# Representational Practices in the Activity of Student-Generated Representations (SGR) for Promoting Conceptual Understanding

Orit Parnafes, School of Education, Tel-Aviv University, Israel, oritpa@post.tau.ac.il

**Abstract:** This research aims to investigate student-generation and elaboration of visual representations as a tool for promoting understanding of difficult conceptual domains. The paper focuses on students' naturally occurring representational practices as identified in an activity of student-generated representations (SGR). The research is based on observations of pairs of students, ages 10-14, generating representations while trying to understand the phenomenon of the moon phases. The activity involves a few stages. First, each student generates a representation to promote his or her own understanding of the phenomenon. Then, the students negotiate and co-construct representations with their peers. Finally, they design representations for explaining the phenomenon to an external audience. The analysis identifies various representational practices utilized by students for making sense of the phenomenon, developing explanations, and communicating their ideas to their peers. The analysis examines how these practices support students in achieving some cognitive and communicative goals.

## Introduction

This research aims to investigate student-generation and elaboration of visual representations, as a tool for promoting understanding of difficult conceptual domains. In particular, it examines students' practices of using drawings and visual representations to advance their own understanding.

Generally speaking, the idea of SGR can be motivated by combining 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 *student-generated visual representations* as a means for explaining difficult phenomena to promote learning and genuine understanding.

Student-generated explanations can take different forms (or representations). In most studies the self-generated explanations are either verbal or textual. Chi et al. (1994) mention that other forms of nonverbal constructive activity, such as diagram drawing, may also be effective at enhancing learning. This is 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). 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, if we look at school practices, students' opportunities for expression involve, for the most part, verbal and textual forms. Visual forms are mainly offered to students as resources, and rarely as forms for expression and self-generation.

This rational is stimulated also by examining representational practices in scientific areas. 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). DiSessa et al. (1991) studied students' competencies in various representational practices. They show that students, as young as elementary school students, have sophisticated 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. This may well be an important competency to develop, given that it is a common practice in scientific work, involving a fair amount of inventiveness and creativity.

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 increasing interest of the research community in self-generated representations. While much of this research comes from cognitive science, comparing various cognitive differences between experimental settings, there is a growing research that uses qualitative methods for examining activities of students' SGR in an open ended setting (Bamberger, 2007; diSessa, 2004; Danish & Enyedy, 2007; Enyedy, 2005; and Nemirovsky & Tierney, 2001).

The current research explores the proposal that SGR can be a powerful tool for thinking and for developing understanding of difficult topics. One path of exploration of the current research, and the focus of this paper, is examining students' naturally occurring practices of SGR, and analyzing the means by which these practices shape and facilitate their developing explanations and conceptual understanding. The analysis attempts to address the question: In what ways could naturally occurring SGR practices support the achievement of conceptual and communicative goals in the process of developing and elaborating explanations of difficult phenomena?

## Methods

### Data collection

The research is based on observations of 7 pairs of students (see table 1), generating representations while trying to understand the phenomenon of the phases of the moon. The students were 10-14 years old (4-8th grade). Each pair attended a session of one to two hours.

Table 1: the research subjects.

| | Gender | Grade level |
|---|---|---|
| Rose and Natalie | Two girls | 5th grade |
| Merav and Maya | Two girls | 5th grade |
| Tal and Rotem | Two boys | 5th grade |
| Ran and Gil | Two boys | 4th grade |
| Liron and Itai | Two boys | 5th grade |
| Roni and Tom | Two boys | 6th grade |
| Or and Meital | Two girls | 8th grade |

The scientific domain selected for this study is the *Phases of the moon.* The instructional design of the sessions involves four parts, following a beginning, in which the students receive a brief explanation about the research and the session.

1. *An introductory activity:* a brief interview about what the phases of the moon are, the cycle of the moon phases over a month, and the system of moon, Earth and the sun including relations between rotations and revolutions. The interview usually ends with soliciting students' initial explanations about the causes of the phases of the moon.
2. *Personal representations:* the students are asked to draw some representations (diagrams or sketches) to explain the cause of the phases of the moon.
3. *Collaborative representations:* the students are asked to share their representations with one another and to explain the cause of the phases of the moon to their peer based on the representations. Then, they should negotiate and co-construct a shared representation that they both agree on. This part is usually the longest of all parts and the students go through several drafts as they refine their shared understanding.
4. *Presentable representations:* the students are asked to produce a diagram for people that are not present in the activity. Student design a PowerPoint presentation in this phase. In some cases, this stage is conducted in a separate session, a few weeks or even months after the first session.

During the session, the researcher's role is mostly a participatory observer. In principle, interventions are kept to the minimum, and if made, it is for the purpose of clarifying meanings, or asking challenging questions when the students seem to be satisfied with their state of explanation. The sessions are videotaped and then digitized for further analysis. The representations produced are collected and scanned.

### 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 are then explored in other cases, which may support the categorical concept or suggest modifications to make it more generalized.

To conduct the analysis, the various sources of data are examined: 1. The representational forms that the students produced during the session; 2. The video recordings of the interaction between the students as they work together, including their actions such as pointing to aspects of the representations, gesturing, highlighting, arguing, refining, agreeing, disagreeing and so forth. From this close examination some categories emerge concerning *actions and practices of SGR*. These categories were applied on two of the sessions and refined through several iterations of applications. When the framework stabilized and the categories demonstrated usefulness and insight with regards to the issue at hand, the categories were applied on other case studies. The analysis is carried out using the Transana[i] video analysis software.

## Preliminary findings

The preliminary findings are presented in this paper in the form of a set of categories of actions and practices of SGR produced by the analysis. In addition, a sample analysis of one episode is provided to demonstrate how some of the actions and practices support the achievement of conceptual and communicative goals in the process of developing and elaborating explanations using the generation and elaboration of representations.

### The System of Categories

The system of categories includes two sets of categories. The first set includes categories of observed actions operated on the representations, and the second set includes categories of practices for achieving cognitive and communicative goals. Below is a description of each category with some accompanying examples.

<u>Observed Actions Operated on the Representations:</u>

A. *Generating representations* - Students draw representations, either from scratch, or, they continue elaborating a representation that already appears on the paper. Students generate representations with various degrees of innovation and inventiveness. Some of their drawings are customary representations of objects and relations between them (see Figure 1 on the left). Generating representations can also be done by borrowing a representation invention or convention from other resources. Resources can include representational aspects drawn by the peer, or a conventional representation seen in a textbook or elsewhere (See Figure 1 in the middle). Ultimately, a representation could be generated by making a representational innovation, in which students use various common signs (circles, lines, words, numbers, and colors) inventively. In Figure 1 on the right, students use big circles to indicate the field of view from different positions on Earth.

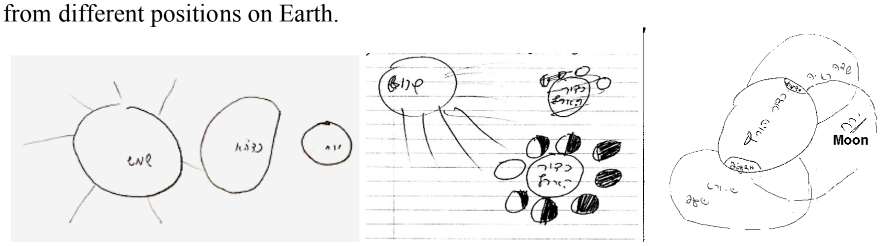



**Figure 1 - various degrees of inventiveness in generating representations**

B. *Gesturing over a representation* - Students make gestures to express various ideas. There are various types of gestures that are found to be used by students through their discussion, including pointing, animating and covering a representation. For example:

   a. Animating: Figure 2 shows a selection of animating gestures on the static drawing for representing motion. The two pictures on the left demonstrate gestures that represent the motion of the sun rays from the sun to the moon. The two pictures on the right show gestures that represent the rotation of the Earth around its axis, and the revolution of the moon around the Earth, accordingly.

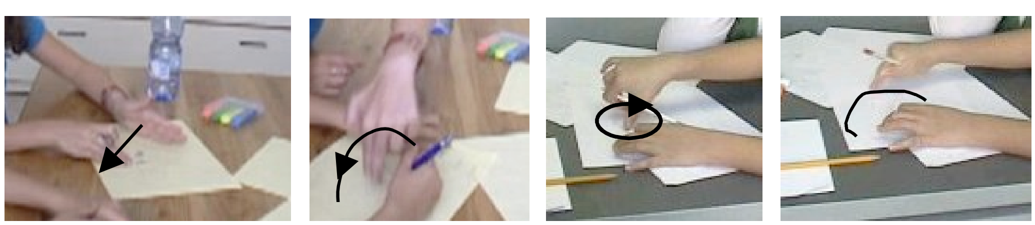


**Figure 2 - animating gestures for representing motion**

   b. Covering: Students cover parts of the representations with their hands. In Figure 3 on the left, the student covers parts of the representations to highlight only one moon on which she wants to focus. This is an example of covering and hiding details to reduce destruction from unnecessary details (in this case, drawn by her peer). In the picture on the right, the student covers with her hand half of the moon – the part that is not seen by people looking from the Earth. In this, she tries to reason about the part that is seen from Earth.

**Figure 3 - covering gestures**

C. *Highlighting selected details* - The students select certain details in the representation and highlight them either by circling, shadowing, or making any other form of highlighting. For example, when Natalie talks about the day and night on Earth, she highlights the line splitting the Earth into two halves – the one that's facing the sun, and the one that is not. Another example is highlighting and shadowing a part of the moon that is not facing the sun to show that half of it is shadowed. The students keep highlighting and shadowing the part even though it is already shadowed.

D. *Transforming a representation* - Students transform a piece of an existing drawing by adding details, changing, and deleting. They add details that were not on the original drawing, change some aspects, or delete aspects of the representation. For example, Natalie explains that the moon in the picture cannot be seen from Israel but can be seen from the US. Rose argues with her, saying that even US cannot see it because this moon is dark – the Earth casts shadow on it. She darkens the moon (it was only a blank circle before) and in that transforms the representation to represent a dark moon.

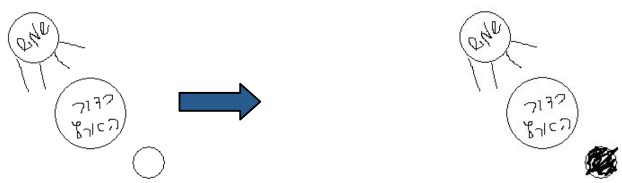


**Figure 4 - Transforming a representation**

As with the "generating representations" category, students transform representations with various degrees of innovation and inventiveness.

## 3.2 Practices Used for Achieving Cognitive and Communicative Goals

Students generate representations, gesture over, highlight and transform representations as a means for achieving some task-related goals. Following are five functions identified in the data for achieving cognitive and communicative goals in this sense making activity.

E. *Organize information* – Students organize on the paper all the relevant information – usually the objects and their spatial relations. This is usually happens at the beginning of producing a drawing.

F. *Construct and communicate an explanation* – Students use representations to generate an explanation either for enhancing their own understanding, or to communicate their explanation to their peer or to the researcher.

G. *Manage complexity* – Students use the representations to reduce or organize epistemological complexity. This can be done by freezing a state in a dynamic process, or by selecting a focus on only one state, by ignoring some details, etc.

H. *"See" better – perceptual aid* - Students use various common signs (circles, lines, words, numbers, and colors) inventively to achieve some communicative goals and to "see" new ideas better.

I. *Claim accountability* - A student uses the representation as evidence for her previous arguments or her peer's previous argument. The representations enable students to make their arguments with reference to the external representations they have produced. They can point to objects in the representations that they wanted to argue about, or to elaborate their ideas on, agree or disagree to statements with reference to them. The instructor can use this practice as well to set the students' attention to a particular issue and to talk about it.

Following is a sample analysis of one short episode. The episode was identified as one in which representations are used for the function of "seeing better" (category H). It is analyzed to reveal how the various actions operated on the representations support the specific cognitive and communicative goal.

## Practices of Using Representations to "see better" – Sample Analysis

Rose and Natalie are 5th grade students. They are towards the end of the third part of the activity, where they made an impressive development in their explanations and understanding. This is their last attempt of explaining the phases of the moon before they move on to the fourth part, where they'd try to generate representations for an external audience. They already explained nicely what happens in the mid month phase (according to the lunar calendar) – when the moon is full. Now, they try to see how other phases are formed. They are now focusing at the location of the moon described in Figure 5:

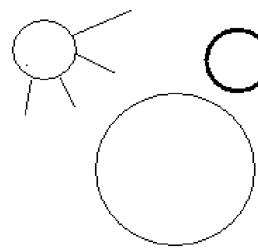
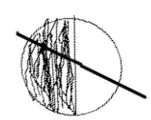


**Figure 5 - The moon in a new location**

Natalie colors the moon in the new location – the part facing the sun is now lit (the colored part is the lighted part). Rose adds a line splitting the moon to two other halves, an important move for highlighting the observer's point of view and how the moon is seen from Earth:

Rose: So we… what we actually, see, is this part *(drawing a line almost vertical to the colored part)*, more or less…



Her explanation combines both the illumination of the moon (represented by the colored and non-colored parts of the moon), and the part that is seen from a particular position on Earth. She makes a representational innovation, using a line to see the illuminated part seen from Earth. This representational innovation enables the students to "see better" what is actually seen from Earth.

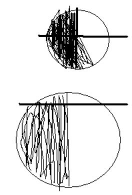
Indeed, following Rose's elaboration of which particular part of the illuminated moon is seen, Natalie gains a meaningful insight:

Natalie: Ah! One moment, *(takes Rose's hand away from the representation)* the moon doesn't really get larger and smaller, it's simply what we see. We see only the illuminated part [Rose: right!] *(Natalie colors the illuminated part again)*, and now it's like, only half of it, and it's possible that if we'll look before… so maybe it'll be only this part. This line here [Rose: right]. It depends *(looks at me)* on when we look and… when the moon...

This is a moment of "aha" for Natalie. She realizes that the moon does not really get larger and smaller (an idea she kept voicing throughout the session, meaning that only parts of the moon are seen due to occultation), but it is the observed illuminated part seen from Earth that changes. She summarizes by saying that this is a combination of “when we look” (the point of view) and “when the moon” (how it is illuminated). This is a clear case where seeing better leads to a clear development of conceptual understanding.

Rose reiterates the same ideas and combines, more explicitly, the moon illumination and the way an observer sees the moon from Earth:

Rose: So in fact, when the moon is here, so this part is lit *(colors again the half moon that faces the sun)*, and Earth, say, this part *(draws a line on the Earth to show the field of view)* sees relatively this part *(draws a line on the moon to split it – the line is parallel to the line she drew on the Earth)* here, something like that, from the moon, that’s lit



Natalie: That’s why we see it… These are the phases of the moon!

Rose makes a creative use of signs to emphasize this integration. She colors the half of moon facing the sun, and the other half remains blank to indicate illumination. Next, to represent the observer’s point of view, she draws a line splitting the moon into halves, which is parallel to a line representing the field of view of the observer. The half moon facing the Earth is what the observer can see of the moon.

This is an example of how transforming a representation (category D) in an innovative way can facilitate seeing better (category H) of a specific aspect of the phenomenon that is crucial in making sense and understanding it. Rose and Natalie transform the drawing of the moon in a way that highlights and makes visible two important aspects:

1. The illumination of the moon by the sun, represented by the colored part.
2. The part of the moon visible from Earth, represented by the line that splits the moon to the part that faces the Earth, and the part that is hidden from the Earth.

The combination of these two aspects constitutes the core of the explanation of the phases of the moon. The inventive way by which they transformed the representation signifies precisely this important combination.

## Conclusions and further analysis

The analysis classified students’ various SGR practices that were used authentically by students when they were asked to generate representations to understand the phases of the moon, and then to communicate their ideas to their peers. These practices support their efforts in thinking, reasoning and making sense of a difficult phenomenon, and maintained their attempt to explain the cause of the phenomenon to their friend, and exchange ideas.

The sample analysis demonstrates the practice of performing certain actions to help one seeing better a particular aspect of the phenomenon. In this case, this was a central aspect at the core of the scientific explanation – the phases of the moon are caused by the combination of the illumination of the moon by the sun and the visibility of the part of the moon from Earth. The students transformed the illustration of the moon in a creative way that expressed this combination, and in fact, helped seeing the shape of the moon seen in the specific phase. The action of “transforming a representation” supports the students’ efforts in “seeing better”, to facilitate their thinking, reasoning and making sense of a difficult phenomenon, and sustained their attempts to explain the cause of the phenomenon to their friend, and exchange ideas.

In a later analysis, students’ trajectories of developing understanding will be described in detail. The SGR practices will then be examined in conjunction to the paths of development, to suggest ways in which such practices could support the process of learning and understanding. Such interrelations will serve to answer questions such as what practices should be fostered, which ones should be discouraged, how specific practices contribute to the development of conceptual understanding? Could some of these practices be taught? How such practices could be supported and enhanced by adequate technological innovations? These can serve as the basis for instructional recommendation of using SGR for science learning.

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[i] The data was analyzed with the support of video analysis software – Transana (Wisconsin center for education research, http://www.transana.org). The software was developed specifically for educational research, and it enables uploading video movies, transcribing them, writing notes and interpretations, and creating small clips for easier access and examination.

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