Self-Generated Representations (SGR) for Promoting Conceptual Understanding

Orit Parnafes
Tel-Aviv University
oritpa@post.tau.ac.il

Abstract

This research aims to investigate the potential of students' self-generation and elaboration of visual representations, to enhance and advance their understanding of difficult conceptual domains. The research is intended to inform the design of technology-based interface that could promote self-generated representations (SGR) for enhancing conceptual understanding.
Two objectives are central to this research: 1. examining ways for *advancing students' understanding of difficult conceptual domains* using the tool of SGR; 2. examining ways *for promoting new tools and practices for thinking and developing understanding* - an important part of promoting life-long learning.

The research is based on observations of pairs of students, ages 10-14 (4-9th grade), self-generating representations while they are trying to understand a difficult phenomenon (e.g., phases of the moon). First, the students self-generate representations for themselves, then negotiate and co-construct representations with their peer, and finally, design computer-based representations for an external audience. The data are analyzed qualitatively to gain insight as for the processes of developing understanding during SGR. Results from this exploratory research may serve as a good foundation for designing curriculum materials as well as innovative technological tools, with the goal of enhancing SGR competency, and supporting conceptual understanding.

Keywords: Self-generated representations, visual representations, constructivist learning, representational practice, technology-enhanced practices.

Introduction

The proposed research aims to investigate the potential of students' generation and elaboration of visual representations, to enhance and advance their understanding of difficult conceptual domains. In particular, it examines students' practices of using drawings and visual representations inventively and creatively to advance their own understanding, as an aspect of meta-representational competency (diSessa, 2004).

This research follows from findings of a previous research that investigated students' developing understanding with pre-crafted computer-based representations (simulations) originating from normative representations (Parnafes, 2005; 2007). The representations were designed to mediate conceptual understanding highlighting specific aspects that are essential for understanding the phenomenon. Results showed that students' ability to develop their understanding using external representations is contingent on their conceptual resources (Parnafes, 2005). Subsequently, the current research is focused on students' conceptual resources, and *their own constructions* based on these resources.

Inspired by constructivist perspectives, the earlier idea of imposed external representations for developing students' understanding is now transformed into the idea of student-generated representations to reflect their current understanding, as a tool for elaborating understanding, and as a tool for communicating ideas. This transformation is significant, as it gives an honest opportunity for the well-advocated constructivist approach to be manifested in students' genuine ideas and their expression in various forms. While the previous research was based heavily on innovative technology such as computer animations and simulations, the current research begins with the simple old-fashion technology of paper and pencil, along with some more recent technologies (the visual representational aspects of PowerPoint) with the goal of developing new technologies for advancing the practices of Self-Generated Representations (SGR).

The theoretical foundation of this research is motivated by the combination of two important components that have been shown valuable for learning: First, a wide range of research has shown that *learning with visual representations* enhance learning and understanding (e.g., Larkin & Simon, 1987; Scaife & Rogers, 1996; Ainsworth, 1999; Parnafes, 2007). Second, research has shown that *self-generated explanations* (Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Chi, de Leeuw, Chiu, and La Vancher, 1994) promote deeper understanding. This research proposes to combine the two components and investigate the potential of *self-generated visual representations* as a means for explaining difficult phenomena to promote learning and genuine understanding.

Visual explanations are particularly important given that our world is rich in visual images, and this era is characterized in an ever increasing amount of innovative and sophisticated diagrams and visualizations that enhance various types of information in many fields (e.g., Tufte, 2001). Scientists use representations in their practice to promote their own understanding, to think with in order to make scientific progress, and to communicate with other scientists (Latour, 1986; Lynch and Woolgar, 1990; Ochs, Jacoby, & Gonzales, 1994; Nersessian, 2002). It is only sensible to enrich students' repertoire of self-explaining tools to include visual means to enhance their own understanding and learning of researched phenomena. Furthermore, humans think occasionally with images and visual models and those could be expressed in order to be operated on and communicated with. Yet, in school practices, students' opportunities for expression mainly involve verbal and textual forms. Visual forms are mainly presented as instructional means, and not as forms for expression and self-generation.

DiSessa et al. (1991) studied students' competencies in participating in various representational practices. They show that students, as young as elementary school students, have many competencies for creating, critiquing and inventing new representations (meta-representational competencies). Developing these competencies, they conjecture, is important in enhancing students' representational innovation, as well as deepening their understanding of any kind of representation (diSessa, 2004). From a meta-representational point of view, the competency of grappling with a tough conceptual field through the *generation and elaboration* of representations was not explored.

Research programs that have already been conducted on SGR (e.g., Ainsworth & Loizou, 2003; Roy & Chi, 2005; Cox & Brna, 1995; Cox, 1999; Gobert & Clement, 1999; Hall, Bailey, & Tillman, 1997) demonstrate the growing interest of the research community in the relation between self-generated explanation and external graphical representations. The majority of research comes from cognitive science, comparing various cognitive differences between experimental settings, e.g., reasoning with self-constructed external representations and reasoning with presented representations.

Following the potential of SGR in promoting learning, expressed by existing research, the current research explores the proposal that SGR can be a powerful tool for thinking and for developing understanding of difficult topics. It investigates students' practices of using drawings and visual representations inventively to advance their own understanding, as an aspect of meta-representational competency (diSessa, 2004). In particular, the research is designed to inform technological innovations that support SGR for promoting understanding.

The focus of the proposed research is students' expression and projection of their current understanding and its elaboration using diagrams, drawings, sketches and other visual representations. The research program is guided by the following objectives:

1. Examining ways to *advance students' understanding of difficult conceptual domains* using the tool of SGR (both paper and pencil and more advanced technologies for SGR). This objective combines the constructivist notion of building on students' own ideas and conceptions on the one hand, with the power of visualization in enhancing understanding on the other hand.

2. Examining ways to *promote new tools and practices for thinking and developing understanding*. This is an important part of promoting life-long learners - learners that are able to use a range of representational tools (paper-and-pencil-based representations and computer-based representations) for advancing their own understanding of difficult phenomena.

Research Design and Methods

Subjects

The research is based on observations of 4-9th grade students' self-generating representations while they are trying to understand a difficult phenomenon. Students work in pairs. Each pair attends a session of one to two hours, on one of the following topics:
6-7 pairs of 4th-6th grade will be engaged in an activity about the phases of the moon.
6-7 pairs of 6th-8th grade will be engaged in an activity about floating and sinking of objects.
6-7 pairs of 7th-9th grade will be engaged in an activity about the oscillatory motion.

Procedure

At the beginning of the session, the students are engaged in an introductory activity on the topic. Following the introductory activity, the SGR activity is constructed in three phases, in which the students are asked to generate representations for:

1. Themselves – students draw some diagrams to help themselves understand the phenomenon.
2. Their friend – students share their representations with one another and explain their understanding to their peer based on the representation. Then, they should negotiate and co-construct a shared representation that they both agree on. This section may be longer and the students might go through several drafts as they refine their shared understanding.
3. Outside audience – Students produce computer-based representations for people that are not present in the activity. In this phase, we use features of PowerPoint as a tool for creating computer-based dynamic and interactive representations.

The sessions are videotaped for further analysis. The representations produced are kept for further analysis.

Data Analysis

The methodological orientation of this research encompasses a fine-grain detail qualitative analysis of case studies. The theoretical framework is developed in an approach similar to the grounded theory methodology (Glaser & Strauss, 1967; Strauss & Corbin, 1990). The construction of a theory is done by generating categories from evidence taken from a few focus cases. These categories can then be explored in other cases, which may support the categorical concept or suggest modifications to make it more generalizable.

Preliminary Results

The preliminary results follow from the first three studies conducted in this research, on the phases of the moon. In these studies there was an evident development in students' understanding of the cause of the phases of the moon. The development processes resulted from an ongoing negotiation between the students over their representations, and some challenging questions made by the researcher. In each of the phases, we could see a deepening of understanding, starting with an initial process at the first phase, a deeper discussion that led to a deeper learning through the negotiation in the second phase, and yet a further deepening in the third phase where students became"instructional designers" using PowerPoint presentation to explain what they already understood in a creative and instructive way using new tools of representations (dynamic and instructive).

Through this preliminary analysis, a list of SGR practices was collected by examining students' interactions, talk and actions. This list refers to how students use representations inventively to help themselves think and understand a difficult topic, and to communicate their ideas to others. Below are the specifications of each category of students' SGR practices, along with a few examples:

1. *Claiming accountability* – a student uses a representation as a clue or evidence for a previous argument of a peer (unlike oral practices, "waving hands" is less feasible – the argument leaves traces).
2. *Adding, changing, erasing* – the students build on each other arguments by making some transformations and introducing some new ideas into the representation.
3. *Dragging* – a student drag a representational invention from one inscription to a new one – either one's own previous inscription or the peer's inscription.
4. *Infusing meaning* – a student uses the representation as an object that expresses meanings and concepts that he knows or believes in.
   Example: Rose drew the standard textbook drawing: a sun shining on the moon and earth – and around the earth there are multiple moons with different phases (Figure 1). The moon closest to the sun is a full moon, and the farther from the sun is a dark moon (because the earth fully shades it). This reflects her prior conception that the sun lights the moon in different ways every day. She draws a picture that she knows is somehow adequate, and she attempts to give the familiar picture a meaning – she *infuses* the meaning of the shadow of the earth on the moon, although this was not the meaning intended in the original picture.
5. *Transforming an inscription* – a student uses an existing inscription and transforms it so it expresses new ideas, by adding details, shading, highlighting etc.
6. *Using signs inventively* – a student uses various common signs (circles, lines, words, numbers, colors) inventively and creatively to achieve some communicative goals.
   Example: Towards the end of the session, Roze and Natalie drew a moon with a line that represents the part that is lightened by the sun, while the half facing the sun is yellow, and the other half is black. On top of this drawing they put a line that represents the part that the earth "sees" (Figure 2 – the moon that is pointed to by an arrow). This example demonstrates how circles, lines and colors, can be put together by students in a way that they serve a conceptual function. With a technological tool, the range of inventiveness can widen, as it enables presentation of step by step, animation of various objects, and a creative use of the feature of interactivity.

7. *Gesturing over a representation* – a student uses the inscriptions as objects of reference (boundary object: Latour, 1986; Roth & McGinn, 1998) and makes gestures to express various ideas by pointing, covering, waving etc.
8. *Talking through* – a student draws a representation and talks through while drawing (it is interesting to realize what is mentioned and what is not mentioned in students' talk) Collections of various occurrences in each category will show the range of students' practices of self-generating representations and will provide a view of aspects of inventiveness in this activity as well as aspects of meta-representational competencies. These categories can help answer questions such as what practices should be fostered, which ones should be discouraged, how specific practices contribute to the development of conceptual understanding? Can some of these practices could be taught or trained? Furthermore, such a collection of categories of students' practices of SGR can serve as a basis for an informed design of technologies that support and enhance such practices.

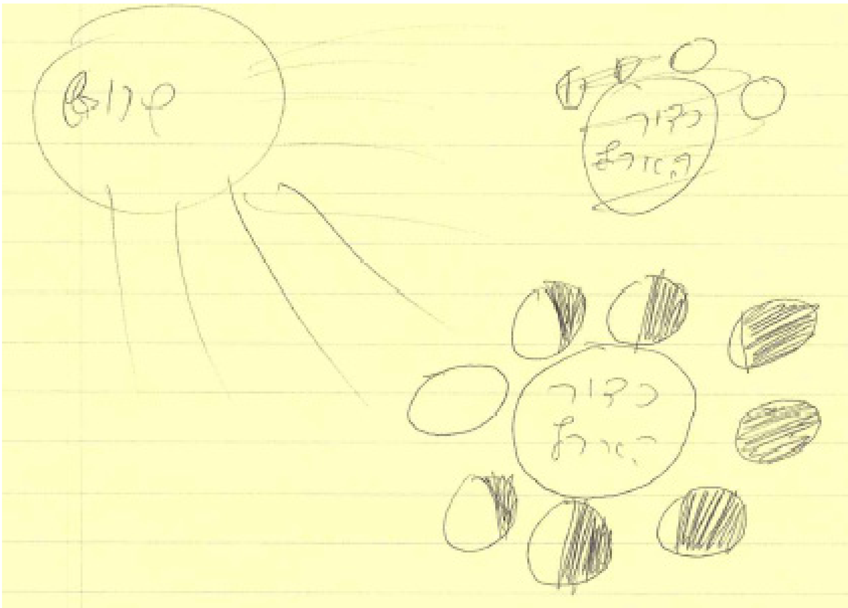

Figure 1 – Rose's first drawing of the phases of the moon

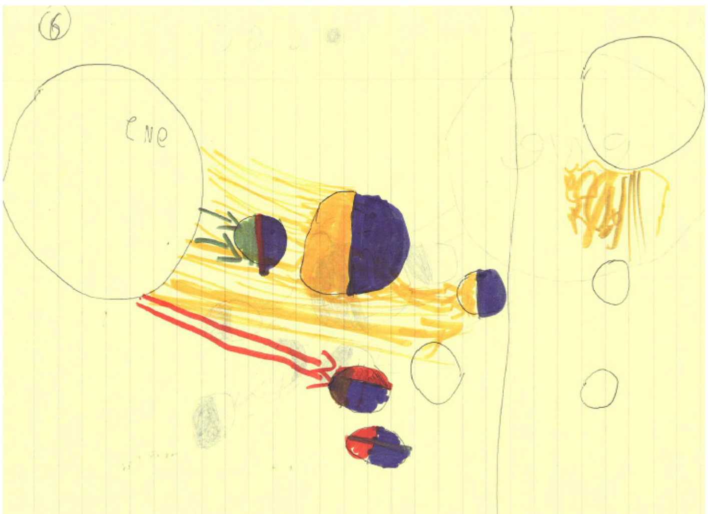

Figure 2 – A drawing of the phases of the moon designed for outside audience

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