussing. The processes included the following: conjecturing, raising different points of view, pupils asking questions, identifying components and relations, categorizing, comparing, concluding, combining, using different representations, claiming, reasoning and evaluating. The investigating strategy for example included the processes: asking questions, raising different points of view, representing, conjecturing and reasoning.

D. Types of the HOTS Activities

The HOTS activities are basically of two types, depending on the strategy that the student decides to use: (1) Explorative activity that can be performed with technology (in our case GeoGebra), where the teacher can investigate with the pupils mathematical concepts or relations, (2) Constructive activity where the teacher constructs with a technological tool (in our case GeoGebra) mathematical concepts or develops mathematical objects that have specific relations.

The various aspects of preparing pre-service mathematics teachers require assessing this preparation to be ensured that the activities were accurately written and taught.

VI. ASSESSING THE PRE-SERVICE TEACHERS' EXPERIENCE

To study the process of the pre-service teachers' training, as well as their experience to prepare and teach HOTS mathematical activity, we interviewed the pre-service teachers twice in the academic year (at the end of the first semester and at the end of the practical training year), asking them about the experiment. The interviews included questions about the writing process, the teaching process, the pre-service teachers' perceptions of HOTS and their perceptions of GeoGebra as a helping technological tool to perform HOTS activities. Furthermore, to describe the contribution of HOTS activities to pupils' learning of mathematics, we videoed the performance of a HOTS activity, where this activity was prepared and taught by one pre-service teacher.

A. The Pre-Service Teachers' Writing Process

Most of the students reported the following steps as

constituting the process of writing a HOTS activity: Reading the ministry of education document about HOTS and the remarks taken during the lectures, trying to write questions that integrate HOTS, having difficulty doing that, reading again the ministry of education document about HOTS and the remarks taken during the lectures, trying again to write questions that integrate HOTS, reflecting on the written questions, improving the questions as a result of the reflection. Some students reported that they also consulted the pedagogical supervisors regarding the correctness, adequacy and appropriateness of the questions, and as a result improved the questions.

B. The Pre-Service Teachers' Teaching Process

The pre-service teachers' teaching developed as their experience in teaching with HOTS activities advanced. It began with following the prepared worksheet questions' text verbally, then it advanced to follow the text more freely according to the advancement of the mathematical investigation and discussion with the pupils, and afterwards to instinctively improvise additional questions that fitted the mathematical situation and discussion.

C. The Pre-Service Teachers' Perceptions of HOTS Activities

The pre-service teachers perceived HOTS activities as contributing to teaching and learning mathematics. They described teaching with HOTS activities as more precise and as improving teachers' own thinking. On the other hand, they described teaching with HOTS activities as encouraging pupils' creativity, giving them freedom of thinking and behaving, improving their thinking, helping pupils internalize the mathematical concepts and relations, helping them connect between different mathematical concepts, and inquiring about alternative ways of solution.

Moreover, the pre-service teachers claimed that participating in a practical training workshop with their pedagogical supervisors that involves HOTS, as well as watching the teaching of their in-service teacher trainers who use HOTS were the best ways to develop the ability to be involved in HOTS. In addition, they perceived 'what if not' strategy as helping them write HOTS questions. Moreover, they claimed that the actual practice of writing HOTS activities following the suggested model, including all the activity components; especially the categorization of the questions according to the HOTS, resulted in their professional development. This professional development included improvement in their content knowledge as well as technological pedagogic content knowledge (TPACK).

D. The Pre-Service Teachers' Perceptions of Geogebra

The pre-service teachers perceived GeoGebra as a helping technological tool to develop and perform HOTS activities, especially when raising conjectures and verifying their correctness, and performing the thinking processes involved in HOTS. Moreover, the pre-service teachers perceived GeoGebra as an illustrative dynamic interactive tool that supports them in discovering, with their pupils, the

mathematical relations because of manipulating the mathematical objects, which also supported them in applying successfully the strategies and processes that they used in the HOTS activities.

VII. HOTS ACTIVITIES IN THE MATHEMATICS CLASSROOM

To examine the contribution of HOTS activities to pupils' learning of mathematics, we videoed the performance of a HOTS activity, where this activity was prepared and taught by one pre-service teacher. Analyzing this performance, we noticed that pupils' mathematical behavior included the following learning processes when carrying out the HOTS activities with GeoGebra: Manipulating mathematical objects; making conjectures and verifying them through the use of the measurement tools in GeoGebra; using GeoGebra geometrical tools to extend the mathematical situation when answering 'what if not' questions; using the illustration and dynamic tools in GeoGebra to discuss mathematical relations and giving various correct answers to open questions.

VIII. CONCLUSION

GeoGebra was practiced and conceived by our pre-service teachers as a tool that helps pupils perform the processes that HOTS activities are involved with, especially asking questions, conjecturing, using different representations, claiming, reasoning, raising different points of view, and identifying relations. These processes are in the heart of doing mathematics [7].

Participating in writing and teaching HOTS activities with GeoGebra improved pre-service teachers' different types of knowledge, especially their technological pedagogical content knowledge (TPACK). This improvement is one of the main targets of teacher training colleges for preparing pre-service teachers towards the twenty first century skills [8].

Furthermore, participating in writing and teaching HOTS activities with GeoGebra, the pre-service teachers are encouraged to be innovative teachers, by trying new methods in their teaching, without the fear of working with new ideas and implementing them in the classrooms.

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