How can teachers influence their students' (mathematical) mindset?

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Interventions aimed at fostering students' growth mindsets have been carried out in 21 classrooms (with a focus on Grade 7 and Grade 10) in the Netherlands. The intervention consisted of three main elements: introduction to neuroplasticity, the importance of learning from errors in learning processes, and growth-mindset feedback. Before and after the intervention, the students finished a questionnaire, and during the intervention, students and their teachers were interviewed. Results indicate that the students' mindsets tended to be more towards a growth mindset after the intervention, in particular for the Grade 10 students. Students were very positive about the intervention, especially the neuroplasticity and the attention for and learning from errors. Teachers and students valued the changes in attitudes and interactions with a new language for teaching and learning mathematics.

Keywords: Learning motivation, teacher influence, psychology.

Introduction

"I don't understand anything" or "What a stupid mistake" are phrases students often say out loud. For teachers, when they pay attention, these words can be an important signal to indicate that students are working with a fixed mindset. Recognition of the mindset by the teacher and explanation of the theory of mindset can help students change their mindset, and by that change their beliefs and attitudes towards mathematics. To influence students' mindset the role of the teacher is indispensable.

Theory of the mindset

The concepts of fixed and growth mindset were introduced by Carol Dweck (Dweck, 2006; Dweck, Chiu, & Hong, 1995). She distinguished, based on 20 years of research, two types of mindset:

- FIXED: you have certain talents, and they remain the same throughout your life.
- GROWTH: what you can do or learn now forms the starting point from which you can develop.

Their studies show that the effects of these different mindsets on how students learn are significant, especially in how they deal with challenges and obstacles. When students have a fixed mindset they prefer not to get any challenges. One might think: "Suppose I fail, then people will think I am not very clever, and as this cannot change, I will stay dumb for the rest of my life." If something goes wrong, and the students have a fixed mindset, then they will feel stuck in a situation to which they cannot change anything. On the other hand, when students are working with a growth mindset then they want challenges. The outcome does not really matter to them; they know and feel that it is

important just to try, that they can learn from their mistakes, that their brains are at work, and that they can change (Boaler, 2016; Dweck, 2006).

The mindset students have is influenced by their upbringing. For example, parents who say "I was never able to do mathematics when I was young" unintentionally influence their children into a fixed mindset. The emphasis on performance in our school systems also plays an important role. High grades and quick results are seen as positive, while they can make students insecure and tend to create a fixed mindset (Dweck, 1995; Dweck, 2006; Mueller & Dweck, 1998). A recent large scale study among undergraduate students showed that their teachers' mindset beliefs influenced classroom experiences and had a substantial effect on their achievements in STEM fields (Canning, Muenks, Green & Murphy, 2019).

'Mindset' is not a trait and it cannot be measured exactly. A mindset may vary with context and over time (Dweck, 2006). However, one's mindset has an impact on how one approaches and becomes involved in an activity. When students behave according to a fixed mindset while encountering a problem, they are likely to give up quickly and tell themselves: "I will never learn this." In contrast, when students are working with a growth mindset, they ask themselves "what can I learn from this", and "how can I try not to make the same mistake too many times." (Dweck, 2006). For teachers, when they pay attention to the words of their students, these words can be an important signal to indicate that students are working with a fixed or growth mindset. Recognition of the mindset by the teacher and explanation of the theory of mindset can help students change their mindset, and by that change their beliefs and attitudes towards mathematics (Boaler, 2016).

Interventions that encourage a growth mindset

For everybody, students and teachers, it is important to become aware of the impact of their mindset and of its possibilities and challenges (Dweck, 2006). With this awareness, in combination with relatively small social psychological interventions, it has been found that teachers can encourage students to adopt a growth mindset (Yeager & Walton, 2011).

If students believe that they can be smarter and that hard work can help them with this, then they are more willing to exercise (Blackwell, Trzesnieuwski, & Dweck, 2007). This process has a lot in common with 'self-efficacy' that Hattie (2018) is using in his work. Hattie emphasizes the strong correlation between self-efficacy (the confidence that students have in themselves and that can make their learning happen) and student achievement.

Mathematics is eminently a subject where mindset plays an important role. On the one hand, the discipline is highly regarded in our society and it is often associated with something you are good at or not. Good grades for mathematics are seen as a clear proof for being intelligent. And parents compare the results of their children quickly with their own school experience and, unconsciously, emphasize the perspective of being either good or bad in it. Unluckily all these aspects foster a fixed mindset. On the other hand, doing mathematics can give students frustration when they do not see the solution right away. Consequently, working with a growth mindset will help them a lot.

Many ideas for mathematical activities that invite students to develop a growth mindset are provided by Boaler (Boaler, 2016). Some of these interventions, especially the ones that are also described in the studies of Yeager & Welton (2011), Blackwell (2007), and Hattie (2008), have been tested in the school year 2016-2017 at the Goois Lyceum, a secondary school in a small town in the Netherlands.

The evaluation of these tests showed that three main elements of the intervention were easy to implement and were experienced as very valuable: (1) an introduction to the theory of mindset and the importance of neuroplasticity, (2) attention for the importance of learning from errors in the teaching process, and (3) classroom as well as individual growth mindset feedback.

In this study, we investigated to what extent this growth mindset-oriented intervention can improve students' attitude towards mathematics.

Method

During the school year 2017-2018 the intervention was further developed and implemented in the first grade of secondary school (grade 7) and in upper secondary school mathematics A classes (mainly grade 10). Grade 7 was chosen because these students recently switched to a new school. In upper secondary education, classes with mathematics A were chosen because mathematics A (preparing for humanities) is seen as 'easier' than mathematics B (preparing for natural sciences). These students often feel that they have chosen a 'lower' form of mathematics and that they cannot perform well in this subject. This lower self-efficacy might indicate a fixed mindset, and it is interesting to see whether this can be changed by the interventions. We advertised the possibility to join the project in a newsletter reaching mathematics teachers all over the Netherlands. In total 512 students in 21 classrooms, from nine schools, joined the experiment, of which 383 filled in both the questionnaires.

Preparation of the teachers

The teachers that were involved in the intervention were given a training of 5 hours at Utrecht University in which the theory of mindset was explained. During the training, teachers got the opportunity to work on some sample activities (low-floor-high-ceiling tasks, Boaler, 2016, or 'My favorite no', Alcala, 2011) followed by an extensive instruction of the different elements of the intervention. The presentations of the training, the presentations and tasks for the students, and suggestions for further reading were shared online. During the intervention there was a regular exchange of experiences, questions and information through email with the teachers. The intervention contained the following three main elements:

1) Explanation about mindset and the functioning of the brain (neuroplasticity). Although the theory of mindset is a psychological theory it is well supported by brain researchers in relation to the plasticity of the brain (e.g. Woollett & Maguire, 2011; Helden & Bekkering, 2015). Nerve cells, or neurons, can make better and more connections throughout our lives (or loose connections when not in use). This allows a rich distributed dynamic network with many opportunities to learn new things, also referred to as neuroplasticity. Because of this neuroplasticity people have the opportunity to learn and expand their knowledge. It is not just the capacity to learn a new language but also new hobbies and new habits. For example, if you fear failure through training you can learn to become more confident (Hanson, 2009). It is like walking a new path through the jungle; first you need a machete to break through, but after some time when you use the same track more often, a path is created and it gets easier and easier to travel.

At the schools this part of the intervention started with a presentation for all students on the functioning of the brain and on the theory of mindsets. The corresponding task was to make a difficult mathematical assignment without the explanation of new theory. A student with a fixed

mindset would not like this, they avoid starting out of fear of making mistakes. A student with a growth mindset would like to continue, thinking “I'm going to try it” or “If it doesn't work out I ask it.” The role of the teacher is to give the right growth feedback and to regularly remind students of the neuroplasticity of the brain.

2) The importance of making mistakes and learning from errors. Brains of people who make mistakes with a growth mindset are more active than the brains of someone who makes mistakes with a fixed mindset (Boaler, 2016). When students do not understand the assignment right away and they are thinking with a fixed mindset, they might believe “Now everyone will notice that I am not smart.” They start to get stressed and stress hormones ensure that no new connections between the neurons grow (Dirksen, 2012). Students with a growth mindset will see obstacles more as challenges. They can see that making a mistake is the beginning of learning something new (Chödrön, 2006). They then start to feel more confident which in turn sets the brain in a responsive mode, and this stimulates making new connections in the brain (Hanson, 2009). The teachers are stimulated to use feedback like “I want to understand the way you think and together we can discover what the next step is.”

This intervention started with a presentation about the function of making mistakes and the role of mindset. The teachers started several lessons with “My favorite no” (Alcala, 2011). To change the way in which teachers cope with mistakes is also an aspect of this intervention.

3) The use of feedback. It is important that teachers are aware of the feedback they give, especially while making errors. If they say “what a stupid mistake” they can bring students more towards a fixed mindset. And it is not just the words but also the body language and tones they use. The challenge is to give feedback not on properties or features but on the process (Boaler 2016). It may seem great to hear that you are smart. However, it is a kind of label, leading to overconfidence, or to self-doubt like: yes I am smart now but what if I make a mistake, will they call me dull-brained? (Mueller & Dweck, 1998). When giving feedback on the process it should be true feedback; only when a student has really worked hard one can evaluate this.

It is not just the feedback that students get from others, it is also the feedback they give themselves. In a class, it is helpful to listen carefully to what students say while making the assignments or as they chat. For example, when they say “this is too hard”, this can be associated with a fixed mindset. Whereas when they are saying “this may take some time” this can be associated with a growth mindset.

The attitude of the teacher is important; when a teacher, from a fixed mindset, has the opinion that the performance of the students stays the same throughout the year it might lead to stagnation. On the other hand, when a teacher, from a growth mindset, believes that the performance of the students can grow than students evolve more easily. Good teachers believe in development of intelligence and talent, which is a growth mindset, and they are fascinated by the learning process (Dweck, 2006).

At the start of this intervention on feedback the students were shown a short presentation on feedback, words, and the link to mindset. The assignments they then got were low-floor-high-ceiling tasks, for example “what is the largest surface you can make with 36 piles of 1 meter?”. Students can easily start and while working can make things more and more difficult. The teacher helps them by giving growth and encouraging feedback and challenge them.

To participate in this study teachers were asked – as a minimal requirement – to teach the previously described elements of the intervention (on the plasticity of the brain and the consequences for learning, the importance of errors, and the role of feedback in learning). Furthermore, they were asked to implement at least one growth-mindset task with every intervention. Finally, they were invited to examine their own attitude towards mistakes and to practice with growth-mindset feedback in their classroom.

Procedure of the intervention

At the start and at the end of the intervention, students filled in a questionnaire to determine their mindset. This questionnaire consisted of 25 statements that were compiled from the literature of Blackwell and Dweck (Blackwell, Trzesnieuwski, & Dweck, 2007; Dweck, 2006). Students were asked to label their level of agreement to the statements on a 6-point Likert scale. The statements were divided in four types: mindset, effort belief, response to failure, and learning goals. With these different types the impact of the intervention could be measured in different domains. Example questions were:

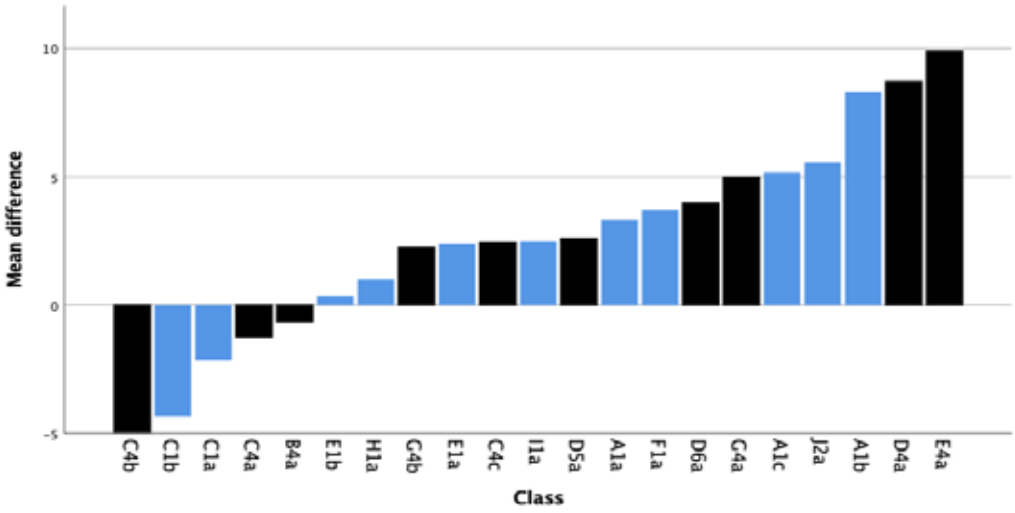
> Q1. You have a certain amount of intelligence and you cannot do much to change it
>
> Q3. An important reason why I do my schoolwork is because I like to learn new things
>
> Q5. It does not matter who you are and where you come from, you can always change your level of intelligence
>
> Q16. If you have to work hard for a subject, you are probably not very good at it.

During the interventions at five schools a lesson with the intervention was observed and students and teachers were interviewed about their experiences.

Results

In Figure 1 the mean differences in the total score of the questionnaire are represented. It can be seen that in only five classes the total scores after the interventions had lowered, indicating a more fixed mindset. In the remaining sixteen classes the scores went up, indicating a more growth mindset. The Grade 7 classes are drawn in black and Grade 10 in blue, with no clear differences emerging.

Figure 1. The mean differences in the total scores per class



In Table 1 the average scores on the different scales are given for the two grades. It can be seen that the effect of the interventions is most clear for the mindset score (e.g. +3.1 for the Mindset scale in Grade 7). Both in Grade 7 and Grade 10 the post intervention mindset scores are higher.

Table 1: Results of the scores of the pre- and posttest (the questionnaire before and after the mindset interventions); the average of the different grades in the different domains

(Grade 7 N = 246 Grade 10 N = 137)

Sub scale	Grade level	Pretest		Posttest		Difference
		M	*SD*	*M*	*SD*	
Mindset	*Grade 7*	27.8	6.8	30.9	6.6	+3.1
	Grade 10	27.1	6.2	29.0	7.0	+1.9
	Total	27.5	6.5	30.2	6.8	+2.6
Learning goals	*Grade 7*	16.2	3.4	15.6	3.8	-0.6
	Grade 10	14.3	3.6	14.8	3.7	-0.5
	Total	15.5	3.6	15.3	3.8	-0.2
Effort belief	*Grade 7*	28.8	3.4	29.0	3.7	+0.2
	Grade 10	27.3	3.3	27.8	3.8	+0.5
	Total	28.2	3.5	28.5	3.8	+0.3
Response to failure	*Grade 7*	38.8	4.9	38.8	5.0	0.0
	Grade 10	37.5	5.4	36.9	5.8	-0.6
	Total	38.4	5.1	38.1	5.3	-0.3
Total score	*Grade 7*	111.6	12.9	114.2	12.8	+2.6
	Grade 10	106.3	13.2	108.4	14.8	+2.1
	Total	109.7	13.2	112.1	13.8	+2.5

In Table 2 the results of the changes of the individual students show a similar pattern of more pronounced changes in the mindset score compared to the scores in the other domains. Also, here the change towards a more growth mindset is larger in the Grade 7 classes (67.5%). This trend may indicate that the mindsets of the Grade 7 students are more intensely influenced by the interventions.

Table 2: Results of the changes of the individual students

Change on	**Percentage of changes***	**Difference between grade 7 and 10**
Total score	39.7% negative change 4.7% no change 55.6% positive change	Grade 7: 38.6% negative, 6.1% =, 55.4% positive Grade 10: 41.6% negative, 2.2% =, 56.2% positive
Mindset score	29.0% negative 7.3% no change 63.7% positive	Grade 7: 26.4% negative, 6.1% =, 67.5% positive Grade 10: 33.6% negative, 9.5% =, 56.9% positive
Learning goals	45.2% negative 14.4% no change 40.4% positive	Grade 7: 49.6% negative, 16.3% =, 34.1% positive Grade 10: 37.2% negative, 10.9% =, 51.8% positive
Believe in effort	39.7% negative 14.6% no change 45.7% positive	Grade 7: 42.7% negative, 12.2% =, 45.1% positive Grade 10: 34.3% negative, 19.0% =, 46.7% positive
Response to failure	45.4% negative 14.1% no change 40.5% positive	Grade 7: 41.9% negative, 15.9% =, 42.3% positive Grade 10: 51.8% negative, 10.9% =, 37.2% positive

* a negative change is a change towards a fixed mindset; a positive change is a change towards a growth mindset.

All the teachers were very much involved in the intervention. During the interviews they made comments like: “As a mentor, and as a teacher in mathematics, I can now discuss more easily how important it is to learn from your mistakes. I also designate my own mistakes more consciously, and I explain how I deal with them.’’

Another teacher writes that she has become more careful with her words. Even small, seemingly unimportant words like quickly (make your assignments quickly) she tries to avoid as it disempowers her lessons. The classes that show a decrease or stability in mindset scores are one Grade 7 class and two Grade 10 classes. Two of these teachers were starting teachers who were very enthusiastic about the intervention but for whom teaching itself was relatively new. The third teacher was a more experienced teacher and also very committed to the interventions. However, in his class there were a lot of changes in the composition of the class, which may have influenced the outcome.

The questionnaire at the end of the intervention included questions about which part of the intervention the students appreciated most. They valued the entire intervention because of its content and also because of the changes in their teacher’s attitudes. The lesson on the brains and on the mistakes were most highly appreciated. One student explained: “I have to stop thinking ‘this will cost too much time’, or ‘I really cannot do this’; instead I can persevere or try again later.”

The personal interviews with students also revealed that the lesson on making mistakes was experienced as the most positive, though also after the interventions one student made the following remark: “I did learn that making mistakes does not matter, however I still do not like it.”

Students and teachers reported during the interviews that an important element of working with mindset is the use of words. One student noticed “It sometimes seems as if we have learned a new language together.” Another student said “Sir, this feels like a fixed remark, do you mean it like that?” One teacher said: “I find it a real challenge, you have to pay attention to all the words the students are saying, also the words they say to each other and to themselves. To be able to do that of all the students is not (yet) possible, however with a few students separately I do succeed.”

Discussion

The mindset theory addresses issues that are highly relevant for current teaching practices in mathematics education. We are aware that changing teachers’ teaching and students’ learning behavior can hardly be achieved through a one-day training for teachers. Nevertheless, this study shows that teachers did become sensitive for changing their practice towards fostering a growth mindset after a training of only five hours and some initial experiences with the interventions. From this study, the effects of changing practices on student achievements are not clear. What it does show is an obvious attitude change towards students’ own learning and towards the importance of making mistakes in learning mathematics. These are important first steps towards a changing culture in the mathematics classrooms. Finally, teachers reported that the mindset theory provides an inspirational vocabulary and set of tools to implement and improve daily teaching practices.

The training of teachers was first seen as a preparation for the three elements of the intervention mentioned above, but actually it turned out to be a separate intervention. Once teachers were familiar with the theory of the mindset they changed their lessons: teachers were more aware of the mindset from which they taught their students, of the importance of learning from their mistakes and the feedback they gave. And this had a direct impact on the mindset of their students.

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