How to Create a Supportive Learning Environment in Mathematics Classes - An Example from a Norwegian Lower Secondary School Class

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Abstract
Mathematics is an important subject in school, however, many students find this subject very challenging. Some even dread mathematics as they do not master it and they may fear that their social status will be negatively influenced by this. It is therefore important that the teacher facilitates for creating a learning environment where students feel they can be open and supported when they struggle. The aim of the current study is to investigate how a five-step method including individual reflections and classroom discussions may facilitate for this type of supportive and motivating learning environment. The method builds on self-determination theory and theory of self-regulation. The five-step method was applied through a four-week long intervention in an eighth grade and focused on numbers and algebra. The students reflected on the following five questions: 1) What is important to learn in algebra and why? 2) What do you already master in relation to algebra? 3) What is difficult and prevents you from learning algebra? 4) What will you focus on improving the next few weeks? and 5) How exactly will you do this? The students filled in evaluation forms including both open and closed questions after the intervention (n = 15). The findings showed that six of the students agreed that the method helped them find out what was important to learn, seven followed the plans they made, five agreed that they had become better at dealing with challenges and three students felt more comfortable in class after the intervention.

Keywords: Mathematics, Algebra, Learning Strategies, Self-Regulation

Introduction

Principles for learning and personal development in the Norwegian curricula speak clearly about what is expected of the education. It is said that education is to 'contribute to students reflecting on their own learning, understanding their own learning processes and adapting knowledge independently (The Ministry of Education and Research, 2017, p. 12, our translation). Self-regulation and learning strategies are very relevant when a goal for students is to develop the ability for lifelong learning. This study illustrates how a five-step method may support students in reaching this goal of becoming self-regulated learners mastering different strategies (Langeland & Horverak, 2021), by facilitating for a supportive learning environment in mathematics classes.

The five-step method for mastery and motivation applied in the current study is an example of a metacognitive learning strategy, relevant to apply to achieve self-regulation. Metacognition can be defined as 'thinking about thinking' (Mevarech & Fridkin, 2006, p. 86). In addition to building on theory of self-regulation and metacognition, the five-step method also builds on self-determination theory, claiming that to achieve intrinsic motivation, the basic needs of competence, autonomy and relatedness must be met (Ryan & Deci, 2017). Another theory that has inspired the method is Bandura's theory on self-efficacy, claiming that an increased feeling of competence leads to an expectation to succeed with new tasks, which again may influence motivation positively (Bandura, 1997). The essence of the five-step method is that when students get to choose what they need to work with, and how, they will achieve intrinsic motivation and perseverance in learning.

There are different definitions of self-regulation. Zimmerman's definition focuses on how thought processes are started, and actions planned to achieve goals (2000). Pintrich's definition focuses on how self-regulation is a process where students make goals and try to monitor their own cognition, motivation and behaviour (2000). There are different self-regulation models, but common for most of them is that they have three main phases; planning, action and self-reflection (Zimmerman, 2000; Perels et al., 2005; Schmitz & Perels, 2011). Self-regulation is seen as a means to improve performance (Schunk, 2005). Teaching self-regulation skills should be implemented already from primary school, particularly in mathematics, where it appears that it is the teachers' job to regulate the students' learning (de Corte et al., 2011). Mastering various learning strategies is related to efficient learning, but to become conscious about one's own learning process and strategy use must be learnt and is something that develops gradually (Aastrup & Johnsen, 2014).

Self-regulated learning is not something that appears spontaneously and automatically, there is a need for training (De Corte et al., 2011). Research in mathematics has shown positive development of self-regulation competence when self-regulation and problem solving are combined (Perels et al., 2005). Positive effects on self-regulation competence and mathematical performance have also been found when students monitor their own homework in mathematics through writing reflections in personal journals (Schmitz & Perels, 2011). A more extensive intervention study shows that mathematical performance was improved after self-regulation training (Dignath & Büttner, 2008). The effect sizes were largest in primary school, and somewhat lower in lower secondary school. The researchers reflect on whether this may be related to the fact that motivation generally drops in lower secondary school. Compared with results in reading and writing, the study shows that the self-regulation competence improves more in mathematics. The study also showed that training in self-regulation is more effective the longer it lasts. Another study has also documented that the

students' ability to make goals improves gradually during training self-regulation (Perels et al., 2005). Based on these findings, an urgent need is advocated for research on how self-regulation can be promoted in the classroom (Dignath & Büttner, 2008).

Learning strategies are central in the domain of self-regulated learning. Previous research shows that it is important that students have strategies to solve exercises (Otto & Kistner, 2017). Self-reflection does not help the students if they do not have appropriate learning strategies (Schmitz & Perels, 2011). The students do not just need a list of strategies, but they need a deeper understanding of when, how and why the different strategies are applied (Aastrup & Johnsen, 2014). This requires extensive competence on the part of the teacher as well, as the teacher is responsible for providing students with this understanding. In Dignath and Büttner's study (2008), interventions carried out by researchers gave better results than interventions carried out by teachers, and the teachers' lack of competence on self-regulation is mentioned as an important element here. Other studies emphasize the importance of teachers going through and presenting self-regulation methods for students before they are to apply these methods and explain the point of self-monitoring to them (Schmitz & Perels, 2011; Kramarski & Mevarech, 2003). The teachers' own competence within self-regulation is crucial for students to succeed with self-regulation practice.

The research question for this study is: How can teachers facilitate for a supportive learning environment in mathematics classes, enhancing self-regulation and intrinsic motivation. The study is limited to focus on learning algebra, as this is a central part of what students are to learn in mathematics. Learning algebra forms a basis for generalising and modelling in mathematics (Norwegian Directorate for Education and Training, 2020a) and there are several competence aims concerning algebra after year 8 in the curriculum (Norwegian Directorate for Education and Training, 2020b). Still, algebra has been a topic where Norwegian students have had low scores over several years on the TIMSS surveys. The most recent report from 2019 shows that within the Nordic countries, Norwegian students have the lowest scores (Kaarstein et al., 2020). This study illustrates how the five-step method may be applied with a focus on teaching algebra in mathematics, and how this may contribute to develop a supportive learning environment where motivation and self-regulation are in focus.

Methodology

To answer the question of how teachers can facilitate for a supportive learning environment in mathematics classes, a short intervention of three sessions over three weeks was carried out in an eight-grade class. The topic being taught this period was numbers and algebra, with a focus on equations, and using algebra-tiles as an alternative learning strategy. The intervention carried out included a five-step method for self-regulation of learning. The sample consists of 16 students (66 % of the 24 students in the class), of which nine were girls and seven were boys. The data was collected anonymously, and the students consented in participating in the study.

Intervention

The five-step method applied in the intervention of this study included the following five questions: 1) What is important for you to succeed with learning in the chapter 'Numbers and algebra', 2) What are you already good at which helps you mastering algebra, 3) What is difficult and prevents you from learning algebra? 4) What will you focus on improving the

next weeks, and 5) How will you carry this out? The teacher led a class discussion about these questions, and then the students wrote individual, anonymous answers (see figure 1).

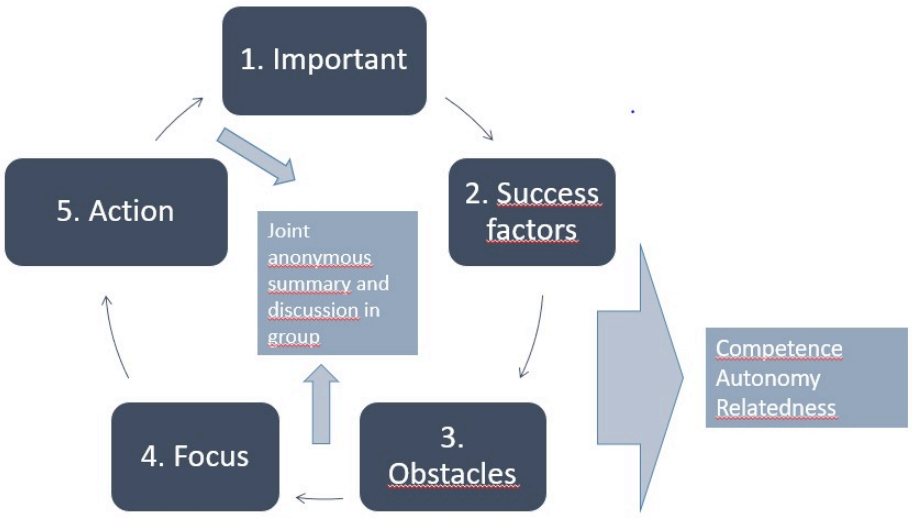

Figure 1. The Five-Step Method for Working with Student Participation, Mastery and Motivation (Previously Published in Horverak & Aanensen, 2019; Horverak, 2020).

Before the intervention including the five-step method started, the students filled in a questionnaire concerning what learning strategies they applied in mathematics. In the first session applying the five-step method, the students were first introduced to the method and factors that influence motivation in general. Then the students discussed the first question in pairs, and they summed up what was important in the chapter on numbers and algebra by making a mind map together on the blackboard. The teacher supplemented what was left out by the students. Then the students were given examples of possible success factors and obstacles, both general and subject-specific factors, and they answered questions one to three in writing in personal logbooks with anonymous codes on instead of names. The teacher collected the logbooks after the session. The point of having anonymous logbooks is that this method is supposed to support students in taking responsibility for their own learning process (Langeland & Horverak, 2021). They write reflections for their own sake, not for the teacher, and if they use names, there is a risk that the teacher takes over the control of the process.

In a following session, the students practiced different learning strategies relevant when learning algebra, for example, solving equations algebraic and using algebra tiles. The teacher and the students wrote rules in separate rulebooks. In the second session of the five-step method, the students were first presented with anonymous reflections from the logbooks from the first session, then the teacher presented division as a possible focus area for the students, as this was something several of the students found difficult, but also important. The students were asked to come up with ideas of what they could do if division was challenging. The answers were put in a mind map on the blackboard, and then the teacher presented other learning strategies the students could apply to solve equations. Finally, the students were to answer questions four and five in the five-step method, what they were to focus on and what action they were to take. The students continued their work with solving equations algebraically using both addition and subtraction, then more steps were included with division and multiplication. The students were reminded about their chosen focus areas.

In the third and final session with the five-step method, examples of action plans with focus areas and planned actions were presented - some good plans, and some that could have been improved. The students were encouraged to talk in pairs about how they could have improved these plans to make them more specific. After having filled out a questionnaire about what learning strategies they used to learn mathematics, the students were asked to choose a new focus area and a new plan for action, or improve the action plan they already had.

Measuring Instrument

The data collected in this study includes anonymous reflections from students' logbooks, answers to a questionnaire concerning learning strategies in mathematics, and self-reported data on how the five-step method worked. The questionnaire concerning learning strategies was filled in before and towards the end of the intervention. In addition, the students filled in an evaluation form after the intervention period.

In the evaluation form the students answered the following questions about the five-step method on a five-point scale from 'strongly disagree' to 'strongly agree': The method helps me find out what is important in the subject, the method makes me motivated to work with what is important in the subject, I have managed to follow my own plans, I have become better at working with what is difficult in the subject, the method makes me feel more comfortable in mathematics classes, I like using the five-step method. In addition, they were asked to give examples of something they had focused on.

Examples of student reflections on the five questions of the five-step method are presented in the results, as well as learning strategies the students applied. In addition, the students' answers on the evaluation of the five-step method are reported in a table. Some students reported that they struggled with understanding the questions in the five-step method, and this may have influenced the outcome of this study.

Results

On the first question of the five-step method, concerning what is important to learn in the chapter of numbers and algebra, the students answered: the four main types of calculations – especially division, solve equations, and learn central concepts. In addition, the students write that it is important to practice, listen to the teacher's explanations, do exercises, repetition, do homework, ask about help and to dare to try and fail. Some answers also concerned attitudes, that it was important to be interested, get enough sleep, and be concentrated and motivated. There were also elements focused on the teacher, asking the teacher to give thorough instructions and to do difficult exercises on the blackboard.

When defining success factors, the students wrote for example that they were good at finding the value of x, managing the four main types of calculations, even though some leave out division, doing homework, paying attention and keeping focus, and avoid talking in class. One student writes 'I think I am very good at using the tiles we have received, I think this makes it simpler.'

The obstacles the students write about are getting enough practices, tiredness, lack of motivation and focus, boredom, difficult exercises, difficult formulas, too much to remember, and that much is confusing, and the tempo is sometimes too high. One student writes 'we just

do easy exercises on the blackboard, therefore it is difficult to do the more challenging exercises that we are to do on our own'.

When the students chose focus areas, 27% focused on division among others. Some students chose several focus areas. Examples of chosen focus areas are to do text exercises, use more time on exercises and not give up, try to become more interested and better in mathematics, pay attention in class, find x, learn how to write calculations, and repeat the multiplication table. When the students were to consider changing focus area the second time, almost half of the group made a change. The focus areas that were chosen the second round was much related to solving equations with the methods they had practiced, as well as fraction and becoming more motivated.

The action plans are generally short and include just a few elements such as 'do it', 'practice' and 'do exercises'. Other more specific plans include to become better at division, and do exercises related to the multiplication table without using calculator. One student writes 'not just guess before thinking this is difficult, but use enough time'. Other elements mentioned are to get enough sleep and develop interest.

Learning Strategies in Mathematics

The answers to the questionnaire on learning strategies reveal that before the intervention, many students experienced instruction from the blackboard and working with exercises to be dominant in mathematics. On a question of preferred strategies, the students write using calculator, collaboration, videos and working with exercises. When doing homework, the students use strategies like using the internet, asking parents, doing exercises, watching videos, and using the book and calculator.

After the intervention, the students present a longer list of learning strategies they apply compared with before the intervention. They report using a rule book, campus increment (videos), asking for help, solving equations by using the algebraic method, in addition to the strategies reported the first time. Using calculator is the most frequently reported preferred strategy. Of the participants in this study, 57 % report that they have used either the tiles, the rulebook, videos on youtube or campus increment more than usual, during the time of the intervention.

Student Evaluations

The results of the student evaluations show that many students are unsure about how the five-step method works for them, but in general, there is a tendency towards positive responses (see table 1). Forty percent of the students agreed that the method helped them find out what is important to learn, and 13 % agreed that the method made them more motivated. Thirteen percent also disagreed that the method helped them become motivated. As much as 47 % reported having followed their own plans, and only 20 % disagreed that they had done so. Thirty-three percent reported having become better at working with what is difficult in mathematics, and 27 % disagreed to this. Twenty percent felt more comfortable in mathematics classes due to the use of the method, and 14 % disagreed to this. Most students did not have any particular opinion when it comes to whether they liked the method or not, but 13 % responded that they agreed that they liked the method, and 13 % disagreed.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree
The method helps me find out what is important in the subject.	-	-	60 %	40 %
The method makes me motivated to work with what is important in the subject.	-	13 %	73 %	13 %
I have managed to follow my own plans.	-	20 %	33 %	47 %
I have become better at working with what is difficult in the subject.	7 %	20 %	40 %	33 %
The method makes me feel more comfortable in mathematics classes.	7 %	7 %	70 %	20 %
I like using the five-step method.	-	13 %	73 %	13 %

Note: No students answered 'strongly agree' to any questions, therefore this category is left out.

Table 1: Student evaluations of the Five-Step Method (N = 15)

When asked about what they chose to focus on, the students answered taking small steps, motivation, equations, practicing on tests and keeping focus. What the students reported here did not correspond to what they wrote in their action plans during the intervention.

Discussion

The five-step method builds on the same pedagogical ideas as studies of self-regulation in mathematics (Schmitz & Perels, 2011; Dignath & Buttner, 2008; Mevarech & Fridkin, 2006), which have shown that self-regulation may be useful in mathematics. The current study reports on a very short and limited intervention, and perhaps, if the five-step method had been implemented over a longer period, the results may have been different. It may be that the five-step method has contributed to strengthening metacognitive thinking, and that this will show more over time. When looking at the results presented in this study, we see that the students have applied more learning strategies after the intervention, and some of the students report positively when reflecting on how the approach has worked. This demonstrates that the five-step approach may have the potential of creating a supportive and motivating learning environment.

This study has not examined the effect of the five-step approach, but rather how the students reflect when the method is applied, how they experience applying the method, and how this may support self-regulation and motivation. Many students report that they neither agree nor disagree in the evaluation of the method, which could mean that they are not sure about how the method works for them. Young people do not always have insight into how different strategies work, so it may be that the intervention has influenced them more than they are aware of. They may have adopted the way of thinking presented in the five-step method without being conscious about it. However, more research is needed to investigate whether the approach leads to changes in metacognitive thinking and learning behaviour.

The students perceived reflecting in this way, identifying obstacles and making action plans, as both new and difficult. As previous research has shown, setting goals and managing self-regulation takes practice (Perels et al., 2005). In addition, more work on learning strategies is

probably needed, as providing students with a list of strategies is insufficient. As pointed out by Aastrup and Johnsen (2014), students should work focused on specific learning strategies to learn them properly. Even though this was not done, some of the student reflections on how to apply strategies were quite good, and they reported applying more strategies at the end of the intervention compared with the beginning.

More of the students in the class expressed that motivation, interest and keeping focus was something they struggled with in mathematics. This could be related to what Dignath and Büttner (2008) write about sinking motivation as students progress in school. Some even chose these elements as focus areas. Working with one's own motivation is central in Zimmerman and Moylan's self-regulation model (2009). The idea in the five-step method is that students will experience mastery and motivation through identifying success factors and obstacles, and choosing focus areas and strategies to improve, and follow up on these plans (Langeland & Horverak, 2021). Following the students from this study over time would have been interesting, to find out if they improved their motivation and interest, and increased their self-regulation competence, which is something that takes time and practice (de Corte et al., 2011).

As this study presents a limited and short intervention covering three sessions, where the five-step method was applied in relation to one specific topic in mathematics, there is a need to find out how the method could be applied more extensively over time in the mathematics subject. The method may be an alternative answer to Dignath and Büttner's (2008) call for how to work with promoting self-regulation in mathematics classes. The progression in topics in mathematics may be too rapid, as we saw that the students changed their focus area to algebraic solving of equations towards the end of the intervention, when the topic of algebra was concluded. Perhaps students need more time for practice and repetition in each topic. There is a danger that the focus area will be forgotten, so preferably, the students should be given some time during class to follow up on their plans with some teacher support. Another challenge can be that as the teacher progresses to new topics, the students still want to focus on a topic that has been dealt with previously. Perhaps some students need more practice on basic mathematical skills as multiplication or division, even though the teacher moves on to more complex topics.

There is no easy solution to this dilemma - the teacher needs to keep a certain progression on to cover all topics in mathematics, and the students need more time to practice on each topic. Perhaps the teaching should be more adjusted to the students' needs, and better adjusted to the different students' needs and abilities. Applying the five-step method is not only facilitating for developing self-regulation competence, it also helps the teacher identify what the students in the class struggle with, and what they may need more time to work on. Taking the principle of student participation seriously, applying the five-step method may lead to a supportive and motivating learning environment with more adjusted teaching and progression and a better relationship between the teacher and the students.

Conclusion

This study has investigated how a group of eight-graders responded to the implementation of a five-step method, aimed at increasing a feeling of mastery and motivation through self-regulation. The students are unsure about how the method has influenced their learning, but the findings show increased use of various learning strategies after the intervention, and a tendency towards appreciation of the method. This may support the idea that applying this

approach facilitates for a supportive learning environment. For the students to experience improvement in the ability to self-regulate learning, it is crucial that they practice during a longer period, as research shows that developing self-regulation skills take time and increase over time.

It is difficult to make any certain conclusions based on the current study, as it is limited in scope and duration. There is a need for more extensive and longitudinal studies to be able to make more certain conclusions. Still, this study illustrates the potential of the five-step approach in mathematics classes, and this way of using this approach may be further developed in future studies.

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References

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.

De Corte, E., Mason, L., Depaepe, F. & Verschaffel, L. (2011). Self-regulation of mathematical knowledge and skills. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance: Educational psychology handbook series* (pp. 155-172). Routledge Taylor & Francis group.

Dignath, C. & Büttner, G. (2008). Components of fostering self-regulated learning among students: A meta-analys on intervention studies at primary and secondary school level. *Metacognition Learning 3*(3), 231-264. https://doi.org/10.1007/s11409-008-9029-x

Horverak, M. O. & Aanensen, M. (2019). Decreased motivation and increased mental illness among young people – a need for teaching life mastery skills in school. *The 7th European Conference on Education (ECE), Independence & Interdependence, official conference proceedings*, pp. 239-251.

Horverak, M. O. (2020). Developing resilience and life mastery skills in the classroom – a multiple case study comparing a Norwegian and Peruvian context. *The 5th IAFOR International Conference on Education – Hawaii2020 Official conference proceedings,* pp. 31-44.

Kramarski, B. & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal 40*(1) 281-310. https://doi.org/10.3102/00028312040001281

The Ministry of Education and Research. (2017). *Verdier og prinsipper for grunnopplæringen – overordnet del av læreplanverket.* Regjeringen. https://www.regjeringen.no/contentassets/53d21ea2bc3a4202b86b83cfe82da93e/overordnet-del---verdier-og-prinsipper-for-grunnopplaringen.pdf

Kaarstein, H., Radišić, J., Lehre, A. C., Nilsen, T. & Bergem, O. K. (2020). *TIMSS 2019. Kortrapport.* Institutt for lærerutdanning og skoleforskning, Universitetet i Oslo. https://www.uv.uio.no/ils/forskning/prosjekter/timss/2019/timss-2019-kortrapport.pdf

Langeland, G. M. & Horverak, M. O. (2021). *Hvordan legge til rette for mestring, medvirkning og motivasjon: i ungdomsskole og videregående skole*. Cappelen Damm Akademisk.

Mevarech, Z. & Fridkin, S. (2006). The effects of IMPROVE on mathematical knowledge, mathematical reasoning and meta-cognition. *Metacognition and Learning 1*(1) 85-97. https://doi.org/10.1007/s11409-006-6584-x

Ministry of Education and Research. (2017). *Verdier og prinsipper for grunnopplæringen – overordnet del av læreplanverket.* Regjeringen. https://www.regjeringen.no/contentassets/53d21ea2bc3a4202b86b83cfe82da93e/overordnet-del---verdier-og-prinsipper-for-grunnopplaringen.pdf

Otto, B. & Kistner, S. (2017). Is there a Matthew effect in self-regulated learning and mathematical strategy application? - Assessing the effects of a training program with standardized learning diaries. *Learning and Individual Differences 55*(1) 75-86. https://doi.org/10.1016/j.lindif.2017.03.005

Perels, F., Gürtler, T. & Schmitz, B. (2005). Training of self-regulatory and problem-solving competence. *Learning and Instruction 15*(2), 123-139. https://doi.org/10.1016/j.learninstruc.2005.04.010

Pintrich, P. B. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 451-502). Academic Press.

Ryan, R. M. & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* The Guilford Press.

Schmitz, B. & Perels, F. (2011). Self-monotoring of self-regulation during math homework behaviour using standardized diares. *Metacognition and Learning 6*(3), 255-273. http://dx.doi.org/10.1007/s11409-011-9076-6

Schunk, D. H. (2005) Self-Regulated Learning: The Educational Legacy of Paul R. Pintrich, Educational Psychologist. *Educational Psychologist 40*(2), 85-94. https://doi.org/10.1207/s15326985ep4002_3

Norwegian Directorate for Education and Training, (2020a). *Kjerneelementer (MAT01-05).* https://www.udir.no/lk20/mat01-05/om-faget/kjerneelementer?lang=nob

Norwegian Directorate for Education and Training, (2020b*). Kompetansemål og vurdering (MAT01-05).* https://www.udir.no/lk20/mat01-05/kompetansemaal-og-vurdering/kv16

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspevtive. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13-39). Academic Press.

Zimmerman, B. J. & Moylan, A. R. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 299-315). Routledge.

Aastrup, S. & Johnsen, K. S. (2014). Kartlegging og undervisning i dynamisk perspektiv. In T. S. Gustavsen., K. R. C. Hinna., I. C. Borge. & P. S. Andersen (Eds.), *QED 1-7: Matematikk for grunnskolelærerutdanningen* (bind 2, pp. 757–812). Cappelen Damm Akademisk.

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