E-contests in Mathematics: Technological Challenges versus Technological Innovations

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Abstract. This study introduces the idea of e-contests for mathematics. The idea is based on screen-casting students’ problem-solving processes in a computer environment and assessing their solution processes of doing mathematics including the final product of their work. This process-oriented assessment may promote the integration of cognitive tools in technology and introduce open-ended problems and problem posing into the math contests. The ability to assess student solutions electronically may promote students’ interests towards mathematics and advance students’ cognitive abilities. In addition, performing e-contests in online environments can allow more students to access and benefit from math contests.

Keywords: e-contests, mathematics assessment, cognitive abilities.

I INTRODUCTION

Mathematics contests have a leading role in mathematics education because they provide many opportunities for students such as introducing advanced topics and challenging problems, exploring mathematics deeply, and discovering the beauty of mathematics. Moreover, students get a chance to understand and advance their cognitive abilities by studying contests problems and becoming members of a mathematical community by interacting with other contestants and mathematics experts. There are a number of national and international institutions, as listed under the item “list of mathematics contests” on Wikipedia web site (WIKIPEDIA, 2008), providing a variety of different math contests available to the students.

Integrating technology in the current formats of math contests could be challenging. However, using technology can be an effective format that could provide significant effects on math contests. The use of technology in math contests could be either as a cognitive tool or as an assessment tool. Dynamic Learning Environments and Computer Algebra Systems are the cognitive tools that can be used to advance students cognitive abilities. Given that research suggests that working memory has limited capacity and performs limited operations (MATLIN, 2005; STERNBERG & GRIGORENKO, 2002; SWANSON, 1995; SWELLER, 1999), using cognitive tools may result in better student performance in mathematics contests.

Technology provides new opportunities to track, monitor, and analyze students’ problem-
solving processes. By employing the features of technology, two forms of assessment can be explored: dynamic assessment and process-oriented assessment. Dynamic assessment is defined as the “procedures that attempt to modify processing” (Swanson, 1995) and widely used in assessment of low-achievers by helping and encouraging them to keep solving their problems whereas process-oriented assessment focuses on analyzing problem-solving processes.

In this paper, we explore the opportunities and obstacles of the process-oriented assessment by employing “frame analysis method”. This method allows us to track students’ problem-solving processes by capturing their work done on the screen. Two research questions have been the focus of this study: (1) Could the frame analysis method be a process-oriented assessment tool and help us analyzing students’ problem-solving processes and (2) What possible effects of technology integration should we expect in terms of content and format of the problems in math contests?

After reviewing the literature related to these questions in the next section, we describe the frame analysis method and share some of the data collected and analysis of the dataset in the later sections. In the conclusion, we share our reflections on what we have learned from this study.

II E-CONTESTS IN MATHEMATICS

Integrating Dynamic Learning Systems, such as Geometer’s Sketchpad and GeoGebra, and other cognitive tools, such as spreadsheets and Computer Algebra Systems, into math contests and developing online environments for e-contests may provide more opportunities to the students in terms of accessibility, promoting their interests towards mathematics, and encouraging them to advance their own cognitive abilities. The effects of this integration into the mathematics environments have always been a strong interest for mathematics educators (i.e. Gadanidis et al., 2002; Santos-Trigo, 2006). Santos-Trigo (2006) explores the use of computational tools in mathematics and documents the benefits of this integration as posing and exploring new questions, making connections between different domains of mathematics such as algebra and geometry, and promoting thinking mathematically. Gadanidis et al. (2002) argue the features of effective online mathematics and share their expectations for the future.

Moreover, different types of technology use in mathematics and the transfer of mathematics problems from paper-and-pencil environment to the computer environment have also been of major interest areas for researchers. For example, mathematical modeling (Konold, Harradine, & Kazak, 2007; Lesh, & Caylor, 2007) and exploration of concepts (Eisenberg, 2008; Tabach, & Friedlander, 2008) are some of the uses suggested by mathematics researchers. Each of these studies investigates opportunities of integrating technology into mathematics education whereas Threlfall, Pool, Homer, and Swinnerton (2007) explore “the effect on assessment of ‘translating’ paper-and-pencil test items into their computer equivalents” (p. 335) and document that both paper-and-pencil and computer environments could lead students to better performance and be legitimate to the assessment depending on the assumptions and expectations that have been done. With regards to the assessment of the problem-solving processes, Marshall (1989) suggests using the graph theory model with nodes and interconnections between these nodes. She argues that current assessment techniques assess nodes and that there is a need for assessing interconnections. Furthermore, she concludes that “At the moment, protocol analysis and interview techniques are the best means we have for conducting this form assessment.” (p. 175).

However, assessment in online environment seems the most significant challenge in technology integration as well as the key concept in overcoming this challenge. Technological innovations in recording and image-processing have created many sustainable solutions. Tracking students’ mouse movements as they click on specific buttons (Marshall,
1995) and eye-tracking (Eyetracking, 2008) of the users are some of these methods. With support of these innovations in tracking techniques, the assessment of processes as well as the products could be possible. Recording and analyses of students’ construction processes in solving a geometry problem or analysis and comparison processes in identifying the properties of a group of graphs may affect current assessment criterion. The ability of tracking thinking processes and problem-solving procedures in traditional and open-ended problems could lead us to consider more process-oriented assessments. This reflection could also contribute to these investigations by developing “e-exercise bases in mathematics” (Cazes, Gueudet, Hersant, & Vandebrouck, 2006).

In this study, we used the frame analysis method, which is based on recording and assessing students’ work, to assess students’ problem-solving processes. Based on the result of our preliminary analysis, this method may provide us the opportunity of assessing students’ “process of ‘doing’ mathematics ... more than just calculation or deduction” including observation of patterns, testing of conjectures, and estimation of results (NRC, 1989, p.31).

III THE STUDY

In this qualitative exploratory study, we used Geogebra software as a cognitive tool and Wink software as a screen-casting tool and recorded students’ problem-solving processes. The reason for choosing these tools is that they are freeware software and easy to use. Participants of the study were mathematically and technologically talented high school students living in Ontario. Although they are technologically talented students and the software was easy-to-use, the students were taught how to use both screen-casting and dynamic mathematics software before starting the study.

Participants were given 24 problems in the 6 sessions - 4 problems in each session - and asked to solve the problems in the computer environment by using any software without any restriction. However, most of the questions were designed to be solved using the Geogebra platform. The problems asked in one of these sessions were traditional function problems similar to those asked on a regular math contest whereas the others are open-ended or exploratory problems from the secondary school curriculum. The students recorded their solution processes without any hesitation and delivered to us on CDs after saving in the software’s own format. Although it is possible to ask them to export the recordings in video format, we did not ask much technical work in order to avoid possible technological problems.

Data collected on CDs were analyzed by employing the frame analysis method. Unlike video-recording, the frame analysis method uses screen-casting software to record students’ work. The frame analysis method is based on analyzing students’ recorded work by focusing on each frame. A frame is defined as the snapshots of the computer screen at a specified moment, which means every half-second in our study. Given that the recording software was set to record 2 frames per second, we could easily track every mouse movement and keyboard entry done in each half second. During the analysis, the solution processes were separated into chucks, which could be defined as any meaningful move or any period of time with “no change” on the screen. Those moments with no change are analyzed by taking into account what is done after that particular period of time. We could clearly track what they were doing and how they were employing the cognitive tool; and, as a consequence of this tracking, we developed an analysis report based on their solution processes including their results as the product. We did not limit ourselves and the students using only the cognitive tool rather let them use any software – word processing, spread sheet etc. - installed in their computer (see figure 1).

In order to understand students’ perception against solving traditional problems in computer environments, we provided function problems, which could also be solved in paper-and-pencil environments, in one of the sessions and let them use any software installed
in their computer. They used MS Word to write their solutions and equation editor for mathematics symbols. In one of the problems, they needed to draw a number line to represent two overlapping intervals and find the intersection of these intervals. Instead of using a drawing tool, they preferred solving mentally which was confirmed by the students.

In regard to the content and format of the study, we spent relatively more time to develop relevant problems for this study in contrast to developing paper-and-pencil problems. As opposed to our challenge, students showed no hesitation during the problem-solving sessions, and declared no concern when we asked their experiences.

IV RESULTS

We conducted this research to investigate the challenges and opportunities for e-contests in mathematics. Our first question for this study was to explore the features of the frame analysis method for a process-oriented assessment and for tracking and to analyze the students’ problem-solving processes. Although the software used in this study is not specifically designed for this purpose and we had some technological challenges during recording and transporting large files, we are quite confident to say that the frame analysis method can help contest reviewers to track and analyze students’ problem-solving processes. We could easily track students’ problem-solving processes including their thinking periods. We interpret these thinking periods, with no change on the screen, based on the attempts done after those periods. The challenge for this tracking and analyzing process is the need for a specifically designed software to allow focusing on a specific frame and/or monitoring the entire process at a certain time.

Next we will discuss the assessment issues. First of all, partial credit should be re-considered as an appropriate assessment feature. Since the reviewers have a chance of tracking every detail in solution process, each detail, pre-defined as an important step, should have a value. Furthermore, we have a chance of assessing students’ problem-solving processes, thinking processes, and application processes including choosing proper tools to solve the problems, and communicating their ideas depending on the available tools such as video and voice recorders. But what about unexpected mistakes, such as missing a number or a sign, and unexpected solution strategies? In one of the solutions, one of the participants solved a geometry problem by employing her calculus knowledge (figure 2: middle and right frames).
The question shown in the figure is about to find the minimum sum of line segments $AC$ and $BC$, where $A=(0,2)$, $B=(4,1)$, and $C=(k,0)$ – meaning that $C$ is a point on the x-axis. One of the students found the minimum sum by manipulating the slider after defining the points as described (figure 2: left frame). However, another student defined two functions representing the length of each line segments (figure 2: middle frame) and a third function representing the sum of the first two functions (figure 2: right frame) so that the minimum value of the third function would be the answer. Both answers are “quantitatively correct” but what about “qualitatively”? We may need to redefine the meaning of correct by considering “quantitative” and “qualitative” assessments when talking of the process-oriented assessment. We, as mathematicians and mathematics educators, know that there are multiple solution procedures for some problems each providing a correct result, however, some of those solution processes look qualitatively better because they contain mathematical creativity. As the frame analysis method or some other similar and/or diverse tracking techniques are integrated into the assessment process, the quality of solution may become more significant.

Beside the assessment issues, content of the contests is another major theme in our analysis. Current mathematics contests consist of single-and-absolute result problems, which may be relevant for paper-and-pencil medium. However, we may have more opportunities using technology integration such as open-ended problems and problem posing. These opportunities may help students to explore mathematics deeply and develop their own solutions. As a result of this exploration, they may discover the beauty of mathematics and develop an increasing interest against mathematics which is expressed a major goal of math contests in the introduction section.

Open ended problems, in contrast to the single-result problems, provide students to explore and discover the connections and relations between different domains of mathematics. They can analyze the problems in order to understand and develop possible solutions, to make conjectures, and to evaluate these conjectures. In other words, they spend their time to do mathematics rather than to guess and/or to find what the problem creator has thought because students are supposed to find an expected solution in the traditional contest problems. In our study, we used the open-ended approach for most of the problems. For example, instead of asking “the inverse of the function”, we provided the following set of the questions in order to let them explore the function and its inverse and find a general rule for this situation.

Step 1: After drawing the function by typing “$f(x)=\exp(x)$” into the input field of the GeoGebra screen. •••
Step 3: Create a point A with the coordinates of \((k, f(k))\) by typing “A=(k, f(k))” into the input field and be sure to check that the point A is controlled by manipulating the slider k.

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Question 1: How do you interpret the movement of the point A? What do you say about the properties of the point A?

Step 4: Create another point called B with the coordinates \((f(k), k)\) and make the point traceable and colored by using properties toolbox.

Question 2: How do you interpret the properties of the point B? What can you say about the locus of B?

Question 3: How does the point B relate to the point A?

Question 4: What would you say to someone who asked you to generate a rule for this particular situation?

Problem posing has significant effect in promoting students’ problem-solving abilities which could be very challenging in paper-and-pencil environments. For example, by changing the type of the function and/or the definition of the dependant point, point B, students may create as many problems as they want. They can easily test their proposed functions and/or the relations for the second point in order to understand the quality and applicability of the new problem.

V CONCLUSION

In this study, we have explored the frame analysis method to determine if it could be used to analyze students’ problem-solving processes in mathematics e-contests and documented evidence to suggest that a sophisticated software or platform could host e-contests in mathematics. As a result of effective integration of contemporary technologies into this software (or platform), more students can have access to and benefit from the math contests. Moreover, online math camps and math clubs can be established to create online math communities and to increase the global mathematical culture.

The data analyzed in the study has clearly illustrated that students can solve both traditional and open-ended problems effectively. However, integrating more mathematics-specific tools, such as freehand drawing tool, may increase this effectiveness. Another theme emerged from the study is related to screen-casting software. Since we avoid asking excessive technological work from the students, they declared no hesitation. Nevertheless, we strongly recommend a more sophisticated screen-casting tool, which has fast navigation feature between frames and flexible zoom in and zoom out features. Flexible zoom in and zoom out features may help students to use their metacognitive skills.
REFERENCES


