An exploration of students’ discourse using Sim2Bil within group work: A commognitive perspective

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This paper reports on critical aspects of three engineering students’ discourse in group work using a digital tool called Sim2Bil while solving mathematical tasks. Applying a commognitive perspective, where mathematical discourse is characterized by words used, visual mediators applied, narratives developed and routines established, we investigate how these characteristics are influenced by the technological environment. It is found that all of the aspects of the students’ discourse are influenced by Sim2Bil. For instance, a “trial and error” routine directly connected to the use of the tool is present in the students’ discourse.

Key words: Commognition, Discourse, Engineering, Group work, Technological environment

Introduction

Working with mathematics involves using different resources. For instance, students use computers, calculators, and textbooks. These artifacts have been developed through history, and technological tools in particular have undergone major changes in the last decades. Nowadays, software for simulations, animations, graph plotting, dynamic geometry, CAS, and so forth, have emerged in mathematics education. These cultural tools change practices and give possibilities to work with mathematics in new ways.

Much research has been conducted on students’ interaction with technological tools (Beatty & Geiger, 2010; Wijers, Jonker, & Drijvers, 2010), and an important aspect of future education may lay in expanding technology-supported collaborative work between students (Lowyck, 2014). The technological tools considered are, for instance, computer algebra systems (CAS) (e.g. Artigue, 2002) and tools for graph plotting (e.g. Swidan & Yerushalmy, 2014). Some studies have applied the commognitive framework to study how students are communicating using a digital tool (e.g. Ng, 2016) and the impact technological environments have on pupils’ mathematical thinking (e.g. Sinclair & Yurita, 2008).

Previous studies conclude that technology can support students in their graphical approach to integrals (Berry & Nyman, 2003; Swidan & Yerushalmy, 2014). To supplement this research, in the study reported in the present paper we set up a kinematical context for integrals, and the students use integrals for a simulation of movement within a technological environment where students work with a digital tool called Sim2Bil. The students’ interaction with words and visualizations and how they were used in their communication has been analyzed in a previous paper by Hogstad, Isabwe, and Vos (2016). In the present paper, we will view the data from a discursive perspective, analyzing the characteristics of the students’ discourse with the aim of investigating how the digital tool influences the discourse.

Theoretical Framework

The commognitive theory (Sfard, 2008) takes a participationist perspective (Sfard, 1998) – learning is seen as the process of changing and individualizing discourse to become increasingly able to participate in a certain discourse community. The theory provides analytical tools for
analyzing discourses, and especially mathematical discourse. From a commognitive perspective, discourses are different types of communication “set apart by their objects, the kinds of mediators used, and the rules followed by participants and thus defining different communities of communicating actors” (Sfard, 2008, p. 93). Thus, doing mathematics is engaging in mathematical discourse, and this mathematical discourse – indeed any discourse – can be distinguished by four characteristics: word use, visual mediators, narratives and routines (ibid, p. 133-134). *Word use* refers to words specific to the discourse or common words used in discourse-specific ways. *Visual mediators* are “the visible objects that are operated upon as a part of the process of communication” (Sfard, 2008, p.133). Every image of concretes, symbols and icons operated on in communication are visual mediators. *Narratives* are “any sequence of utterances framed as a description of objects, of relations between objects, or of processes with or by objects, that is subject to endorsement or rejection” within the discourse (ibid, p.135). Sfard includes mathematical definitions, theorems, axioms and proofs, as well as formulas and equations, under the term narrative. Other examples could be statements students make during a problem solving process, such as the statement they consider to be a solution to a given problem. Finally, *routines* are “repetitive patterns characteristic of the given discourse” (ibid, p. 135). Such repetitive patterns can be seen in almost any aspect of mathematical discourse: in forms of categorizing, modes of attending to the environment, in ways of viewing situations as “the same” or different and so on (ibid, p.135).

Routines are divided into three types: explorations, deeds and rituals. *Explorations* are routines where the goal is to produce endorsed narratives (ibid, p. 223). *Deeds* involve actions performed with the goal of achieving change in objects. A routine may either be an exploration or a deed, depending on what the performers (in our case the students) are trying to achieve. In particular, the difference can become unclear in those cases when “the objects on which the deed is performed are, in themselves, discursive rather than primary” (p.239). *Rituals* are those actions whose goal is neither to produce an endorsed narrative nor a change in objects but rather to gain the attention and approval of others and to become a part of a social group.

**Methods**

The overall aim of the study is to investigate how students’ mathematical practice is influenced by working in a specially designed small-scale digital learning environment outside of regular lectures. The participants in the activity reported on in this paper were three engineering students. They were in the second semester of their first year at university. Their first year included courses in calculus, linear algebra and physics (including kinematics). Sim2Bil was not familiar to them.

Sim2Bil is an interactive digital tool, the interface of which is shown in Figure 1. At the top left there are two cars – one red, one green – which can drive from a starting line to a finish line. This is called simulation window. Below, there are visualized two graphs, one for the velocity-time function of each car. This is called the graph window. At the bottom right, there are velocity functions for each of the cars. A user can insert parameters here to make 3rd degree polynomials. This is called the formula window. At the top right is a menu window, which is not used in the study and will not be further explained. As a default setting, there are two functions given in the formula window: \( v_1 = 100 \) (for the green car); and \( v_2 = 50t \) (for the red car). With these functions, the students can engage in the environment by pressing the start-button to see the cars run differently and finish together. The distance between the starting line and the finish line is 400 meters. The preset functions make the cars reach the finish line simultaneously (thus
framing the forthcoming requirements), and they also make the graphical representations appear, thus showing how a user can operate with the tool. The shading of the areas under the graphs will appear gradually through an animation, increasing with time. These areas represent the distance travelled for the cars.

![Figure 1. Interface of Sim2Bil.](image)

The students received the following problem consisting of four tasks:

- **a)** Press “Start” in the program, and explain to each other what happens. What do the shaded areas represent?
- **b)** Determine other numbers in the table, so that the cars run with different velocities, and arrive at the finish line at the same time.
- **c)** What can you do to make the green car be only half way when the red car reaches the finish line?
- **d)** Find the velocities of the green and the red car (v1 and v2), so that v2 is half of v1 when they reach the finish line simultaneously at 4 sec. Can you prove that your answer is correct?

The problem is designed for collaboration between the students since the tasks can be solved using different approaches. The formulation of the problem was presented on paper and Sim2Bil was set up on a laptop in front of the students. Other available resources were a calculator, book of formulae, and pen and paper for writing. It was anticipated that the students would see relations between distances travelled, shaded areas under the graphs, and the integral of the velocity functions. The formula window constrains possible solutions by allowing the students to set in parameters only up to 3rd degree functions.
The activity was video recorded using two cameras: one moving, directed at the students and their writing; and one fixed, directed at the computer screen to capture mouse movement, students’ inputs within the interface and gestures like pointing towards the computer screen. One researcher was present during the activity and introduced the interface and tasks to the students. No specific time frame was given for the group work, and it turned out that the students spent in total of 45 minutes on the tasks. The video recordings were then transcribed and coded in terms of the different characteristics of discourse. In what follows, for reasons of space, attention is restricted to the first two subtasks.

Analysis

Briefly describing the students’ work on the subtasks, they begun by reading the tasks aloud. They then pressed the start-button and watched the cars run before discussing what the shaded areas represent. Thereafter they discussed the degree of velocity functions in order to find new parameters which they in turn set in the formula window to see if the cars arrive together.

Looking at the discursive practice of the students, a number of characteristic features can be found. Starting with discourse-specific words, there are several words used to describe mathematical objects, such as: function, graph, area, integral, unknown, rectangle and triangle to mention a few. Still, although the students are mainly engaging in mathematical discourse, they also use terminology that might be considered to belong mainly to discourses of other disciplines. For instance, there are words used which belong to a discourse of physics, such as: position, distance, velocity and acceleration. Actually, one of the students recognized the discourse as being within physics by stating at the end of the session: “that is enough physics for today”. There are also a number of words directly connected to the interface, for instance start (-button), start line and finish line.

Different visual mediators are present in the discourse of the students. Some are of types traditionally connected to mathematical discourse, for instance mathematical symbols and graphs. These are in some cases written on paper, and in some cases are aspects of the digital tool. There are also visual mediators directly connected to the tool, such as the moving cars and the representation of the two velocity functions by a number of boxes (see the bottom right corner of the interface depicted in Figure 1). In addition, gestures such as pointing or tracing the shape of a parabola with your hand are also used. Such gestural actions seem to be used partly for making sure that the students are talking about the same objects.

Concerning narratives, these are also of different types – those connected to the tool and those connected to the underlying mathematical content. Mathematical narratives include, for instance, formulas for the velocity functions as general third-degree polynomials, as well as expressions for distances in terms of integrals of velocity functions. Narratives more specifically connected to the digital tool include interpretations of the various features of the interface in terms of a discourse of mathematics or physics:

Student E: What do the shaded areas represent? It’s the area under the graph.
Student S: Yes. The area, which then is the distance. It is a function.

Another example concerns formulating connections between different features of the interface: “It [pointing at the graph] changes when we push here [by inserting parameters].

The influence of the Sim2Bil tool can also be seen in the types of routines present in the students’ discourse. Some routines are directly connected to the use of the tool. One of the most
common is “running the simulation”, that is, inserting values for the parameters, pressing start, watching the cars run and then pressing reset. On some occasions, this routine had the characteristics of a deed, concentrating on the running of the cars, with the students’ attention focused on whether they arrived simultaneously at the finish line. On other occasions, the routine was more exploratory, with the focus on the graphs describing the velocity functions, and how these influence the movement of the cars. This routine is closely connected to a routine which we might call “trial and error”. Here, values for the parameters are for the most part picked seemingly at random or at least without any explicit reasoning on the students’ part. Then the resulting effect on the graphs and the running of the cars is noted, new values are picked, the effects are noted, and so on. This process is denoted by the students as “playing around”, and particularly one of the students repeatedly invokes this when the other students shift their attention to symbolic and numerical calculations away from the screen: “Can’t we just play around a little? Isn’t that good?”

On the other hand, there are also examples of routines that are more conventionally mathematical, such as “calculating values of expressions”. The calculations consist of writing algebraic expressions (mostly integrals of polynomial velocity functions) on paper and then using a calculator to calculate numerical values. These routines were mostly of an exploratory character. You might argue that there is an element of the deed about them, since the focus is on the numerical results, but these numbers are in turn going to be used to formulate narratives about the comparative movement of the cars in the digital environment.

Discussion

What we have presented above is a mostly descriptive account of the characteristics of the students’ discourse when working on the tasks. Still, looking at these characteristics it is clear that the Sim2Bil tool influences all aspects of the discourse. In particular, there is evidence of routines directly connected to the tool. This corresponds to the findings of Sinclair and Yurita (2008), where the introduction of a digital tool (Geometer’s Sketchpad) changes the routines engaged in the classroom.

The study is also in tune with other studies reporting on new forms of communication mobilized in dynamic environments. For example, Ng (2016) shows how students utilized a variety of resources in their communication, and developed routines for conjecturing and verifying calculus relationships. Such routines can also be found in the discourse of the students in the present study.

The environment described in this study enabled the students to connect algebraic expressions, graphical representations and movements of objects. As the students in the present paper see the growth of the shaded areas as an animation in the graphical window, the idea of area as a function is visually mediated. Although the distinction between dynamic and static visual mediators has so far not been explicitly addressed in the commognitive framework, the distinction is important because of the potential for dynamic visual mediators to evoke mathematical relations, as also stated by Ng (2016).

However, the findings presented in the present paper are only a first step, and in future publications we intend to deepen this analysis, looking at what opportunities for learning are offered by the tool, and how the tool (and the tasks) influences the mathematical thinking and reasoning of the students, as manifested in their discursive practice.

Question for discussions: How to interpret the complex interplay between technological aspects and mathematical aspects?
References


