CREATIVITY IN LEARNING TO REASON INFORMALLY ABOUT STATISTICAL INFERENCE IN PRIMARY SCHOOL

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Abstract

Statistics is a discipline in its own right rather than a branch of mathematics, and the knowledge needed to solve statistical problems is likely to differ from the knowledge needed to solve mathematical problems. Therefore, a framework that characterizes creative performance in learning to reason about informal statistical inference is essential. In this paper we present an initial framework to assess creative praxis of primary school students involved in learning informal statistical inference in statistical inquiry settings. In building the suggested framework, we adapt the three common characteristics of creativity in the mathematics education literature, namely, fluency, flexibility, and novelty, to the specifics of learning statistics. We use this framework to capture creative praxis of three sixth grade students in a 60-min statistical inquiry episode. The episode analysis illustrates the strengths and limitations of the suggested framework. We finally consider briefly research and practical issues in assessing and fostering creativity in statistics learning.

1. THEORETICAL BACKGROUND

1.1 Statistics Education Current Focus

Being able to provide good evidence-based arguments and critically evaluate data-based claims are important skills that all citizens should have, and therefore, that all students should learn as part of their education. It is not surprising therefore that statistics instruction at all educational levels is gaining more students and drawing more attention. Recent instructional guidelines suggest focusing instruction on developing students' understanding of informal statistical inference in an Exploratory

Data Analysis setting (e.g., Franklin & Garfield, 2006; Garfield & Ben-Zvi, in press-a).

Exploratory Data Analysis (EDA) is the discipline of organizing, describing, representing, and analyzing data, with a heavy reliance on informal analysis and inference methods, visual displays and, in many cases, technology (Shaughnessy, Garfield, & Greer, 1996). EDA has been widely adopted by statistics educators in large part because it serves the need for more data and what we can learn from them, and does not focus on the underlying theory and complicated recipes (Cobb & Moore, 1997). Thus statistics teaching can foster a creative statistical thinker rather than merely a procedural technician (Garfield & Ben-Zvi, in press-b). EDA is viewed as a four-stage inquiry

process: a) specify a problem, plan, pose a question and formulate a hypothesis; b) collect and produce data from a variety of sources; c) process, analyze and represent data; and d) interpret the results, discuss and communicate conclusions (e.g., Graham, 1987). In reality however, statisticians 2 do not proceed linearly in this process but rather iteratively, moving creatively forward and backward, considering and selecting possible paths (Konold & Higgins, 2003).

Recent research suggests an important role for developing ideas of informal types of statistical inference even at early educational levels (e.g., Ben-Zvi, Gil, & Apel, 2007). Researchers have developed instructional activities that encourage students to infer beyond samples of data and use technological tools to support these informal inferences. *Informal Inferential Reasoning* (IIR) is the cognitive activities involved in drawing conclusions with some degree of uncertainty that go beyond the data and having empirical evidence for them. Three principles are essential to informal inference: (1) generalization that go beyond describing the given data; (2) the use of data as evidence for those generalizations; and (3) conclusions have a degree of certainty, accounting for the variability or uncertainty that is unavoidable when generalizing beyond the immediate data to a population or a process. In our view, both EDA and IIR are creative activities that resemble in some ways the creativity involved in problem posing and problem solving in mathematics.

1.2 Creativity in Mathematics Education

Creativity is drawing a growing attention in the mathematics education community, in an effort to define, assess and promote students' creative learning processes and products (e.g., Silver, 1997).

Unlike the psychological "genius" view of creativity (e.g., Weisberg, 1988), mathematics education literature views creativity as an orientation toward mathematical activity that can be fostered broadly in the general school population. In this latter view, creativity is closely related to deep, flexible knowledge in content domains; is often associated with long periods of work and reflection; and is susceptible to instructional and experiential influences (Holyoak & Thagard, 1995; Sternberg, 1988). The interplay between problem posing and problem solving is closely connected with creativity: “It is this interplay of formulation, attempting to solve, reformulating, and eventually solving a problem that one sees creative activity” (Silver, 1997, p. 76).

In this literature, creativity is typically characterized by fluency, flexibility, and novelty. In the context of mathematical problem posing and problem solving, *fluency* refers to the number of formulations or reformulations generated or the number of different solution paths explored or solutions obtained; *flexibility* refers to the extent to which shifts in approach, direction or focus were evident during the process of reformulation or solution; *novelty* refers to the originality of the ideas generated, the problem formulation or the problem solution (Silver, 1997).

1.3 Creativity in Inquiry-based Statistics Learning

Research studies on creativity in the statistics classroom are rare. Statistical reasoning is inherently a creative practice, but its image as a challenging and dreaded subject is hard to dislodge. Doing statistics involves many primarily nonmathematical activities, such as building meaning for data by examining the context and choosing appropriate study designs to answer questions of interest.

However, key features of statistics activity resemble features of problem solving and problem posing activities in mathematics. Learning statistical inquiry and inference involves ill-structured situations (open and multivariable), problem posing (research question formulation), problem solving (data analysis and inference), prediction (hypothesis formulation), decision making under uncertainty (handling variability), searching for data-based evidence (inference), and communicating results. Like in mathematics, statistics creative activities can be evident in the interplay of formulation (questions and hypotheses), attempting to solve (data analysis), reformulating, and eventually solving a problem (inference). It is our goal in this study to provide students with an inquiry-oriented statistics learning environment that includes ample opportunities

for developing greater fluency, flexibility and more creative approaches to these statistical activities. We developed an initial assessment framework and implemented it in this learning environment to analyze and assess students' creative approaches to statistics.

2. METHOD

2.1 *Research questions.*

The following research questions are used to structure the current study and

the analysis of data collected: What aspects of statistics inquiry and inference activities should be captured and evaluated to characterize primary students' creative behaviour? What can be learnt about students learning processes from the creativity point of view?

2.2 *Creating* an initial *creativity* assessment framework in statistics.

In order to develop a Creativity Assessment in Statistics Inquiry (CASI) framework, we analyzed the epistemology of key statistical ideas and considered results of the research literature on statistics learning. We then adapted the common creativity criteria in mathematics (i.e., fluency, flexibility, and novelty) to the unique nature of inquiry-based statistical reasoning. Next, we evaluated the CASI framework suitability to assess student's creativity by analyzing episodes of collaborative statistical problems solving.

2.3 The research setting.

In the *Connections* Project (grades 4–6, 2005–2007), the investigators, mathematics educators and statistics education researchers from the University of Haifa, workedwith primary school teachers and students to study students' evolving ideas of statistical reasoning within an empirical statistical enquiry cycle in an computerized learning environment. Students actively experienced some of the processes involved in experts' practice of data-based enquiry by working on data scenarios, investigated by peer collaboration and classroom discussions. The sixth grade learning trajectory (Gil & Ben-Zvi, 2007) provides ample opportunities for students throughout the five-week intervention to account for, describe and argue about variability in samples, sampling bias, and representativeness as they make informal inferences about how these samples relate to the population from which they were drawn, and whether these samples lead them to infer claims about what that population might be. Students generate and (re)formulate the questions they wish to investigate about a population, (re)formulate hypotheses, analyze additional samples of data, interpret the results and draw conclusions about the population. A central feature of learning is the use of *TinkerPlots* (Konold & Miller, 2005), a statistical dynamic visualization tool that is designed to help students develop statistical reasoning and learn new ways of representing data.

Students investigated data that were collected from all students in grades 6 and 7 in school using a 17-item questionnaire about gender and age, issues related to transfer from primary school to middle school (e.g., homework load), and sportsmanship (e.g., long jump results, favorite sport).

These population data were never exposed to students, who were only allowed to randomly sample from this file in order to infer the relevant population parameter.

2.4 Participants.

In the current study we follow in great detail several pairs (or triplets) of sixth

grade students (age 11–12) in a science-focused magnet primary school in Haifa. Most of the students come from affluent background and participated in the *Connections* lessons in fourth and fifth grades. These previous encounters made them fluent with the software and basic informal statistical ideas, language, skills and perspectives. In this paper we report only on one triplet, which was selected based on the richness of available evidence about their collaborative work.

2.5 The episode.

Odi, Eli and Asi (pseudonyms, males) work on their second data investigation. In

the first investigation, which took place few days earlier, they compared homework load of sixth and seventh graders. Unsatisfied from the triviality of their first investigation, the three students decide to look for a more challenging and interesting topic: a comparison of long jump results between sixth and seventh graders in relation to favorite sports. Using the computer, they randomly draw two samples of size 20 (10 from each grade level) from the population and analyze them.

2.6 Analysis.

To assess students' creativity, we used the CASI framework to tally the different categories of fluency and flexibility. We also timed students' independent work to assess novelty.

Video recording of the inquiry session (63 min) were fully transcribed. Two experienced researchers independently tallied the data and their results were compared and points of disagreement were discussed in order to advance and/or reject inferences about the students’ actions. The inter-rater agreement was high in almost all items.

3. CREATIVITY ASSESSMENT IN STATISTICS INQUIRY FRAMEWORK

After several iteration of formulation and data analysis, adaptation of the creativity criteria in mathematics education (e.g., Silver, 1997) to statistical inquiry yielded the following framework.

3.1 Fluency.

Fluency refers to the number of formulations or reformulations generated or the number of different solution paths explored or solutions obtained during the process of statistical

inquiry. We tally the number of different, 1) questions related to statistical context, 2) hypotheses, 3) meaningful and relevant data representation, 4) inferences about the population, and 5) explanations of these inferences.

3.2 Flexibility.

Flexibility refers to the extent to which shifts in approach, direction or focus were evident during the process of statistical inquiry. Table 2 present the 18 assessment criteria used, which are organized by the classical order of the statistical inquiry.

3.3 Novelty.

Novelty refers to the originality of the ideas generated, the problem formulation or the problem solution during the statistical inquiry. Originality can be evident in any one of the statistics inquiry products: the research question or hypothesis, data representations, inferences and arguments. Reference points of novelty in this study can be the expert's point of view, the *Connections* curricular goals, international or local curricular standards, and the learning history of the class. However, using them is complex due to the extreme openness of the *Connections* instructional activities and their unconventionality in comparison to traditional statistics curricula.

Inspired by Leikin and Lev's (2007) idea of *solution spaces*, we have chosen to consider the relative duration of students' independent work as simple measure of novelty. We assume that when students are not following written instructions (although they may still follow them implicitly), there is more room for free, unguided and original orientation and work.

4. RESULTS

4.1 Fluency.

While the three students were moving along their 60-min inquiry, they were fluent in formulating or reformulating many questions and organizing or reorganizing the data in a multitude of numerical, tabular and graphical representations (see Table 1). The most remarkable finding is the large number of different questions or quandaries they formulated regarding various aspects of the statistical inquiry that raised rich discussions among the students. These quandaries were likely related to the complexity of their original research question and the fact that the data were telling them "surprising stories" (e.g., "sixth graders jump farther then seventh graders") in contradiction to their hypothesis and prior knowledge.

The number of different data representations they created is also significant and indicates that the students were fluent in using the software as a thinking tool, dissecting the data from different points of view, searching for answers to their questions by reorganizing the data. Although only one hypothesis was formulated ("seventh graders jump farther than sixth graders") and accompanied their entire inquiry, it provided many issues for thought since it "collapsed", as they phrased it, in the face of the emerging interpretations from their data analysis (two random samples provided the same surprising non-intuitive result). Finally, they uncharacteristically formulated *multiple* inferences and explanations toward the end of the investigation.

Table 1: Assessment of fluency in Odi, Eli and Asi's statistical inquiry.

Fluency Criterion	**Frequency**
Questions related to statistical context	47
Hypotheses	1
Meaningful and relevant data representations	25
Inferences about the population	3
Explanations of these inferences	3

4.2 Flexibility.

Many shifts in approach, direction or focus toward the statistical inquiry were evident in the students' work (see Table 2). These shifts were performed in the three main parts of the investigation: posing a question, data analysis, and drawing inferences. The data analysis stage, which was the longest among the inquiry stages, saw an impressive number of shifts made by the students in terms of changes in data representations, transitions between local and global views of data (see Ben-Zvi & Arcavi, 2001), and transitions between data and context. The students had no difficulty in performing these shifts, and their evident discomfort from the surprising results might have contributed to their flexible disposition toward the statistical inquiry.

Table 2: Assessment of flexibility in Odi, Eli and Asi's statistical inquiry.

Inquiry Stage	#	Shifts / Transitions	Frequency
1. Posing a research question	1a	Change or update of an inquiry topic	1
	1b	Critical discussion concerning a research question	5
	1c	Change of a research question	1
	1d	Replacement or addition of a variable(s) to an existing research question or to the inquiry topic.	3
2. Formulate an hypothesis	2a	Critical discussion concerning an hypothesis	4
	2b	Change or elaboration of an hypothesis	0
3. Data analysis	3a	Change in data representation (transnumeration)	25
	3b	Transition between local and global interpretations of a graphical representation of a sample	10
	3c	Transition between data and context	5
	3d	Inquiry of an additional equal-size sample, or of an increased-size sample (or a suggestion to do that)	3
	3e	Comparing different samples	3
	3f	Transition to a secondary inquiry cycle	2
	3g	Connecting graph interpretation with the sampling method	2
4. Interpretation about the sample	4a	Elaboration or change of an interpretation (a conclusion about a sample)	12
	4b	Elaboration or change of an explanation of an interpretation	2
5. Informal inference (from a sample to a population)	5a	Elaboration or change of an inference (about the population)	1
	5b	Elaboration or change of an explanation of an inference	7
	5c	Connecting an inference to the sampling method	3

The first full research question was formulated only 35 minutes after the beginning of the inquiry, in spite of the worksheet instruction to begin with it. Unlike the clear-cut view of the statistical inquiry cycle, which typically starts from a driving question, these students (like practical statisticians) did not proceed linearly in this process but rather iteratively and flexibly, considering and selecting possible paths. Furthermore, beyond working in a flexible manner, the students had a few meta-discussions about these shifts, for example, while interpreting a graph, they discussed the need to combine global and local views of data. In some cases the rarity of a criterion might be misleading since it pertains to important statistical skills and flexible orientation. For example, in two cases they shifted to a secondary statistical investigation concerning an unexpected phenomenon (e.g., what is the meaning of “other” in the favorite sports data); in five cases they shifted back-and-forth between the data and the context spheres; and they once suggested to draw additional random sample in light of the surprising conclusion.

4.3 Novelty.

The relative duration of students' independent work yielded surprising data. The students followed the worksheet instructions only 10.4% of the total inquiry time (6.5 out of 63 min). In other words, almost 90% of their time was given to independent inquiry work, a rather rare experience in school reality. Indications for novelty are found also in the unusual multivariate research question, analysis with multiple representations, use of secondary inquiry cycles to search for deep meaning of the data, and formulation of many quandaries and genuine efforts to face them.

5. SUMMARY

In this paper we suggested an initial framework—Creativity Assessment in Statistics Inquiry (CASI), and began to evaluate it by assessing primary school students’ learning in statistical inquiry setting. The adaptation of the three common characteristics of creativity (fluency, flexibility, and novelty) to the specifics of learning statistics was found beneficial. In assessing the creative praxis of three sixth grade students in a statistical inquiry episode, we observed many activities that were evidently creative. We are currently studying the strengths and limitations of the suggested framework, realizing that several criteria have to be collapsed and better measures of novelty have to be formulated and tested. We are also studying additional episodes to evaluate the framework’s power distinguishability and completeness and improve methodology as well as the issue of assessing creativity of individual students vs. groups of students. This study may provide new ways to foster students’ representational and strategic fluency and flexibility, and their appreciation for novel research questions, analysis and representation methods, or inferences.

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CREATIVITY OF GIFTED STUDENTS

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INTRODUCTION

Though creativity is accepted as an attribute of gifted children (high IQ) (e.g. Clark, 2002, Rex, 1996; Song & Porath, 2005), the empirical-based evidence regarding this interrelationship is hardly satisfactory. After a comprehensive screening of the accumulated studies till the 80s, Tannenbaum (1983), deduced that the correlation between creativity scores and IQs of gifted children ranged from near-zero to moderately positive and even significant as compared to regular populations. Similar observations were made by VanTassel-Baska (2001) who, more than twenty years later claimed that "creativity is an elusive factor in its relationship to giftedness". Furthermore, Milgram & Livne (2006) while reviewing creativity in Israel, found that two articles that originated from the same researcher (Landau, 1981; Landau & Wiessler, 1998) reported different findings: in the 1981 study the correlation between intelligence and personal traits with creativity of gifted (high-IQ) as compared to non-gifted high school students, was found to be zero, whereas in the 1998 study while using a different measure of creativity of gifted children (fluency and flexibility: Torrance's Circles subset from 1972) a positive correlation between giftedness and creativity was observed.

The contradictory results call for the initiation of research that is rich-knowledge-driven and methodologically systematic (Sternberg, 2006, p. 2) towards understanding creativity as a psychological scientific phenomenon rather than the common mystified attitudes towards this phenomena (Shye & Yuhas 2004).

Yet, with all the shortages regarding the connection between creativity and giftedness, knowledge regarding this phenomena and methodological issues, have been accumulated. Barron (1988) defines creativity as involving "a creative

product produced by a creative **p**erson as a result of a creative **p**rocess". This definition calls the attention to three main components of creativity as a phenomenon: the unique features of the creative person, the unique creative process and the outstanding creative products.

Characteristics of a creative person.

It is agreed that a **creative ability, knowledge** and **readiness to create** are three of the main features that characterize people that were found to construct creative artifacts (Nevo, 1997, p. 638). Amabile (1998) pinpoints similar features and describes them as follow: a. expertise, motivation and the ability to think flexibly and imaginatively as comprising this creative ability. *Expertise* relates to prior knowledge (procedural as well as declarative) in the field of creation. *Motivation* relates to intrinsic dispositions that primarily derive from interest, enjoyment, satisfaction, and challenge to create. The component of *ability* involves complex thinking processes including the ability to integrate divergent as well as convergent modes of thinking (Brophy, 1998; El-Murad & West, 2004; Shye & Yuhas, 2004). It involves insightful thinking that is the ability to see in a new way the missions, givens, problem-constrains, possible solutions and sometimes also the ability to draw unexpected analogies as new and original directions for understanding the problem and getting to an original solution (Mayer 1995).

Features of a creative process.

A creative process is a hard and continuous process towards improving ideas and solutions through gradual alternations and refinement of the work (Harris 1998).

The nature of the product.

Creativity as a phenomenon involves the construction of new and original interpretations (e.g. Runco, 2005). This is actually the punch line of a creative process and an indication that indeed it is a phenomenon of creativity. There are some well-agreed criteria as to the features of a creative product: newness or originality, appropriateness, elaborateness, flexibility, fluency and aesthetics (e.g. Amabile, 1996, 1999; Klavir & Hershkovitz, in Press; Nevo, 1997; Runco, 2005; Shye & Yuhas, 2004; Zuo, 1998). The *appropriateness* criterion reflects the ability of the individual to understand the constraints of the mission. The *originality* criterion reflects the deviation of the product from routine solutions (being different, unique, unexpected and non-conventional). *Elaborateness* relates to the quality of integration between the different components into a new unexpected product. *Flexibility* reflects the individual's ability to shift from one way of thinking to another and extract solutions that refer to different categories. *Fluency* refers to the individual's ability to construct a large number of solutions that meet the limitations of the assignment. The *aesthetics* criterion is considered as one of the most valuable characteristics of highly creative people that create, discover, solve complex problems, constructing insightful products and innovative new ideas.

Giftedness and creativity

The above mentioned features of creativity seem to be features that distinguish gifted populations from the average. Nevo (1997) claims that a high g is a necessary condition for creativity though it is not sufficient. High IQ is actually the determinant of gifted populations. Furthermore gifted were found to be particularly adept at generative thinking (e.g., Ward et al. 1999), in their insight abilities and analogical complex thinking (Davidson, 1986; Klavir & Gorodetsky, 2001); as having flexible abilities (e.g. Dover & Shore, 1991); fluent thinking and reasoning, such as induction, deduction, inference, as well as convergent and divergent thinking (Rex, 1996); deep understanding and effective learning resulting in creation of new and novel ideas (Rex, 1996). The gifted are effective learners and thus possess a vast general knowledge and skills (Runco, 2005; Sternberg, 1999) and their excellence is reflected while coping with mathematics, insight problems, logic and logical-mathematical missions (e.g. Davidson, 1986; Gardner, 1997; Gorodetsky & Klavir, 2003; Mills et al., 1994; Renzulli, 1998). Davidson & Sternberg (see, Davidson, 1986), for example, while trying to learn about the insight thinking characteristics of gifted vs. non-gifted students, used popular insight problems consisting on verbal-insight and mathematical-insight analogical problems. These problems proved to be suitable to expose the uniqueness of the solution process characteristics of the gifted students as more flexible and involving more selective processes of encoding, combination and comparison in comparison to those of the non-gifted students.

The above mentioned features of creativity and the nature of gifted populations have methodological implications regarding the inquiry of the interrelationship between the two phenomena. In the present research we address mainly the nature of the creative product of gifted children as compared to averaged population. The specific context was the construction of new analogical problems. The research design included a phase of learning to make sure that both populations have been exposed to the knowledge relevant to the mission. The examined features of the product (the composed new problems) were: *flexibility, appropriateness, elaboration* and *originality*.

METHOD

The research hypothesis was that the gifted will exhibit a higher readiness to get involved in the construction of new analogical problems and that their constructed problems will be more creative than those created by non-gifted students.

The population

Gifted students: 232 seventh and eighth graders with an IQ defined by the Ministry of Education as being above 131. Regulars (non-gifted): 229 students from a similar urban, middle-class background, attending the same comprehensive school.

The missions

Both groups solved three kinds of complex problems that emphasize different aspects of creative thinking including: an insight–mathematical problem, a mathematical multi-components problem and an insight-non-mathematical problem.

The design

The design included three phases: In the first phase students attempted to solve a source problem. The second phase was the learning phase and included the solution of an analogical problem to the source problem and a distracting problem. The third phase was undertaken two weeks later and the students were asked to solve again the source problem and to invent a new analogous problem.

The learning situations

Students received two solved problems and then were asked to rewrite and explain them in their own words.

Analysis

1. Readiness to invent new problems: These criteria related to the mere construction of an analogous product with no attention to its quality.

2. The quality of the product was analyzed via 4 criteria: **Flexibility**: The extent of resemblance between the surface structures (content and context) of the source and the constructed problems. Three levels of resemblance were defined ***different, similar*** *and* ***identical***. **Appropriateness**: The extent in which the solution structure of the invented problem is ***relevant*** *or* ***irrelevant*** to that of the source

problem. **Elaboration**: The extent of similarity between the solution structures of the source and the invented problems: the more the solution structure was different the more it was considered as elaborated. Since elaboration can be examined only for *appropriate* problems, these two measures were examined as one entity. Three levels were defined: ***irrelevant***, ***identical*** (appropriate but not elaborated) and ***different*** (appropriate and also elaborated). **Originality**: The extent of the constructed problem being new, different, unique, unexpected and or non-conventional in comparison to other constructed problems.

RESULTS

The analysis exposed interesting observations, (a) Gifted students are more ready to be involved in constructing new products (38% gifted vs. 25% non-gifted). (b) The readiness of the gifted students to invent new products didn't change with the change of the kinds of source problems: the mathematical-insight problem (60%), the mathematical problem (77%) and the non-mathematical-insight problem (48%), whereas the non-gifted reacted differently in the three kinds of the problems (33%, 29%, 14%). (c) In general the creative nature of the constructed problems by the gifted students' was higher than that of the non-gifted. This was exhibited in three of the four measures: ***flexibility*** (58% vs. 36%); ***appropriateness*** (50% vs. 30%), ***elaboration*** (18% vs. 14%). (d) The criterion of ***originality*** was similar for both groups.

The presentation will provide more details on these results and the implications will be discussed.

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SUPPORTING ONLINE MATHEMATICAL INQUIRY LEARNING WITH METACOGNITIVE SELF-QUESTIONING

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Abstract

Effects of two online inquiry-based learning methods in mathematics are compared: Online inquiry based on metacognitive support (MS) and with no such support (NS). A total of *80* eighth-grade Israeli students participated in the study. Students were asked to solve online a real-life task and provide feedback to their peers on the solution process. Results indicated that the MS students significantly outperformed the NS students in online problem solving task. The MS students were engaged more in online discussion concerning mathematical (e.g. explanations) and metacognitive (e.g, monitoring) aspects. Theoretical and practical implications of the study are discussed.

INTRODUCTION

Standards in the area of mathematical education have largely emphasized the importance of being engaged in inquiry-based learning. Inquiry is the process in which students solve problems, pose questions, construct solutions and explain their reasoning (e.g., (NCTM: National Council of Teachers of Mathematics, 2000, PISA: Programme for International Students Assessment, 2003).

One obvious way to bring students into the processes of inquiry learning is by offering them environments and tasks that allow them to carry out the processes and help them build a personal knowledge that they can use and explain what they learn. Rapid advances in computer-based learning have facilitated the opportunities to empower inquiry learning. Online discussion is the forum in which people advocate for their own individual opinions, sometimes backed up by facts, sometimes unfounded (Sherry, Billig & Tavalin, 2000).

Discussion mediates shared meaning. Through critically examining others' reasoning and participating in the resolution of disagreements, students learn to monitor their thinking in the service of reasoning about important mathematical concepts (e.g., McClain & Cobb, 2001). Online discussion allows asynchronous exchanges and permits both one-to-one as well as one-to-many interactions. The students exhibit motivation, learn independently, and transfer and apply the knowledge to real-life situations. Learning in such environment requires students to self-regulate their learning; that is, to make decisions about what to learn, how to learn it, when to abandon and modify plans and strategies, and to increase effort. Specifically, students need to analyze the learning situation, set meaningful learning goals, determine which strategies to use, assess whether the strategies are effective in meeting the learning goal, evaluate their emerging understanding of the topic, and determine whether the learning strategy is effective for a given learning goal. Students' need to monitor their understanding and modify their plans, goals, and strategies (e.g., Zimmerman & Schunk, 2001). However, research indicated that too few students are skilled at regulating their learning to optimize self-regulated learning. For the most part, studies have found that students learn little in online environments and they do not deploy key self-regulatory processes and mechanisms such as effective cognitive and metacognitive strategies during learning (e.g., Azevedo & Cromley, 2004).

Recent research has begun to examine the role of students' ability to regulate several aspects of their cognition, motivation, and behavior during learning environments with explicit metacognitive guidance as self-questioning and providing feedback (e.g., Azevedo & Cromley, 2004; Kramarski & Mizrachi, 2006; Kramarski & Mevarech, 2003). However, there is little research in the field of mathematics to accurately determine the benefits and pitfalls of new technology such as online discussion particularly when compared to a learning environment embedded with metacognitive support. Gaining knowledge about process and outcomes of online discussion with and without metacognitive support, help educators and researchers to gain insight on students' inquiry learning based on problem solving of real-life task and online discourse.

The purpose of the study is two-fold: (a) To investigate the ability to solve online real-life tasks of students' who were exposed either to metacognitive support (MS) or with no such guidance NS; and (b) to examine the online discourse of students' who were exposed to these instructions with regard to mathematical and metacognitive aspects.

METHOD

Participants

Participants were 79 (boys and girls) ninth-grade students who studied in two classes in one junior high school in central Israel. The two instructional approaches were assigned randomly to the classes.. No statistical differenced on a mathematical pre test were found between the two groups ($M = 83.30$; $SD = 16.80$; $M = 80$; $SD = 15.70$; $t(78)= 2.01$; $p > 0.05$).

Measurements

The study utilized two measures: (a) an online real-life task; and (b) online discourse.

(a) An online real life task

A real-life task was administrated in online discussion adapted from PISA (2003). The task describes an orchard planted by a farmer. The students are asked to find patterns in change and relationships by comparing the growth of apple trees planted in a square pattern and conifers trees planted around the orchard and to explain their reasoning. Relationships are manipulated in variety representations, including graphical, tabular, and symbolic.

Scoring: According to PISA framework we assessed the task on three problem solving skills: Reproduction, connection and reflection. The reproduction skill refers to the application of routine algorithms and technical skills, the connection skill builds on standard problem solving translation, and the reflection skill includes an element of insight on the part of the solver about the processes needed or used to solve a problem.

Each item on the task was scored from 0 (not responding, or wrong response) to 1 point (correct answer/explanation). The scores were translated to percents. The quality of explanations were analyzed based on two criteria of arguments: Mathematical arguments (e.g., formal or daily arguments); and Procedural arguments (e.g., calculation example).

(b) Online discourse

Students' online discourse during the solution of the real-life task was analyzed in two aspects: Mathematical discourse and metacognitive discourse. Mathematical discourse refers to three criteria: Mathematical terms, mathematical representations and final solution. Metacognitive discourse refers to three criteria: Planning, monitoring the solution process and errors identification.

Scoring: Sum of references provided to each category during the online discussion was calculated.

INSTRUCTIONS

General online discussion instructions: Students from both groups (MS & NS) participated in an asynchronous forum based on problem solving discussion of real-life tasks. Students practiced problem solving in pairs for a four-week period once a week in the computer lab (45 min.). Three stages were implemented in the online discussion: First, each pair was asked to solve the task and to send the solution to another pair online as a text in the forum. Second, each pair was asked to provide and receive feedback to the solution from a counterpart pair. At the third stage each pair corrected the solution and send it as a text to the forum and as an attachment file to the teacher. The teacher encouraged students to be engaged in the whole forum discussion by providing mathematical explanations and feedback, and resend their corrected solutions.

Metacognitive online discussion support: The metacognitive support was based on two parts: The first part was based on the IMPROVE metacognitive questioning method (Mevarech & Kramarski, 1997; Kramarski & Mevarech, 2003) and the second part was based on practicing explicit strategies for providing mathematical explanations and feedback. The IMPROVE method utilizes a series of four self-metacognitive questions during problem solving: Comprehension, connection, strategic, and reflection.

Comprehension questions prompted students to reflect on the problem/task before solving it (e.g., “What is the problem/task all about?”); Connection questions prompted students to focus on similarities and differences between the problem/task they worked on and the problem/task or set of problems/tasks that they had already solved (e.g., “How is this problem/task different from/similar to what you have already solved? Explain why”). Strategic questions prompted students to consider which strategies were appropriate for solving the given problem/task and for what reasons (e.g., What strategy/tactic/principle can be used in order to solve the problem/task?" and WHY). Reflection questions prompted students to reflect on their understanding during the solution process (e.g., “What am I doing?”; “Does the solution make sense?”).

In the second stage students were engaged in a discussion about the question “what does it mean to provide a good mathematical explanation”. They were exposed to features of mathematical explanation such as, mathematical expressions, representations, conclusions and clarity. In addition, students practiced how to provide feedback technique by reflecting and discussing examples. The metacognitive questions and instructions how to provide explanations and feedback were printed on an index card and students referred to these guidance in the following circumstances: during their turn to solve the task, during the discussion about the solution, and their providing explanations and feedback regarding peers' solutions.

RESULTS

The primary purpose of our study was to investigate students' online inquiry learning based on real-life problem solving with regard to mathematical explanations.

We performed a one way MANOVA on real-life task scores. Results indicated that the online MS students significantly outperformed their counterparts (NS) on mathematical problem solving (Connection: M = 92.21; SD = 7.92; M = 87.33; SD = 8.63, $p < 0.01$; reflection M = 85.49; SD = 11.81; M = 63; SD= 17.93; $p < 0.001$). No significant differences were found on reproduction skills.

In addition, we found that at the end of the study more MS students provided mathematical arguments than the NS students (72%; 50%, $t(77) = 3.97$, $p < 0.05$ respectively), whereas no significant differences were found between the two environments on procedural arguments (17%; 20%, $t(77) = 0.57$, $p > 0.05$ respectively).

The second purpose of our study was to examine students' online discourse with regard to mathematical and metacognitive aspects during the feedback process.

We performed a MANOVA and an ANOVA on each criteria of mathematical and metacognitive discourse. Results indicated that the MS students significantly outperformed their counterparts (NS) on mathematical discourse regarding two criteria of providing feedback: Using mathematical terms (M = 15.76; SD = 18.19; M = 4.15; SD = 0.50; $p < 0.001$), and reference to mathematical representations (M = 11.04; SD = 15.71; M = 3.93; SD = 7.60; $p < 0.001$). No differences were found on reference to the final solution.

Similarly, the MS students significantly outperformed their counterparts (NS) on metacognitive discourse regarding two criteria of providing feedback: Errors identification (M = 2.4; SD = 6.11; M = 0.13; SD = 0.04; $p < 0.001$), and monitoring the solution process (M= 7.84; SD = 14.15; M = 4.17; SD = 12.6; $p < 0.001$)). No differences were found on planning the solution.

DISCUSSION AND CONCLUSION

Our findings indicated that metacognitive support in an online learning environment might be a vehicle for students' inquiry learning based on mathematical problem solving and discourse. There are possible reasons for the beneficial effect of the metacognitive support. It seems, that IMPROVE support integrating with discussion about mathematical explanations and providing feedback might help students: Access and interact with the content functionality, think about the deeper concepts and structure of disciplinary relations, and avoid superficial details. Our findings extend other findings in non-technology environments which indicated that metacognitive tools as IMPROVE method had a cognitive effect on students' mathematical reasoning (e.g., Kramarski & Mevarech, 2003).

We recognize the need to understand more about how mathematical inquiry learning based on problem solving and students' discourse emerges in different advanced technology environments. In particular, for students of diverse abilities and characteristics as the higher achievers and the lower achievers.

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THE CREATIVE CLASS

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Based on several studies on the profile of gifted and highly gifted children, as well as on those studies who deal with the relationship between emotional maturity, intelligence and creativity in gifted children, we could see that the highest intelligence cannot fully manifest itself without a corresponding emotional maturity. The highly (severe) gifted children were found high in emotional were higher also in creativity (fluency and flexibility). From this we could also deduct that emotional maturity is necessary for the gifted to actualize their creativity.

From experience of working with gifted children we could observe a gap between their intellectual and emotional functions. The purpose of this study was to explore the inter-relationship between emotional maturity and intelligence in gifted children. Emotional maturity is defined as the strength and courage to actualize individual abilities within the frame of social demands.

Among the highly intelligent group, emotionally mature children were more creative. These results demonstrate that giftedness is conditioned not only by high intelligence but that emotional maturity has its share in it, and their interaction facilitates creative behavior – the actualization of whole personality. It is therefore vital for parents and educators to give the necessary encouragement and nurture to all of the different aspects of child, so that he develops with inner harmony and balance, a balance that will enable him to make the creative, frightening steps forward.

Emotional maturity affects the level of intelligence and the level of creative behavior in gifted children and needs to be stressed when considering their education not only for "knowing" but to be prepared for life. It is thus not enough to study gifted children from the divided aspects of intelligence or other concepts, but to view the gifted child as a whole within a broader framework of internal and external processes.

Intelligence, creativity and emotional maturity are linked in the highly gifted and become their self – the whole which determines the level and the style in which the child thinks, acts and actualizes his self…his lifestyle. This lifestyle is the creation of each one of us. It is imitation in early childhood and later on it is the awareness of different options from which we choose our own lifestyle.

In the last couple of years, we hear more and more of a new class in society the “Creative Class”. In his book, “The Rise of the Creative Class”, Richard Florida (2002) speaks of the social and economic systems that tap individual creativity and make use of it as never before. The number of people doing creative work has increased vastly in the past century and especially over the last two decades. The author interviewed scientists, engineers, artists, musicians, designers and knowledge-based professional educators who are paid principally to do creative work for a living whom collectively he calls “Creative Class”. This creative class has power, talent and numbers to play a big role in reshaping our world. Its numbers – in fact all of society – now have the opportunity to turn their introspection and soul-searching into real energy for broader renewal and transformation, the creative lifestyle. Some 38 million Americans, 30 percent of all employed people, belong to this new class. He defines the core of Creative Class to include people in all fields of human endeavor whose economic function is to create new ideas, new technology and/or new creative content.

The people, Florida interviewed report that they have little trouble integrating such multiple interests and personae. This kind of synthesis is integral to establishing a unique creative identity. It’s almost impossible to be a nonconformist today because conformity is no longer an issue.

But at the same time, this more open attitude toward lifestyle forms a deep and growing division between the Creative Class and the more traditional classes.

Because we identify ourselves as creative people, we increasingly demand a lifestyle built around creative experiences. We are impatient with the strict separations that previously demarcated work, home and leisure. Whereas the lifestyle of previous organizational age emphasized conformity, the new lifestyle favors individuality, self-statement, acceptance of difference and the desire for rich multidimensional experiences.