Teaching for Mathematical Dispositions as Well as for Understanding: The Difference Between Reacting to and Advocating for Dispositional Learning

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ABSTRACT: Mathematics teachers know the value of teaching for understanding and to listen for students' sense-making. However, the importance of teaching for a mathematical disposition needs to be recognized as equally valuable and we need to explore more aspects of developing it. In previous studies, the work with dispositions has focused on using rich problems to enable positive dispositions. This study, however, emphasizes the importance of teachers thinking about students as dispositional learners. More specifically, two vignettes are presented in which the teacher's role and perceptions played an equally important role in noticing and developing the students' mathematical dispositions.

RESUME: Les professeurs de mathématiques sont conscients de la valeur attribuée à la compréhension et à l'écoute de la logique des étudiants. Il est à noter cependant que l'importance de l'enseignement pour ceux qui sont prédisposés aux mathématiques, doit être reconnue comme une valeur telle. De surcroît, nous avons besoin d'aller plus loin dans l'analyse des aspects du développement. Dans des études précédentes, le travail sur ces dispositions s'est concentré sur l'utilisation de problèmes intéressants afin de s'appuyer sur des dispositions positives. Cette étude met, cependant, l'accent sur l'importance que les enseignants accordent aux apprenants qui sont prédisposés. Pour apporter plus de précisions à l'étude, les deux aperçus présentés montrent les perceptions et le rôle de l'enseignant qui ont joué une part également importante en remarquant et en développant les dispositions aux mathématiques des étudiants.

> There is now rather general agreement that the ultimate goal of student learning is the acquisition of a mathematical disposition rather than of a set of isolated concepts and skills. (De Corte, Verschaffel, & Op'T Eynde, 2000, p. 687)

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When teaching mathematics, it is becoming commonplace to recommend that teachers teach for understanding and listen for students' sense making. However, if the "ultimate goal," as stated in the opening quote by De Corte, Verschaffel, and Op'T Eynde (2000), is to acquire a mathematical disposition, then just teaching and learning for understanding falls short. In 1933, Dewey suggested that:

> When the teacher fixes his attention exclusively on such matters as these [the acquisition of skills and knowledge], the process of forming underlying and permanent habits, attitudes, and interests is overlooked. Yet the formation of the latter is more important for the future. (1933, pp. 57-58)

This is particularly poignant with regards to teaching and learning mathematics.

While mathematical dispositions are valued by the mathematical community, it is time to revisit them and bring them forward again to the larger community of educators. Classroom teachers need to know what mathematical dispositions are. Teachers also need to be cognizant that students' dispositions can be interpreted in multiple ways and that their interpretations may affect how they continue to help students gain a mathematical disposition. In order to understand the dispositions, though, it is important to review the desired dispositions identified in the mathematics literature and then examine them in context.

Identifying Mathematical Dispositions

The desired mathematical dispositions or ways of thinking have been articulated by NCTM (National Council of Teachers of Mathematics, 1989, 2000) and others (e.g., Maher, 2005; De Corte, Verschaffel, & Op'T Eynde, 2000; Polya, 1969). NCTM (1989) specifically states, that dispositions are more than attitudes; dispositions are about ways of thinking and being. They state that the desirable ways of working with mathematics include confidence, flexibility, perseverance, interest, inventiveness, appreciation, reflection, and monitoring.

De Corte, Verschaffel, and Op'T Eynde (2000) referred to the mathematical dispositions as ways of utilizing one's specific knowledge base, developing heuristics, incorporating meta-cognition, self-regulatory cognitions and volitions, and beliefs that are all centered around thinking and doing mathematics. More specifically, they describe mathematical dispositions as the following:

1. A well-organized and flexibly accessible domain-specific knowledge base.

> 2 Heuristic methods, that is, search strategies for problem solving that do not guarantee, but significantly increase the probability of finding the correct solution because they induce a systematic approach to the task.
> 3. Meta-knowledge ... knowledge about one's cognitive function ... and knowledge about one's motivation and emotions that can be used to deliberately improve volitional efficiency.
> 4. Self-regulatory skills, which embrace skills relating to the self-regulation of one's cognitive processes ... and one's volitional processes.
> 5. Beliefs about the self in relation to mathematical learning and problem solving, about the social context in which mathematical activities take place, and about mathematics and mathematical learning and problem solving. (pp. 689-690)

The National Research Council (NRC, 2001) pointed out that dispositions were one of five strands of mathematical proficiency (i.e., conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition). Specifically, they describe a productive disposition as a "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (p. 5) that is intertwined with the other strands of mathematical proficiency in thinking and learning.

While NCTM (1989, 2000), De Corte et al. (2000), and the NRC (2001) referred to different aspects of desirable mathematical dispositions, Polya (1969) highlights developing dispositions as part of one's habits of mind during problem solving.

Polya (1969) states:

> This is the general aim of mathematics teaching – to develop in each student as much as possible the good mental habits of tackling any kind of problem. You should develop the whole personality of the student and mathematics teaching should especially develop thinking. Mathematics teaching could also develop clarity and staying power. It could also develop character to some extent but most important is the development of thinking. My point of view is that the most important part of thinking that is developed in mathematics is the right attitude in tackling problems, in treating problems. (Part II, pp. 5-7)

Maher (2005) reminds us of Freudenthal's work of describing the desired mathematical dispositions as persons' active involvement in the ownership of their own thinking and meta-cognitions. She quotes Freudenthal as saying, "the learner should reinvent mathematising rather than mathematics; abstracting rather than abstractions;

schematizing rather than schemes; formalizing rather than formulas; algorithmising rather than algorithms; verbalizing rather than language" (Freudenthal, as cited in Maher, 2005, p. 2).

Teaching Involving Reflections on Dispositions

As we begin to think about how to get teachers to teach mathematical dispositions, it becomes clear that the dispositions described above do not address how to teach for the desired mathematical dispositions. Brahier (1995) suggested that interesting problems, tools, and opportunities to work with others, have the potential to bring out persons' positive mathematical dispositions. While teachers and students can make an uninteresting problem more interesting, problems that are interesting to begin with make it easier for desirable dispositions to happen naturally. More specifically Brahier pointed out,

> Since most of the lessons followed a traditional path of checking homework, "showing" new sample problems, and allowing students to begin their homework, there was little opportunity for students to demonstrate positive dispositions. A problem posed in the classroom needs to be rich enough to evoke curiosity or to make the students feel that it is "worth" pursuing. Though very infrequent in my observations, the classroom experiences that involved teamwork, calculators, and "real-life" problems appeared to evoke positive dispositions. (1995, p. 7)

Tishman, Jay, and Perkins (1993) add that:

> People's actions, including their intellectual actions, are typically linked to the contexts in which they find themselves, and learning situations are no exception. In schools as in other settings, learners tend to act in ways cued and supported by the surrounding environment. (p. 149)

One exemplar can be noted at Railside High School in California (Boaler, 2006). There, the school experienced improvements in the students' desirable dispositions, such as perseverance, when teachers included questioning, social aspects of learning, different representations and explanations, and emphasis on the concepts and principles.

> At Railside the teachers created multi-dimensional classes by valuing many aspects of mathematical work. When we interviewed students at the school about what it took to be successful in mathematics class, they described a variety of practices, such as asking good questions, helping others, using different representations, rephrasing problems, explaining ideas, being

> logical, justifying methods, or bringing a different perspective to a problem. (p. 365). ... Such practices contributed to the high levels of persistence we observed in the classrooms. (p. 367)

They also described the importance of math problems that were "group worthy."

> These were problems whose solutions required the perspectives of different students, that could be solved using different methods, and that emphasized important mathematical concepts and principles ... [The group worthiness of the task was] sufficiently challenging and open to allow different students to contribute their ideas. (Boaler, 2006, p. 366)

While NCTM (2000), Brahier (1995), and Boaler (2006) have emphasized techniques for bringing out desirable mathematical dispositional learning, there is still no guarantee that students will engage in problem-solving, reasoning, and making connections (Katz, 1999; Tishman et al., 1993). Consequently, we need to look at a different aspect by examining teachers' perceptions of the learners and to be more intentional about advocating desirable math dispositions. This study emphasizes the importance of how teachers think about students as dispositional learners. It also examines the kinds of evidence that we, as teachers, are using to identify and perceive students' dispositions and how that becomes a circular process that can be limiting or advancing.

Context

In order to set the stage for the vignettes that follow, it is important to know that the teacher, in our study, had the students work math problems in small groups and then debrief together as a whole class. One of her goals was to give the students an opportunity to clarify their own thinking. As students clarified their thinking, the teacher used that information to make choices about how to facilitate the students' learning so that they could understand the mathematics more fully (similar to Boaler's, 2006, Railside example).

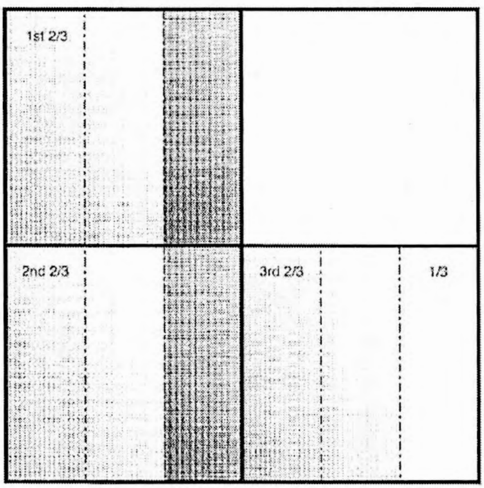
In the following study, the first vignette is presented with several interpretations about the students' mathematical dispositions. The first interpretation represents the teacher's general perception of the students' mathematical and dispositional learning that she has developed at this school over time. The other interpretations of the first vignette are alternative ways of thinking about the students' dispositional learning.

The second vignette provides an example of how the same teacher made a shift and became intentional about focusing on and developing the students' *desirable* dispositional learning. In other words, she was an advocate for the students' developing a healthy disposition for learning mathematics rather than lamenting on their dispositional weakness and focusing on their cognitive learning.

Vignette #1: Listening to the Ambiguities of Students' Dispositions

The math problem. The first vignette takes place on the fourth day of the semester. A group of five females (labeled as Group-A) were working to visually demonstrate the answer to 3/4 ÷ 2/3 within their small group. Then, they came back to the whole group for a continued discussion of the problem.

Group-A began their work by drawing a box.



Vignette #1. Group A box drawing.

They divided this box into 4 smaller boxes and colored in one box. The remaining three visually represented 3/4 of the box. Next, they divided each of the three boxes into thirds. One group member stated that 3 2/3's fit into the 3/4. Then, she questioned this answer because it did not match her answer based on calculations completed with the "invert and multiple rule." After about eight more minutes of work and with hesitation in the voices, they concluded that their answer according to their picture was 4 1/3.

During this small group time, the teacher circulated among many of the groups during the entire time as they were completing the problem. She asked questions to understand, clarify, and expand the students' thinking. However, she was unable to make it to every group. The group that is highlighted in the vignette was one that she did not visit.

As the teacher called the whole class together for a discussion, one Group-A member said to a peer, "*Maybe they'll show us.*" During the whole class discussion, the members of Group-A frantically recorded how other groups had solved the problem. When the teacher asked for questions about a solution, one member from Group-A commented to another group that was sharing ideas, "*Can you join our group?*" This was met with a little laughter. Finally, no one in Group-A offered their solution or their process for solving the problem.

Imagining a show-and-tell disposition. During the whole group time, while the teacher was soliciting students to socially construct their mathematical knowledge, it appeared that the students in Group-A wanted to listen, rather than talk, during whole group discussion. As result, the teacher could not be privy to their sense-making, thus leaving their work and thinking processes open to interpretation. This means that the teacher's interpretation would primarily center around the group member's comment to a peer (and not to the whole class), "*Maybe they'll show us*" as the class was transitioning from small groups to the large group discussion. One inference could be that the students were hoping for someone else to literally show-and-tell the correct answer, which happens with more traditional problems, as Brahier (1995) indicated. Likewise, the same inference could be made about the Group-A members when they were copying the other students' work from the board; they were seeing this as their "show and tell" opportunity provided by others for their benefit, as a way to expedite the answer but not necessarily their reasoning.

With this perspective, the teacher assumes that Group-A had been influenced by a different kind of socializing experience (Resnick & Nelson-Le Gall, 1997) in previous math courses, in which only the correct answers would be shown to the whole class. So, the teacher would see the students as valuing past classroom dispositions such as avoiding confusion and uncertainty, rather than being driven by the disposition of curiosity. Tishman, Jay, and Perkins (1993) point out that people do "carry with them pre-existing and well-entrenched conceptions of how things work [in this case, how teaching and learning works]. These conceptions can have deep roots and are often surprisingly resistant to change" (p. 151). Ball extends this by noting that some students may believe that "those who struggled in math may nevertheless assume that this is the way mathematics *must* be taught and that they are simply among the 'have-nots' in mathematics" (1989, p. 3). As a result, the students may not internalize the dispositions to reflect on and evaluate their work, which would make it difficult to change. Consequently, the teacher's reaction would be a reasonable one regarding the students' dispositions.

Reflecting on the small group. However, this interpretation of the show-and-tell disposition may not be the only way to look at the scenario and the silence if other pieces of evidence are taken into account. Even though the teacher regularly walked around to observe and discuss students' work during small group time, the teacher did not make it to all of the groups. In this case, she did not stop by this group (Group A) and so was not privy to the small group's work. However, the group's work was captured on video. So, it is worth considering the dispositions exhibited by Group-A during their small group work. More importantly, the small group dispositions were a contrast to the silence and dispositions that Group-A exhibited during whole group time.

Excerpt. The excerpt from the case that illustrates this follows:

Group A member: Then, she questioned this answer because it did not match her answer based on calculations completed with the "invert and multiple rule." After about eight more minutes of work and with hesitation in their voices, they concluded that their answer according to their picture was 4 1/3.

First, the group utilized desirable mathematical dispositions when they engaged in the following process. For instance, they worked continually on the problem during the small group time. When they came to an answer, they did reflect and monitor their work when they stated that it did not match the answer from an alternative method. Their awareness of verifying their answer was appropriate for their working flexibly toward an answer that is correct and meaningful. Perseverance was demonstrated when these students continued to work during the remainder of their group time to reconcile their two answers. Even though the students did not sound confident in their answer according to their picture, the students chose this strategy and answer as the one to focus on during whole group time. One reason could be part of the classroom norm or to please the teacher, since the teacher encourages the class to show their work using pictorial representations. Another reason could be out of curiosity because they were less sure about it.

Putting the evidence together to interpret and promote dispositions. Another perspective combines the whole group and small group interpretations and illustrates a need for teachers to consider multiple contexts in making interpretations about the students' dispositions. And, it is within the purview of teachers to make these same kinds of interpretations and attributions while teaching. So, if Group-A wanted to learn more about the problem by reflecting on others' work and comparing it with their own during whole group time, then the copying of other students' work from the board could be a way for them to have a record that they could use to continue their reflection and analysis of their work in relation to others' sense-making. If this is the case, they could be taking some ownership by continuing to work on the problem, even if it is in silence to the whole class (and the teacher). When Group-A said, "*Can you join our group?*" they may have wanted to enlarge their small group. They literally and figuratively may have been inviting other students into their group to help them make sense of the math on the table. And it was a part of the culture in the classroom to have the teacher encourage the students, even during whole group time, to ask each other questions about their thought processes.

Stepping back to reflect on the students' dispositions in relation to teaching. The first perspective highlighted the students' dispositions that could be interpreted as a lack of ownership and involved emotional dispositions involving possible feelings of uncertainty and embarrassment by the students. This type of interpretation springs up when a teacher has preconceived ideas about the students and their background and when the teacher may not be considering all of the evidence and looking for other plausible interpretations. As a result, the non-participation-looking silent disposition can be deafening and scary because of the lack of ownership behind it as described in this interpretation. When this happens, neither the teacher nor the students can hear or understand as well because fingers are being pointed in many directions (i.e., to the past, to the students, to a different approach, etc.). Consequently, the situation becomes a source of tension for the learning process. For instance, the tension can be interpreted as teachers' seeing and reacting to the students as lazy and students perceiving and reacting to the teachers as not being helpful (and withholding information intentionally), even though both have an inherent desire to learn. When teachers hear these kinds of dispositions from their students, it is easy to use them as excuses and to focus on their students' past. As a result, it becomes a rationale for teachers to react with complaints and to go about their business as usual, without reflecting on their own approach to teaching so that it can be revised to assist students better in acquiring desirable mathematics dispositions, such as perseverance, volition, and reasonable disequilibrium.

If the silence were viewed with both contexts of whole group and small group, the silence may provide the teacher with an opportunity to listen and reflect in yet a different way about students' dispositions. In other words, the teacher would listen for the different contextual variables that made a difference for when students did and did not engage in mathematizing, that is, a disposition for thinking about and working with the mathematics. The reflection on the silence also gives teachers a prime opportunity to advocate or promote mathematical dispositions, even though that promotion from the teacher did not happen in this vignette. As Katz (1993) points out, "if teachers want their young pupils to have robust dispositions to investigate, hypothesize, experiment, and so forth, they might consider making their own such intellectual dispositions more visible to the children" (1993, p. 10). As a variation of Katz' recommendation, the teacher could have repeated her expectations to the class and recommended to the students that they continue to reflect on their own work, as they learn other ways of understanding the problem during this sharing time. In this way, when another group was sharing their sense-making with the whole class, they were indeed joining everyone's group, even Group-A's, to make sense of the problem and solution, even if others remained silent.

So, is a mathematical disposition dependent upon problems? In this case, it was not about the problem. Is it dependent upon the cultural environment of the classroom? Is it dependent upon the context, such as small group and whole group? Yes, it could be. Is it dependent on the teacher's interpretations and facilitation? Yes, it could be that also. So, if teachers' interpretations of students' working on problems are so powerful in facilitating students' dispositional learning then this needs to be examined in more detail.

Vignette #2:
The Intentional Promotion of Dispositional Thinking

In the next vignette involving students' silence, the teacher does reflect on the students' understanding, their dispositions, and how she can facilitate both. She is not focusing on the mathematical understanding. She is not focusing on choosing an engaging problem. She is not reacting to their dispositions. Rather, she is consciously trying to advocate a way of thinking about mathematics that will transcend her classroom so that they will be able to mathematize for themselves. This was a significant change for this teacher who normally reacts to the students' dispositions. The following vignette is a written reflection by the teacher.

> *What an interesting class today. I posed the question about why some decimals terminate and some repeat. There was literally no response and no group talk. The students just sat and stared at the board. I was truly worried about what to do when they didn't talk. If I gave them more information, would I be giving them too much and giving it all away?*
>
> *All I could think about was the conversation I had with my colleagues at lunch. How am I helping them develop dispositions? What can I do to support their belief that they can do this? What can I do to scaffold things so that they might begin to try to find an answer?'*
>
> *Out of the blue (or it must have seemed that way), I asked them what I'd have to multiply 32 by to get 100,000. They told me 3125. I asked what I'd multiply 64 by to get 1,000,000. They told me 15325. I asked about 10,000,000. Again, they told me the answer – 78125. I put this information into a chart and then worked my way up the chart with 10000, 1000, 100, 10.*
>
> *Students started to murmur as though they thought they were seeing something. Eventually, some reported a pattern in our chart. Then they shared that they noticed other parts of the pattern. Some of them tried to make connections with last semester's work. Some seemed amazed that anyone would notice these patterns, and others thought that the number system had been created to do just this – that the inventors of the system knew about these patterns as they invented the system. Amazing.*
>
> *After class, a student came up and said she had tried finding the pattern for another set and was wanting to test our pattern now. We talked about some possibilities for this. Wow!*

Analysis of intentionally promoting dispositional thinking. In this reflective, second vignette, the teacher was intentional about teaching for dispositions, and she found a way to listen to their silence. While it would have been easy to interpret the students' silent behavior as defiant (i.e., waiting for the teacher to tell), the teacher found an alternate interpretation and alternate route to engage the learners with the mathematics. She started with where they were and provided enough structure so that the students could begin to think about the problem in a meaningful way. In doing so she discovered that the students did possess some desirable dispositions about math and their own learning. For example, the students started to report the patterns without more solicitation. They tried to make connections with last semester's work. They were curious about the historical aspects, and at least one student was interested in doing some more investigations on her own. In a conversation with the teacher afterwards, the teacher stated that she felt differently about the students and her own teaching, as a result. She felt more energized because they had became engaged and even went beyond the lesson with their questions and connections. The lesson became more than just picking engaging problems and focusing on the students' understanding. It became about advocating and engaging the students' dispositions, through mathematizing, as well.

Discussion

As Taylor (2003) points out, students can be very challenging to teach with some of their dispositions. However, this does not mean that the dispositions are impossible barriers or that they have to be ignored or sidestepped. When teachers listen to the students' mathematical thinking, the teachers gain an understanding of where the students are and what kinds of strategies and concepts or procedures are needed. When teachers listen to the students' silence in new ways, the teachers can reframe their dispositional learning. In the second vignette, when the teacher was able to approach the students' dispositions in the same way as she approached their learning, (i.e., by meeting them where they were, not where she wished they were) she was able to make the same kinds of in-roads in their dispositional learning as she did with their mathematical understanding. In other words, not only was the teacher engaging the students' minds, but she was being their advocate and engaging their dispositions for learning. More precisely, Ball and McDiarmid state, "teachers' intellectual resources and dispositions largely determine their capacity to engage students' minds and hearts in learning" (1990, p. 12). In addition, the teacher was also engaging her own heart and mind when she advocated for their dispositional learning.

In summary, teaching for understanding is a goal of most math teachers and is reflected in the NCTM standards, no matter what level. Likewise, learning for understanding is desired by most students, no matter what level. While a teacher's choice of engaging problems and context may assist that understanding, the teacher's choice to react to or advocate for students' dispositional learning is just as important. As a result, teachers need to make it a priority to care about students and their desirable mathematical dispositions *as well as* their understanding.

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