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Teachers' formative assessment practices when interacting with learning analytics

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Conducting a student-centered discussion in a mathematics classroom is not a trivial task. Teachers must follow their students' work, then use the relevant information to conduct a meaningful discussion. This challenge is greater when digital environments are involved, or when students work remotely and submit their work only online. A possible solution to this challenge may come in the form of accessible learning analytics (LA) that can assist teachers to gain insight about their students' work. In the presented case study, which is part of an extended research project we focus on the interaction of teachers with LA and the formative assessment practices of teachers when dealing with students' answers to example-eliciting tasks in a digital environment.

Keywords: Teacher dashboard, topic-specific learning analytics, online formative assessment

Rationale and Background

Conducting mathematics lessons based on students' ideas and on analysis of their answers is a good example of meaningful student-centered teaching. Using this analysis, teachers are required to conduct class discussions that promote formative assessment (FA) interactions. We focus on formative assessment, conceptualized as "all those activities that are undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (Black & Wiliam, 1998, p.7-8). In technology-enhanced learning settings, teachers are required to assess their students' work in multi-participant classes and direct their teaching accordingly, often in real time. Studies show that teachers who integrate digital systems in their classes choose to do so based on their usual habits and views on teaching mathematics in general (Drijvers et al., 2010). At the same time, the technological learning environments can provide an immediate picture of students' work for teachers. Each environment offers different learning analytics (LA) in the form of a single display that aggregates various indicators about learners, learning processes, and learning contexts into one or multiple visualizations (Schwendimann et al., 2016). In the meantime, it remains a challenge to provide a meaningful LA to teachers in real time. Numerous technological learning environments have been developed to provide teachers with an immediate snapshot of students' work for example, DESMOS and TI-Nspire (Clark -Wilson, 2010). Another example is STEP, a formative assessment platform that uses example-eliciting tasks (EETs), with more than one correct answer, to support conceptual learning. Students are asked to construct an example that meets or contradicts certain conditions, after which the environment analyzes the answers according to mathematical characteristics (Olsher, Yerushalmy, & Chazan, 2016). STEP provides teachers with accessible statistical data and helps them shift from focusing mostly on errors to making decisions based on the analyzed data (Olsher & Abu Raya, 2019).

In this study, we explore the effect of accessible LA on teachers' formative assessment practices, by providing them with means to respond to student submissions based on the LA. We explored the

potential of a technological environment on teachers' formative assessment using the FaSMEd framework evolved to describe the use of technology in formative assessment. The three-dimensional FaSMEd framework extends Black and Wiliam's (2009) model, which includes five FA processes: (a) clarifying and sharing learning intentions and criteria for success; (b) engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding; (c) providing feedback that moves learners forward; (d) activating students as instructional resources for one another; and (e) activating students as the owners of their own learning. The FaSMEd model takes into account three main dimensions: the five key FA strategies, three main agents (teacher, student, peers/group), and functionalities by which technology can support the three agents in developing the FA strategies. The three categories of the functionalities of technology are: sending and displaying (SD) when technology is used to support communication among the agents of FA processes, processing and analyzing (PA) includes all the functionalities that support the processing and the analysis of the data collected during the lessons, and providing an interactive environment (PIE) are functionalities of technology that enable to create a shared interactive learning environment where mathematical/scientific contents could be explored (Aldon, Cusi, Morselli, Panero, & Sabena, 2017). Aldon and Panero (2021) use the FaSMEd framework to demonstrate that different FA practices of the different participants (teacher, students) are not necessarily similar during different parts of a learning activity, and for different ages levels. In this study we hypothesize that teachers' practice is affected by the type and design of data that LA offers teachers, which means that the functionalities of each report affects teachers' formative assessment practices.

Methodology

This study examines teachers' interactions with LA as well as its effect on class discussion and on changes in the contents of teaching the topic of functions using STEP. The lessons were conducted in Israeli middle schools (grades 8 and 9) during the 2020-21 school year. The research question is: What formative assessment processes do teachers use when they interact with LA when evaluating student answers to EETs in a digital environment?

Sample

Three 8th and 9th grade teachers, experienced in teaching using the technological platform, participated in the study. The teachers had attended a professional development program and used the platform in their classes, which made them appropriate candidates for the study.

Research tools

The research tools included STEP reports and video records of the teachers using the reports. Teachers used STEP in their classrooms as part of their routine teaching sequence and conducted a discussion after the students completed the activity based on the STEP reports. The lessons were video-recorded, and the teachers were interviewed to clarify various decisions and actions that were noted during the lesson. The STEP teacher dashboard produces six types of reports: tables, grids, histograms, Venn diagrams, perceptual landscapes, and bubble reports (Abu Raya & Olsher, 2021). Each interactive report was designed to address specific pedagogical needs. Mathematics teachers were introduced to the design principles of STEP and its usage ideas in professional development

programs. In this report we focus on four of the reports: table, grid, histogram, and Venn diagram, and present separately the goals and mechanisms of each report.

The grid report presents a snapshot of student submissions in a collage (Figure 1) that resembles those of other platforms (e.g., TI-Nspire). This report makes available to the teacher the work of the students in the classroom, allowing the teacher to filter student work based on predefined characteristics. The filtering mechanism is similar to that of e-commerce websites. For example, users looking for a small black purse can check each one of the characteristics for the relevant meta-data category (size, color). The grid report allows teachers to choose one or several characteristics as either present or absent and to create “and” and “or” relations between them (Figure 1), making possible in-depth analysis of submissions based on their characterization. The interactive report also enables teachers to choose a picture by clicking on it and to display the interactive diagram that the student submitted. Filtering helps the teachers detect various phenomena in the students’ work, as opposed to merely scanning the snapshots to identify characteristics relevant for the ensuing classroom discussion.

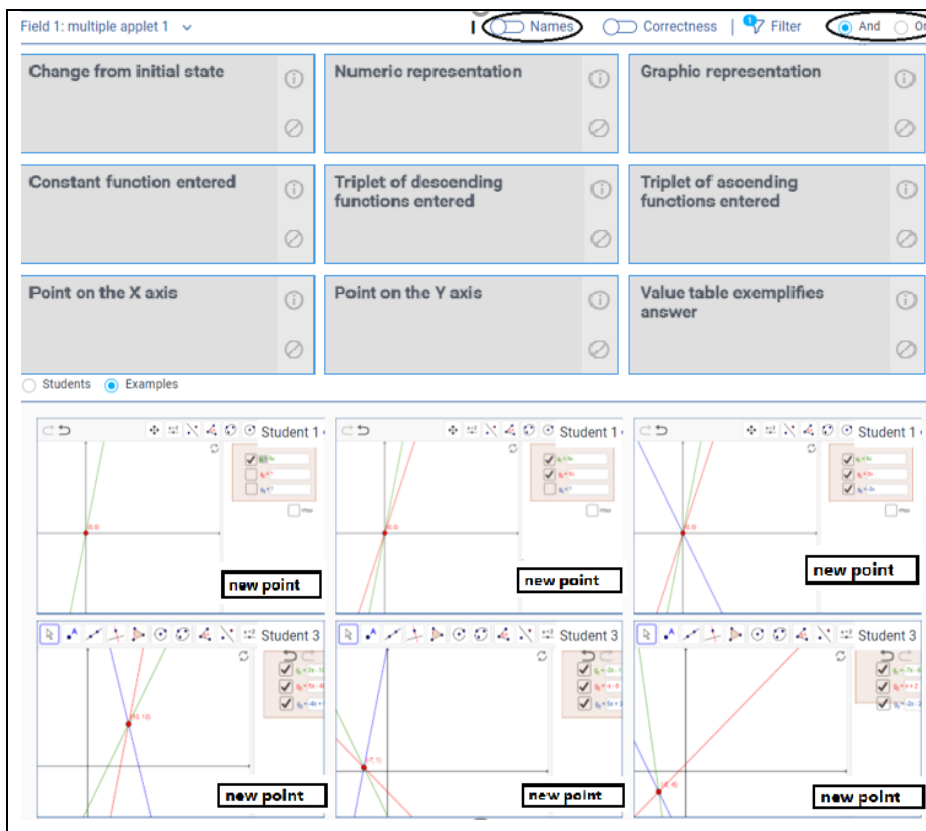
	<ol style="list-style-type: none"> 1. presents a snapshot of student submissions in a collage 2. allows teachers to filter student work based on predefined characteristics. 3. allows teachers to choose one or several characteristics as either present or absent. 4. enables teachers to choose a picture by clicking on it and to display the interactive diagram that the student submitted.
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Figure 1: Grid report with filtering activated, name display button (I), and/or buttons, (II).

The table report displays a row for each student, and a column for each characteristic, indicating which characteristics are present in each student submission. Presentation is similar to that of conventional spreadsheets. The goal of the report is to provide information about submissions of student in class, especially about characteristics that are prominent in each submission.

The histogram report presents a distribution of the characteristics across submissions. Each characteristic is represented as a bar whose height corresponds to the number of submissions having that characteristic (Figure 2a). The report provides a visual representation of the frequency of each characteristic of a task in students' submissions. Clicking a column brings up a filtered grid report below the histogram, allowing the teacher to further analyze student work directly.

The Venn diagram shows the relations between characteristics in the students' submissions (Figure 2b). It displays up to three characteristics simultaneously, each color representing a different characteristic. The Venn diagrams show the distribution of more complex phenomena in student submissions, which could not be captured by a single characteristic but only in the relations between several. The diagram provides an indication whether certain characteristics coexist. It also displays numeric values that enable determining the phenomena that are more prominent in students' work. Similarly to the histogram report, clicking on a part of the diagram displays a filtered grid report according to the selected region, for example, the intersection of three characteristics.

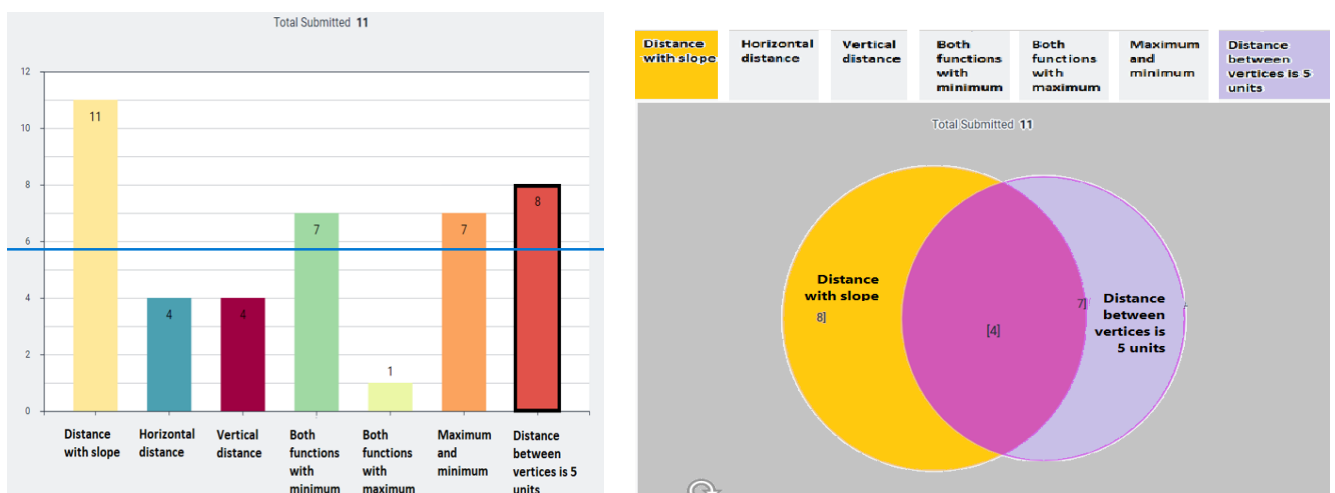


Figure 2: Histogram report (a) and Venn diagram (b)

Data sources and analysis

Data sources include student submissions for the tasks, interviews with each of the teachers, conducted after the class discussion that followed the students' submissions, and classroom observations. Each teacher assigned five tasks in five separate lessons. We used the FaSMEd analytical framework to describe the findings.

Findings

The findings show how teachers conducted formative assessment in their teaching using the data they obtained from the different reports. Below we describe the teachers' use of each report, focusing on the different report functionalities, indicating the role of these affordances in describing the FA properties that teachers focused on in the ensuing discussions.

Grid report

The use case for this report concerns a task asking students to find a linear function equation from two given points, which was assigned in the course of an 8th grade mathematics lesson. The students were asked to “Construct a linear function whose graph passes through the two given points. If you believe this cannot be done, explain why.” The interactive diagram that was provided included multiple linked representations of the function, and the students could choose the different points by pressing a “New points” button that generated semi-randomized pairs of points (Bagdadi, 2019).

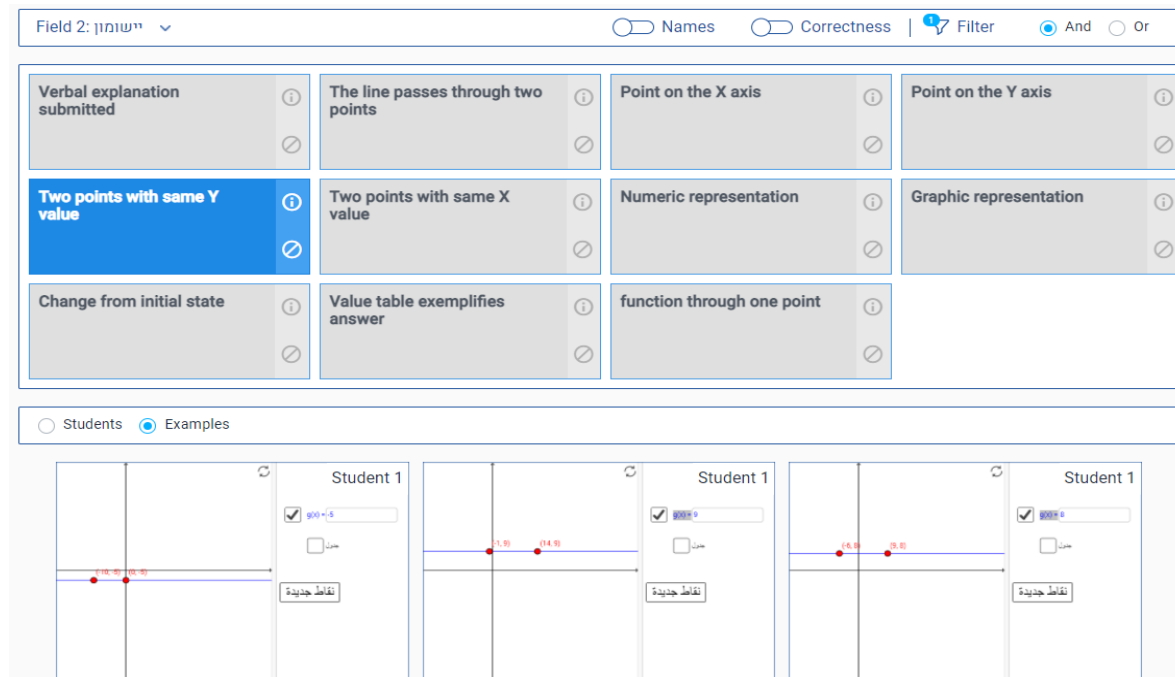


Figure 3: Filtered grid report presented during classroom discussion

The teacher chose to address the characteristic “Two points with same Y value,” based on the analysis (PA) provided by the platform. The teacher *clarified and shared learning intentions and criteria for success*. She indicated that “this characteristic describes a constant function and helps students solve this type of a task efficiently, saving them time” (Asala, questionnaire). Analysis of the classwork reveals that the teacher presented examples of student submissions with this characteristic (Figure 3). In the process, the teacher used an interactive component of the report (PIE) to choose a filter based on the automatic analysis and displayed students’ work (SD). Next, the teacher decided to give students tasks for discussion to *elicit evidence of their understanding, organizing an effective classroom discussion* based on the data she collected from the report. Lesson observations reveal that she asked students questions like “What did these students do?” “What type of function do you get in this situation?” “Do you think it [constant function] is easier [than a function with a slope]?”

“How would you find the equation?” The teacher also addressed student submissions in which the two points coincide, which enabled students to submit non-constant functions. Generally, it was apparent that the teacher *activated students as instructional resources for one another and as the owners of their own learning*. The teacher indicated that this choice of points helped students

understand that an equation can be written without calculating the slope and plugging in the X and Y values of the points. The teacher used the different functionalities of the report to *provide feedback that takes learners forward*. In general, the grid report offered the three functionalities of technology that enabled teachers to relate to all the five FA strategies (Figure 4a).

Table report

The use case for this report concerns a task asking students to find several linear functions that intersect a given point and also intersect the positive part of the Y axis. The task was part of an 8th grade mathematics lesson. The students were asked to “choose a point and construct several expressions of linear functions whose graph passes through the given point and intersects the positive part of the y-axis.” Based on the report (PA), the teacher found that none of the students paid any attention to the table of values provided in this task (“numeric representation” characteristic in the table). She later said: “I chose to pay attention to this characteristic because none of the students used the table. In addition, it was important for me to emphasize that the table helps illustrate characteristics of the function” (Asala, questionnaire). Observation of the lesson revealed that the teacher used the report to *clarify and share student learning intentions* and to *orchestrate the discussion*. The teacher continued to *provide feedback that takes learners forward* by showing the students how the table of values could assist them in verifying their solutions by displaying an additional report, the grid report (SD). This report is limited to two functions of the technology, *sending and displaying* and *processing and analyzing* (Figure 4b). Although teachers can use the analysis provided by this report to activate the students, our current findings do not indicate that they did so.

Histogram report and Venn diagram

The use case for these reports concerns a task involving quadratic functions, specifically, identifying the extremum and calculating the distance between two extrema of two different quadratic functions. The task was formulated as follows: “Functions $f(x)$, $g(x)$ are from the family $y=a(x-p)^2+k$. Claim: there is only one situation for the functions $f(x)$ and $g(x)$ in which the distance between the extremum points of each function is 5 units. If you think this claim is true, provide the algebraic expression of each function. If not, use the interactive diagram to create five examples of different functions.” The teacher used the histogram to *clarify learning intentions and criteria for success*: “I presented the grid for each characteristic separately and we discussed the effect of the parameters for each characteristic” (Ranya, interview). She noticed that most of the students gave correct answers, and that most of the students provided a distance that was not a vertical one, something she did not expect (PA). Following this insight, she presented (SD) the filtered grid report for the characteristic “vertical distance” and *conducted a discussion around it*. Next, she used the filtered grid report of a distance that has a slope (i.e., not vertical/horizontal) to *share the students’ work* (PIE) (Figure 2a).

The Venn diagram was used for the same task. Indeed, it was the histogram report that encouraged the teacher to use another representation of the data from her classroom. In the histogram report, the teacher noticed that most of the student submissions were correct, and that most of the submissions had distance with a slope (PA): “The histogram showed that most of the students gave examples with

a slope, which was strange for me since they didn't study the distance formula yet. So I turned to the Venn diagram to see the interrelation between the characteristics" (Ranya, interview). On the Venn diagram (PA), the teacher checked the interrelations between the two characteristics (PIE) (Figure 2b) and noticed that only 4 out of 11 submissions were both correct and with a slope. She said: "I chose to look into this characteristic. Even though there were many submissions with a slope, they were not correct, since they calculated the distance only according to the X values" (Ranya, interview). One student used the Pythagorean theorem and calculated the distance based on the length of the hypotenuse. Following this insight, the teacher asked this student to reveal her solution (SD) and used it to explain to the other students why it was not correct to calculate the distance the way they did, *activating students as instructional resources for one another and as the owners of their own learning*. Based on the analysis and on the interactive reports, the teacher gathered valuable information about the students' learning that assisted her *to manage an interesting discussion* about a rare correct solution of one of the students. In the course of this discussion, she provided feedback to the whole class about the common mistake. In general, these two reports offer the three functionalities: sending and displaying (SD), processing and analyzing (PA), and providing an interactive environment (PIE), of the technology to teachers. By using these functionalities, the teachers can apply the five strategies of the FA (Figure 4c). By clicking on any characteristics in these reports, the platform provides additional information about the student's works, which helps the teacher *give effective feedback and serves as a powerful resource for activating the students*.

Summary and discussion

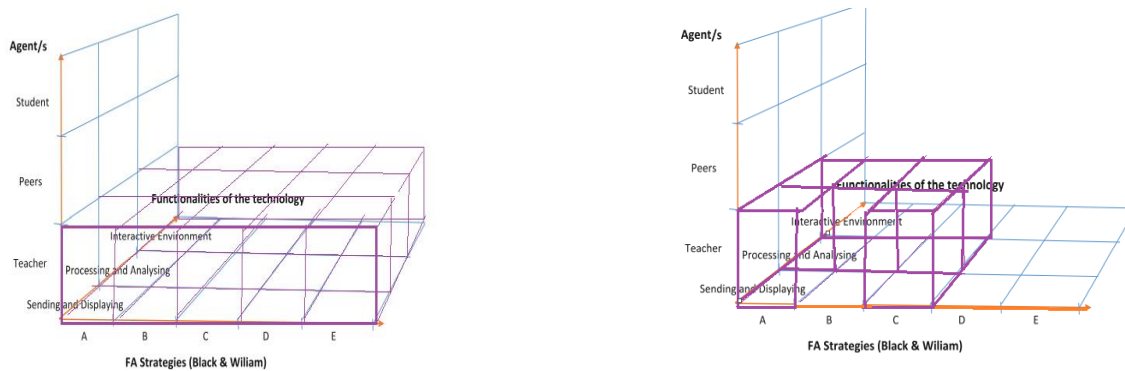


Figure 4: Grid report and Venn diagram interactions (a) and table report interactions (b)

In this report, we used the FasMed framework to describe the FA practices of teachers interacting with LA based on students' answers to EETs in a digital environment. LA were accessible by means of different interactive reports. The use cases presented show that in using the reports, teachers resorted to different strategies, ranging from locating work with specific characteristics to discovering meaningful complicated logical conjunctions of characteristics. In the grid report, students' work is accessible in a single report, and teachers could filter student work according to pre-designed characteristics. Teachers used all the functionalities of the technology, which enabled them to advance learners in the course of a class discussion that deployed the five key strategies of FA interactions (Figure 4a). By contrast, the table report provided only the functionalities of sending and

displaying, and of processing and analyzing. Teachers used these functions to clarify, guide the discussion, and provide feedback. (Figure 4b). The histogram and Venn reports offer correlations between the different characteristics, and grids of students answers for the correlation they chose. In these reports, findings show that teachers used all three technological functionalities for effective FA that also included all five strategies (Figure 4a). The examples show how the design principles of each report served teachers in different ways and demonstrate the role of interactive environment in the teacher's FA. At the same time, other facets of the interaction and of FA characteristics remain to be further investigated. By enabling the teacher to display the students work (SD), then to click on one of the columns in the histogram report (PIE) then get the filtered grid (PA), STEP demonstrates a wide range of opportunities to use technology in teacher's formative assessment practices.

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