STUDENT RESPONSES AS A BASIS FOR WHOLE-CLASS DISCUSSIONS IN TECHNOLOGY-RICH ENVIRONMENTS

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This paper reports a study of four upper secondary school teachers' use of Connected Classroom Technology to select student responses to computer-based activities, and to use these responses to launch successive stages of a planned whole-class discussion. Although the preparation for the class discussion was quite successful, it was a challenge for the teachers to conduct the whole-class discussion, particularly in posing specific questions based on appropriate student responses.

Keywords: connected classroom technology, mathematics education, whole-class discussion.

In a previous study (Fahlgren & Brunström, 2018) we examined students' written explanations of an observation made in a dynamic mathematics software (DMS) environment. We found that few students offered a complete mathematical explanation. However, most of them provided elements of explanation, many of which that could be useful as starting points for a whole-class discussion. This highlighted a need to provide support for teachers in surveying students' computer-based work, preferably in real time, to inform such a discussion. For example, the participating teachers requested technological support to monitor all the students' work and to easily choose different student solutions for whole-class discussion. Nowadays, there is a type of technology available that can support teachers to achieve this which we refer to as *Connected Classroom Technology* (CCT).

This led us to conduct a case study in a Swedish upper secondary school, working with four teachers and their classes. The overarching aim was to identify critical aspects when using CCT to prepare and conduct a whole-class discussion based on students' responses to computer-based activities. A teaching unit consisting of three stages − *introduction*, *pair work*, and *whole-class discussion* − was designed and trialled with the four classes. In an earlier paper, we have provided a detailed description of the design of the teaching unit (Fahlgren & Brunström, 2019). In another paper we have reported on the teachers' utilization of the CCT during the pair work stage (Fahlgren & Brunström, 2020). The focus in this paper is on the last stage of the teaching unit − the whole-class discussion. The research question is: What are the challenges for teachers when using CCT to select student responses, and use these responses to launch successive stages of a planned whole-class discussion?

WHOLE-CLASS DISCUSSION BASED ON STUDENT RESPONSES

The importance of following up students' previous work in pairs or small groups and using it as a basis for a whole-class discussion is well established in the mathematics education research literature (e.g. Franke, Kazemi, & Battey, 2007; Stein, Engle, Smith, & Hughes, 2008). At the same time, this literature highlights the challenge for teachers to orchestrate student- active classroom dialogues (Ruthven & Hofmann, 2013; Stein et al., 2008). To address this, Stein et al. developed a model consisting of five practices to support teachers in their planning and implementation of whole-class discussion. The first practice, ”Anticipating likely student responses…” (p. 321) relates to the planning of the lesson. The second, third and fourth practices: monitoring, selecting and sequencing student responses, all relate to the stage of the lesson where students are working on activities. Finally, the fifth practice concerns the collective stage of the lesson where different student responses are displayed and discussed in the whole class. Although the model is primarily intended to serve as a road map for teachers, it provides a theoretical frame which researchers can use "…as a way of conceptualizing investigations of classroom discourse" (Stein et al., 2008, p. 314) as well. For example, Cusi, Morselli and Sabena (2017) used this model when investigating how CCT could be used to facilitate whole-class activities.

Kieran et al. (2012), demonstrate the challenge for teachers to orchestrate follow-up discussions which take students' computer-based work into account. In their study, only one of the (three) participating teachers really inquired into students' thinking and utilized it as a point of departure for a whole-class discussion, although such discussions were an expected part of the researcher-designed lessons. However, this was not made explicit in the accompanied teacher guidance since it did not specify how to perform the discussion, although it included suggestions for mathematical content to discuss. Similarly, Ruthven and Hofmann (2013), in a design study, identified situations where disappointing classroom mathematical discussion arose from teachers not capitalising on promising student contributions. To address this, they suggest, there is a need to sensitise teachers, typically through making the potential of such contributions more explicit in the teacher guidance.

METHOD

The fieldwork for this study was conducted in spring 2019 with four upper secondary school teachers and their classes undertaking the 3-stage teaching unit already referred to. In undertaking the unit, two types of technology were used − a dynamic mathematics software (DMS), in this case *GeoGebra*, and a specific CCT, *Desmos Classroom Activities*. During the pair-work stage, the students used two computers; one with *GeoGebra* and one with an e-worksheet in *Desmos*. In contrast to the DMS, the CCT was a novel teaching resource for the participating teachers.

When planning the teaching unit, then, we gave particular attention to providing teachers with guidance on making use of the CCT to examine students' work during the central pair-work stage of the lesson, and to prepare examples from this work for use in the concluding whole-class discussion stage. This guidance was informed primarily by the Stein et al. model, with the necessary mathematical-conceptual detail derived through analysis of student responses (gathered from eight classes in a previous study (Fahlgren & Brunström, 2018)) to the explanation task featured in the lesson (Task 1c in Figure 1). This analysis provided information about answers likely to be produced by students during the pair-work stage, i.e. relating to the first practice in the Stein et al. (2008) model – Anticipating likely student responses.

Task 1 Quadratic functions can always be written in the form $f(x) = ax^2 + bx + c$ where *a, b* and *c* are real numbers and $a \neq 0$.

(a) Investigate, by dragging the slider *c*, in what way the value of *c* alters the graph. Describe in your own words.

(b) The value of the constant *c* can be found in the coordinate system. How?

(c) Give a mathematical explanation why the value of *c* can be found in this way.

Figure 1. The first tasks including a request for an explanation (Task 1c).

Detailed step-by-step guidance, based on the Stein et al. model (2008) and exploiting particular functionalities of CCT, was developed and discussed with the teachers. During the pair-work stage, teachers are encouraged to use two different CCT views to monitor the students' work. In the *Summary* view, the teacher can survey all the students' progression across the whole activity, and in the *Specific item* view, the teacher can monitor all students' answers to a particular task (relating to the second practice in the Stein et al. model – Monitoring student responses). In the latter view, the teacher also can select appropriate student responses to display and use as a basis for the whole-class discussion (relating to the third practice in the Stein et al. model – Selecting student responses). In the view that we denote *Presentation preparation* view, the teachers can sequence the selected student responses (relating to the fourth practice in the Stein et al. model – Sequencing student responses). To support the selection and sequencing, the guidance included response categories to search for as well as a suggested sequencing of the responses (see Figure 2).

Identify and select one or two appropriate student responses from the different categories

(a) Repeating the answer to Task 1b, i.e. only indicating that it is where the graph **intersects the *y*-axis**
(b) Providing **example** (e.g. "if c=3, it intersects the *y*-axis at 3" or referring to GeoGebra)
(c) Comparing with the standard **linear equation**, e.g. "*c* corresponds to *m*"
(d) Indicating that **"*c* is independent of *x*"** or that **"*c* is the constant term"**
(e) ***x* = 0 gives *y* = *c***

Figure 2. Excerpt from the teacher guidance illustrating the response categories.

Moreover, the guidance includes a probing question to pose in relation to each of the different response categories (see Figure 3) during the whole-class discussion. The detailed thinking behind the recommended sequencing and the corresponding questions is reported in Fahlgren and Brunström (2019), but the gist should be clear from inspection of the two Tables. At a planning meeting, the guidance was discussed and the researchers and the teachers agreed that it was appropriate.

(a) *What is the distinction between Task 1b and Task 1c?* (i.e. what is the distinction between a description and an explanation in mathematics?
(b) *Can examples be used as an explanation? Is it enough to refer to GeoGebra (as a mathematical explanation)?*
(c) *What do m in $f(x) = kx + m$ and c in $f(x)=ax^2 + bx + c$ have in common?*
(d) *Could the explanation be strengthened further?, i.e. Why does this mean that the graph intersects the y-axis when y=c?*
(e) These discussions should lead to a class agreement on what constitutes an approprate explanation in this particular case (Task 1c).

Figure 3. Excerpt from the teacher guidance showing the questions suggested.

DATA COLLECTION AND ANALYSIS

We sought, then, to examine how teachers made use of CCT in preparing for, and implementing, the whole-class-discussion stage of the teaching unit. The main data consist of screen recordings of each teacher's computer as well as audio recordings and field notes from the whole-class-discussion. In addition, a joint meeting with the teachers afterwards was audio recorded. The focus in this paper is on the student responses selected and on teachers' utilization of these during the whole-class discussion, guided by the questions suggested in the teacher-support materials.

All student responses were categorized based on the anticipated categories in Figure 2. This analysis provided information about the occurrence of student responses in each class as well as responses selected by the teachers. This enabled us to ascertain whether each teacher managed to select responses from all of the categories available in their class. Screen recordings of the *Presentation preparation* view provided information about the sequencing (of the selected responses) made by the teachers in preparation for the whole-class discussion.

Next, the audio recordings were transcribed and screen shots from the screen recordings were inserted to indicate which response the teacher displayed when posing different questions. These transcripts were analysed to indicate the number of questions posed by each teacher in relation to different response categories. We also compared these questions with the suggested ones, categorizing the teacher's action as Suggested question (or equivalent), Some other form of question, or No question.

RESULTS

This section starts by presenting the findings related to the teachers' preparation in terms of selection and sequencing of student responses. Then the findings concerning their conduct of the whole-class discussions is reported.

Preparation for whole-class discussion

The responses making up our category system are idealized in the sense that each appeals to a single distinctive idea. However, the empirical responses that we received from students could make reference to more than one of theses idealized responses and/or to further ideas absent from the category system. Consequently, these empirical responses were mainly of three types. First, there were those that (in our interpretation) refer only to a single category. Second, some refer to more than one category or combine one category with other irrelevant information. Finally, there were responses that did not relate at all to the anticipated answer categories (categorized as "Other"). These responses were irrelevant, e.g. "Because the *c* variable is the slope in this case", or not informative enough, e.g. "*y=c*".

Although the teachers found the selection process challenging, they all managed to select responses from all categories available (in their class). There were no category (b) answers available in any of the classes, and no category (e) answer in T4's class. As indicated in Table 1, some of the selected responses did not only consist of one category or were categorized as "Other". As will be demonstrated later, this caused trouble in the subsequent stage of the lesson.

Table 1 shows the sequencing made by the teachers. The letters within brackets indicate our categorization of the different student responses. In cases when a student response includes more than one category (or further irrelevant information), both categories are indicated within the brackets. For example, in T1's first presentation view, there are two student responses, one categorized as both (c) and (a) and the other as (a) only. Table 1 indicates that the teachers more or less followed the suggested sequencing, and that three teachers utilized the opportunity to display more than one response on the same presentation view.

Presentation view	T1	T2	T3	T4
P1	(c+a), (a)	(a)	(a)	(a)
P2	Other	(c)	(c)	(c)
P3	(c)	(d+irr)	(c), (c)	(d), (c+e)
P4	(c+d)	(d)	(a)	(d+a+irr), (c+e) as in P3
P5	(e)	(d+irr) as in P3	(d)	
P6		(e)	Other	

Table 1. The sequencing of different student responses in the four classes.

Challenges in launching the stages of the planned whole-class discussion

The times devoted for the whole-class discussion were 18 min. (T1), 10 min. (T2), 14 min. (T3), and 5 min. (T4). The presentation of the results in this section is organized according to two identified critical aspects: *Challenge in using the suggested questions* and *Challenges due to student response features.*

Challenge in using the suggested questions

Table 2 shows the type of question posed by the teachers in relation to response categories (a), (c), and (d). In cases where several questions were posed, the number of questions is indicated within brackets.

Type of student response under discussion	Type of question used by teacher		
	Suggested question (or equivalent)	Some other form of question	No question
(a)	T3	T1, T2	T4
(c)	T3	T1(4), T2(2), T4(2)	
(d)		T2	T1, T3, T4

Table 2. The number and types of question posed by the teachers.

One of the teachers (T3) used the question suggested for category (a), while two of the teachers posed questions without referring to the distinction between a description and an explanation. Instead, T1 focused on assessing the quality of the explanation, "What do you think about that explanation?", while T2 just asked whether the response could be regarded as an explanation. T4 made a point about the differences between "what you can see in the graph" (i.e. a description) and an explanation, although without posing any question.

Questions related to category (c) responses were posed several times in three of the classes. For example, T1 posed questions in relation to three different student responses. However, the question closest to the suggested one, "What do these two have in common?", was posed when pointing to the two formulas (written) on the board ($y=kx+m$ and $y=ax^2+bx+c$), i.e. not based on a student response. This was also observed in T2's class, although at the end of the class discussion. One of the teachers (T3) used the question suggested for category (c); however, the teacher added some further questions that might have been confusing for the students. Most of the questions posed on this category are vague and of a more general character.

In relation to category (d), only one teacher (T2) posed a question, "Is this a mathematical explanation?" The reason why T4 did not pose any question might be that a student provided a satisfactory explanation without any request from the teacher.

Challenges due to student response features

Student responses that include one category plus either one more category or some irrelevant information caused trouble during this stage of the lesson. Two of the teachers (T1 and T4) displayed responses including more than one category. Below are descriptions of these instances.

Unfortunately, T1 initially missed to utilize the Presentation view for displaying the selected (and ordered) responses. Instead, the teacher utilized the *Specific item* view, and displayed the first answer in this view, which happened to be one of the answers in P1. The teacher read aloud the response categorized as (c+a):

Because the value of c is m where the line intersects the y axis $y = kx + m \quad m = c$

Then, the teacher asked "Comparing *m* and *c*, is there anyone who can explain this, the thinking behind it?" Since nobody responded to this question, the teacher shifted the focus towards the part of the response that belongs to category (a), and asked "What do you think about that explanation?" In this way, the teacher did not follow the planned (and suggested) sequencing, probably because the displayed response include two response categories.

When displaying the response categorized as (c+e), T4 directed the focus to the category (c) part of the response, despite that category (c) already had been displayed and discussed. S/he asked "But how do we, then, see that c is m?". One student answered by providing a proper category (e) answer, i.e. focusing on the other part of the response. This illustrates how an answer that includes two response categories might influence the discussion in two ways. First, the same kind of response was discussed several times, and second, there was a mismatch between the question posed by the teacher and the student response.

To summarize, the findings indicate that the teachers quite successfully followed the suggested selection and sequencing. However, challenges during the conduct of the whole-class discussion appeared when student responses including more than one category were displayed. Moreover, it was challenging overall for the teachers to follow the guidance in terms of the suggested questions.

DISCUSSION

Since this is a case study, the intention is not to provide generalizable results, but to identify some challenges appearing when teachers utilize CCT to orchestrate a whole-class discussion based on students' computer-based work. In this way, the findings can provide some guidance for future practice and research.

Although the teachers found the CCT useful, the findings indicate that it was a challenge for them to follow the agreed teacher guidance. Particularly, the suggested question to pose in relation to different types of student response were used to a small extent, and when used, they most often were posed in a quite different way. Of course, there could be several reasons for this, not least the teachers' own beliefs and knowledge as well as the classroom norms (Kieran et al., 2012). However, one reason probably was the need for teachers to make in-moment decisions in the classroom. One way to facilitate for the teachers to follow the teacher guidance would be to embed the planned questions into the presentation view together with the student responses. This could also address the challenge for teachers to base the discussion on proper student responses, a challenge also observed by Ruthven and Hofmann (2013).

It was also a challenge for the teachers to follow the teacher guidance, in cases when they selected responses including more than one category. Two problems were observed during the whole-class discussions. First, the planned sequencing became disturbed, and second it became unclear what part of the response that was discussed. One way to deal with this would be to select only "clean" responses, if possible. This raises the question whether technology can support teachers with the challenging task of categorising student responses on the spot. This is an important issue for future research.

In this study, teachers were supposed to implement an agreed lesson design based on a systematic analysis (done by the researchers). In reflection, the study illustrates that this type of implementation is not straightforward. Some reasons for this and what could be done to support teachers have been discussed.

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