THE EFFECTIVENESS OF AN ENRICHMENT PROGRAM USING DYNAMIC GEOMETRY SOFTWARE IN DEVELOPING MATHEMATICALLY GIFTED STUDENTS' GEOMETRIC CREATIVITY

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The research work presented in this paper was guided by three goals: First, to identify the principles of preparing an enrichment program in Euclidean geometry using Dynamic Geometry Software to develop the mathematically gifted students' geometric creativity in high schools, second, to develop an enrichment program based on the identified principles, and third, to investigate its effectiveness by testing it with high school students. The enrichment program was administered to 7 mathematically gifted students in 12 weekly 90-minute sessions. Results of a pre-post measurements revealed the effectiveness of the program in developing the subjects' geometric creativity as a whole ability and its four sub-components (fluency, flexibility, originality, and elaboration).

INTRODUCTION

The development of creativity and innovation among the gifted students has become a major topic discussed in many international conferences. Consequently, many educational programs were developed to provide the gifted with various experiences in order to promote their creative potential (e.g. Cho et al., 2004, and Mohamed, 2003). In this concern, two main approaches appear. Some researchers see that creativity can be learned and developed directly using specific programs that teach creativity skills and its operations regardless the subject matters, while others assert that teaching creativity should be associated to the subject matters and it should be a part of the corresponding lesson plans that teachers prepare (Jerwan, 2002, p. 38).

With respect to mathematics as a subject matter, there has been a growing interest in using mathematical content to develop creativity and as a result new terminologies about creativity appear, such as mathematical creativity, which refers to the creativity in the field of mathematics. Also, recent studies used *geometric* content to develop the creative potential among students (e.g. El-Rayashy & Ibrahim Al-Baz Mohamed 2000, Ibrahim Al-Baz Mohamed 1999, Mohamed, 2003, Weth, 1998).

In the context of the growing concern of developing creativity in the field of mathematics, a new trend appears that calls for using technology would help promoting creativity. For addressing this call, many studies conducted adopting the integrated learning environment with technology in order to develop creativity, for instance using Computer Algebra Systems (CAS) and Dynamic Geometry Software (DGS) (e.g. Kakihana, et al., 2008 and Wurnig, 2008).

We sought to address the increasing need for qualified programs and curricula in the field of mathematics for mathematically gifted students by developing an enrichment program in Euclidean geometry using DGS and investigate its effectiveness in promoting the mathematically gifted students' geometric creativity. The suggested enrichment program could be considered a forward step towards designing and using precisely tested programs for mathematically gifted students.

This research work is a part of larger experimental study that aims at developing an enrichment program using DGS and deciding on its effectiveness in enhancing the mathematically gifted students' geometric creativity in high schools (El-Demerdash, in preparation). More specifically, the research work was guided by three goals: First, to *identify* the principles of preparing an enrichment program in Euclidean geometry using DGS to develop the mathematically gifted students' geometric creativity in high schools, second, to *develop* the enrichment program based on the identified principles, and third, to *investigate* the effectiveness of this program by testing it with high school students.

PRINCIPLES OF DEVELOPING THE ENRICHMENT PROGRAM

We identified the principles for developing an enrichment program as follows: (1) the activities should provide the students with opportunities to explore some mathematical ideas using the DGS in a creative fashion, (2) the activities should provide the students with opportunities to reinvent mathematical ideas through both exploration and the refining of earlier ideas, (3) teaching the instructional activities should follow van Hiele phases of learning geometric concepts: Information, guided orientation, explication, free orientation, and integration, (4) the activities should correspond to the students' skills, since they should experience success in order to stay motivated, (5) the enrichment activities should challenge students' thinking, enhance students' achievements, and develop students' geometric creativity, (6) the instructional activities should be designed to be effective in revealing geometric creativity and showing the differences between students in terms of their geometric creativity and their responses.

THE SUGGESTED ENRICHMENT PROGRAM

Based on these principles and using the interactive geometry software Cinderella (Richter-Gebert & Kortenkamp, 2006) as DGS, an enrichment program was developed[1]. The program includes three interrelated portions: student's handouts, a teacher guide, and a CD-ROM, which cover 12 enrichment activities. All of them are

[1] More details and all materials are available http://cinderella.de/material/gct/

open-ended and divergent-production geometric situations and problems that require many various and different responses.

There are 15 handouts prepared to guide the student throughout the suggested enrichment program. The student's handouts are prepared in both English and German. The teacher's guide is designed to make the teacher's work and progress along the program's sessions easier and more effective. The guide does not restrict the teacher's work, but is flexible enough for any creative additions. The accompanying CD-ROM contains all dynamic configurations prepared for the program as construction files and also as web pages, together with an index that gives easy access to all activities and examples.

THE GEOMETRIC CREATIVITY TEST

Since the purpose of the study was to develop the geometric creativity of the mathematically gifted students using the suggested enrichment program, we had to design an instrument, a geometric creativity test, to assess the geometric creativity of the mathematically gifted students before and after administering the enrichment program. In designing the geometric creativity test, we used a 6-step process: (1) Specification of the aim of the test, (2) Specification of the components that the test measures, (3) Creation of a preliminary form of the test, (4) Set-up a grading method for the test, (5) Content validity check and (6) Test-piloting. More details about the geometric creativity test and its designing process are available at: http://cinderella.de/material/gkt/.

PROCEDURES OF THE EXPERIMENTAL STUDY

We tested the material with a group of 7 mathematically gifted students in Landesgymnasium für Hochbegabte (LGH), a public high school for highly gifted and talented students in Schwäbisch Gmünd, Baden-Württemberg, Germany. The students came from 11^{th} (5), 10^{th} (1) and 9^{th} (1) grade, two of them were male, five female.

In the study, we used a one-group pretest–intervention–posttest pre-experimental design. In this context the GCT was administered to students as a pretest at the beginning of the study, then the suggested enrichment program was introduced to them in 12 weekly 90-minutes sessions during the first semester of the academic year 2008/09. The students retook the GCT as a posttest at the end of the study.

RESULTS AND CONCLUSION

In order to analyze the subjects' responses, we used a specific grading method to calculate the geometric creativity scores for each subject before and after the intervention.

The statistical significance of the difference between the mean ranks of the scores in the pre-test and the post-test was checked using both the "Sign Test" and the "Wilcoxon Signed Ranks Test". Cohen's effect size indicator d was used to decide on the effectiveness of the suggested enrichment program. The results indicated there are statistically significant differences between the mean ranks of the subjects' scores on the pre-post measurements of the geometric creativity test and its subscales in favor of the post measurement. The results also revealed that the suggested enrichment program was significantly effective in developing the geometric creativity as a whole ability and its four sub-components (fluency, flexibility, originality, and elaboration).

The results of the study suggest – being consistent with prior studies (Kakihana, et al., 2008 and Wurnig, 2008) – that the prepared enrichment program using DGS has a positive impact on the mathematically gifted students' geometric creativity. The positive impact can be traced back to the content of the suggested enrichment program and its open-ended and divergent-production geometric situations and problems. Also, the positive impact can be attributed to the use of DGS along the program's sessions that provide the subjects with many opportunities not only to explore, experiment and make mathematical conjectures, but also to solve problems, and pose related problems.

However, the study requires replication and improvements before any firm conclusions can be made. One of the biggest improvements would be to have more subjects that the results become more generalized and meaningful. Also, for one thing pertaining the experimental design, further studies are needed to investigate the effectiveness of the suggested enrichment program using both quasi-experimental and true experimental designs.

Other avenues for research may focus on students' affective and emotional domains (e.g. self confidence, attitudes, and achievement motivation, among others), and might as well include an analysis of gender-related individual differences.

References

Cho, H., Han, H., Jin, M., Kim, H., & Song, M. (2004). Designing a micoworld: Activities and programs for gifted students and enhancing mathematical creativity. *Proceeding of the 10th conference of the International Congress on Mathematics Education, TSG 4: Activities and Programs for Gifted Students,* pp. 110-118, Copenhagen, Denmark.

El-Demerdash, M. (in preparation). The effectiveness of an enrichment program using dynamic geometry software in developing mathematically gifted students' geometric creativity in high schools. Doctoral dissertation, University of Education Schwäbisch Gmünd, Germany.

El-Rayashy, H. A. M. & Ibrahim Al-Baz Mohamed, A. (2000). A proposed strategy on group mastery learning approach in developing geometric creativity and reducing problem solving anxiety among preparatory stage students. *Journal of Mathematics Education in Faculty of Education* - Benha, Zagazig University, 3, 65-207.

Ibrahim Al-Baz Mohamed, A. (1999). The relative effectiveness of a proposed strategy for teaching solid geometry and the De Bono strategy in developing geometric creativity and creative perceptions in secondary stage. In: A. Rogerson (Ed.) *Proceeding of the International conference on mathematics education into the 21st century*, Vol. 1, pp. 315-316, Cairo, Egypt.

Kakihana, k., Fukuda, C. & Watanabe, S. (2008). Stimulating students' creativity in an integrated learning environment with technology. *Proceeding of The 11th International Congress on Mathematical Education, DG 9*, pp. 314-322. Monterrey, Mexico.

Mohamed, A. I. Z. (2003). Enrichment program in geometry for creative thinking development for talented students, in mathematics in the preparatory stage. Master thesis, Tanta University, Egypt.

Jerwan, F. (2002). *Thinking education: Concepts and applications*. Oman, Jordon: Dar Al-Fikr.

Richter-Gebert, J. & Kortenkamp, U. (2006). The Interactive Geometry Software Cinderella, Version 2.0. Online at http://cinderella.de

Weth, T. (1998). Kreative Zugänge zum Kurvenbegriff. *Mathematikunterricht*, 44 (4-5), 38-60

Wurnig, O. (2008). Some problem solving examples of multiple solutions using CAS and DGS. *Proceeding of The 11th International Congress on Mathematical Education, DG 9,* pp. 358-367. Monterrey, Mexico.