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► To cite this version:

Trude Fosse, Troels Lange, Tamsin Meaney. Issues with using Activity Theory to understand how master's students view their research skills as contributing to their future teaching. Twelfth Congress of the European Society for Research in Mathematics Education (CERME12), Feb 2022, Bozen - Bolzano, Italy. hal-03749087

HAL Id: hal-03749087

<https://hal.science/hal-03749087>

Submitted on 10 Aug 2022

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Issues with using Activity Theory to understand how master's students view their research skills as contributing to their future teaching

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Using Engeström's third generation of activity theory, we explore three master's students' views of their completed research projects on children's argumentation in number stories as potentially contributing to their forthcoming teaching of Grade 1 students. Activity theory was chosen because it provided opportunities to consider how two different activity systems, research as part of teacher education and mathematics teaching in Grade 1, might overlap around the shared artefact of mathematical argumentation through number stories. The three interviews are analysed using Engeström's description of four levels of contradictions identified in a matrix of principles and questions. The analysis raised some issues with the use of Activity Theory to understand the master's students' learning from the contradictions between the two activity systems they were in-between.

Keywords: Master's students, research skills, number stories, third generation of activity theory.

Tensions from looking back, looking forward

From 2017, all preservice teachers for the compulsory years of school (Grades 1-10) in Norway are required to complete a five-year master's degree, but this has raised some concerns about the value to teachers of learning to do research (Smith, 2021; Aam et al., 2017). As Rørnes (2017) stated, "a research-based education must ... be built on R&D work related to real-world issues connected to being a teacher" (p. 8). Yet, there has been little research on how teacher educators could improve their practices by understanding master's students' (MSs) learning of research skills. Learning about research could contribute to expansive learning activity. For Engeström (2001), "expansive learning activity produces culturally new patterns of activity. Expansive learning at work produces new forms of work activity" (p. 139), but this sort of learning may not be able to be predicted beforehand. Non-explicit learning is common, in that "people and organizations are all the time learning something that is not stable, not even defined or understood ahead of time" (Engeström, 2001, p. 137). In this paper, we explore Engeström's (2001) third generation activity theory (3GAT) to determine its suitability for identifying the kinds of learning activity, that could occur from MSs undertaking research. We chose 3GAT because we anticipated that contradictions would appear in the interviews when the MSs discussed the two activity systems of teacher education and school mathematics teaching in relationship to their research projects.

In research, which focused on contradictions in mathematics education, Engeström's (2001) 3GAT has been used to provide insights into when and how learning can occur, when different activity systems are juxtaposed. For example, Engeström's (2014) contradictions has been used to identify the difficulties that students had transitioning from school to university mathematics (Anastasakis et al., 2020). Solomon et al. (2014) identified the contradictions raised by university students and mathematics lecturers in how they viewed the teaching of university mathematics as a way of identifying expansive learning. Whereas in the Solomon et al. (2014) paper, contradictions were between participants in two overlapping activity systems, Anastasakis et al. (2020) focused on survey

responses where students looked backwards at both their school education and their university education. Psycharis and Potari (2017) investigated the contradictions that teachers identified as they worked to develop modelling tasks that used workplace contexts. Although the teachers involved were participating in master's courses, their reflections on the role of research in their teaching practices were not in focus.

As part of a wider research project, we wanted to investigate the contradictions identified by three MSs when reflecting on what they had learnt from doing research both before they began as Grade 1 teachers and after a year of doing their teaching. It was important to understand not just the benefits the MSs saw from doing research on students' mathematical argumentation, but also the difficulties that might hinder them when they were the teacher. Part of our aim for the project was to see what we could learn as teacher educators to improve our practices. In this paper, we explore 3GAT (Engeström, 2001) as a theoretical framework for analysing interviews with the MSs before they began teaching and after they submitted their master's theses. We recognised that we were using activity theory differently to earlier mathematics education research, as we were investigating the contradictions raised, when the MSs looked forward and looked backward regarding doing research about teaching. In particular, we wanted to see whether analysing what the MSs told us would help us to identify and articulate contradictions with the teacher education activity system in which we operated. In his discussion of the Finnish health system around frequently ill children, Engeström (2001) described how difficult it can be for professions to articulate contradictions. Therefore, it was important to determine if 3GAT would provide us with relevant insights about expansive learning.

Theoretical Framework

In elaborating on his theory of expansive learning, Engeström (2001) outlined four questions and five principles. The four questions were described as being essential for any learning theory: 1. Who were the subjects of learning? 2. Why do they learn? 3. What do they learn? 4. How do they learn? The five principles were: the activity system as the unit of analysis; multi-voicedness; historicity; contradictions; and transformations. An activity system involves individual and group actions that operate together. The object of the actions is a cultural entity, formed through mediating artefacts. In the teacher education activity system, the object for the MSs was to complete a master's thesis appropriately, using number stories and research skills as mediating artefacts. In the school mathematics teaching activity system, the object was to teach mathematics appropriately, in our case mathematical argumentation using number stories and potentially research skills.

As "the object of activity is a moving target, not reducible to conscious short-term goals" (Engeström, 2001, p. 136), it is always being reformed both within an activity system and when activity systems meet. As a result, "object-oriented actions are always, explicitly or implicitly, characterized by ambiguity, surprise, interpretation, sense making, and potential for change" (Engeström, 2001, p. 134). This contributes to a multitude of views about the actions within each system, which contribute to its multivoicedness. Multivoicedness can illustrate the similarities and differences between activity systems, because there may be a cross-over in participants. Historicity, or the historical development and the circumstances of that development, of the activity systems determines the actions available. Contradictions are part of each activity system and occur when activity systems come in close contact with each other. Acting upon the contradictions could lead to transforming the activity systems or creating a new one.

Engeström (2014) described four levels of contradictions. At the primary level, contradictions occur within one constituent component of an activity system, such as when a new value system is connected to that component, but other components are not affected. The secondary level is where one constituent component is altered, requiring adjustment in other components in the same activity system. This was the focus for research, such as Psycharis and Potari (2017), where a new teaching method, integrating real-world modelling tasks into school classrooms, was introduced. The tertiary level of contradictions occurs when the object of a culturally more advanced activity system is introduced into another activity system, causing resistance within the other activity system. Anastasakis et al.'s (2020) research about the differences between school and university mathematics could be viewed as being about contradictions at this level. The quaternary level of contradictions is when it is not just the object, but also other elements of the juxtaposed activity systems that are disturbed. Engeström (2014) described this level of contradiction as “conflicts and resistances appearing in the course of the ‘implementation’ of the outcomes of the central activity in the system of the object activity” (p. 72). Solomon et al.'s (2014) research on the views of students and lecturers about university mathematics can be considered as illustrating contradictions across more components of different activity systems, not just the objects.

In examining the interviews with the MSs, we focused on the contradictions that could appear from the juxtapositioning of the two activity systems of teacher education and mathematics school teaching and so were interested in tertiary and quaternary levels. We were interested in determining where and how expansive learning could occur when research skills and understandings, from the teacher education activity system, were introduced as an object into the school mathematics teaching activity system. We wanted to determine if the interview data could be analysed with 3GAT to provide insights that could be used in reflections on our own practices.

Methodology

The MSs were interviewed a few weeks after they had submitted their theses, but before they had received their grades (grading was done by others, not supervisors). As supervisors of two of the MSs, the choice of interviewees was one of convenience. In their master's projects, the MSs had collaboratively designed and implemented a teaching task for Grade 2 students where the students were expected to develop individual number stories, or *regnefortelling* in Norwegian. A regnefortelling usually includes a written problem, a drawing and a solution, sometimes provided through a symbolic algorithm. The MSs collected the regnefortelling and interviewed students to better understand their written and oral mathematical argumentation. Each MS had analysed different aspects of the collected data to produce individual theses. At the time of the interviews, all three MSs had accepted jobs as Grade 1 teachers for the coming academic year.

The interviews were semi-structured, undertaken by the first and third authors, in a mix of Norwegian and English. All responses were translated into English. The focus of the interviews was on how the MSs saw the usefulness of their newly acquired research understandings to their future work as teachers. The analysis was done by first finding the utterances in each individual interview around one topic, that was often connected to a particular thread of questioning. Sometimes this was one utterance, at other times it was two or more consecutive utterances spread across several minutes. For each of these topic discussions, we completed Engeström's (2001) matrix formed from the four questions and five principles. We then identified where contradictions occurred and their level.

We focussed on the contradictions that the MSs described when reflecting on the juxtaposed activity systems because the MSs were in between activity systems. At the time of the interview, they had not started their roles as teachers in the school mathematics teaching activity system but had left the teacher education activity system. Thus, the MSs did not have possibilities to transform either activity system. If expansive learning were to come from reflections on the activity systems, it was for us, as teacher educators, to use knowledge of the contradictions to reconfigure, at least aspects of, the teacher education activity system, while accepting that changing activity system takes time (Engeström, 2001). Although the interviews were individual, sometimes the same contradictions appeared. As discussed in the results section, it was not always straightforward to identify whether the contradictions were at the tertiary and quaternary levels because of the complexity that surrounded the contradictions.

Results and Discussions

In this section, we first describe the discussion topics that produce contradictions at the tertiary level, then at the quaternary level, before discussing the contradictions that were not clearly one or another. In each section, the identification of the contradictions is not straight forward, requiring consideration of what Engeström's (2014) contradictions can contribute to understanding learning.

Tertiary level contradictions

Tertiary level contradictions occur, according to Engeström (2014), when an object and motive from a more culturally advanced activity system is introduced into the central activity of a related activity system. In our data, we took this to mean that tertiary level contradictions would appear when the object of the teacher education system, research skills and understanding, was introduced into the related activity system, that of school mathematics teaching.

One example of a tertiary level contradiction was when two of the MSs reflected on the use of different representations or modes in children's argumentation in their regnefortelling in their individual interviews. From their research, they were able to see how the students were helped in explaining their thinking by using different representations. For example, MS3 described how they decided to not just look at the students' writing and drawings but to interview them, as another way to understand their thinking. This was connected to having the freedom to design their research projects, "I think that is the most interesting part of the project, and also that we could do whatever we wanted to do" (Utterance 12). The valuing of different representations, thus, originated in the teacher education activity system. MS1 highlighted how having students talk about their regnefortelling could be useful in her teaching of Grade 1 students, who may not yet know how to write. Having students talk about their regnefortelling was at this point imagined in relationship to the activity system of school mathematics teaching. MS2 had similar reflections about how drawings, as another mode of representation, could support her as a teacher to understand children's mathematical thinking but also act as a mediating artefact that could help the students to think mathematically, "I as a teacher can see how they have thought, but also that they themselves may be able to see clearly how they think, that they can use drawing for themselves as a thinking tool" (Utterance 11).

The valuing of the use of different representations as tools for students' thinking arose from the MSs' research but gave the MSs insights into different practices that they could use in their future classroom

teaching, both for their own benefit but also for their students'. This could be considered an example of a reworking of what Engeström (2014) described as the established structures to do with the usual text production in schools:

This object is molded by pupils in a curious manner: the outcome of their activity is above all the same text reproduced and modified orally or in written form (summarized, classified, organized, recombined, and applied in a strictly predetermined manner to solve well-structured, "closed" problems). (p. 80)

By valuing students' thinking and supporting them to use a range of modes to engage in mathematical argumentation, the MSs would be providing their imagined, future students with culturally more advanced forms of mathematical argumentation, in which the students had more control of the kind of thinking they were doing. However, it is not clear if the MSs considered this to be a contradiction that arose as result of the object being imposed on the school mathematics activity systems. For the MSs, the contradiction may be at the secondary level in that having students make choices about how to represent their thinking, or even to think, would result in changes within the school mathematics teaching activity system as it redefined who did what in mathematics classrooms. As a result, the possibilities for using research skills to develop their teaching may be de-valued.

For teacher educators, the contradiction between the activity systems from adding research skills and understandings was more obvious in that it made us reflect on aspects of the teacher education activity system, beyond the research skills. MS2 told that in their teacher education, no one had made them aware of the value of drawings to support students to think mathematically and to show their thinking. The contradiction between the two activity systems is complex in that it was not clear if the MSs saw the valuing of other ways for students to show their mathematical thinking as being in contradiction with the existing methods or just something extra to be added on top. Yet, the implied contradiction with what was provided in teacher education can only have an impact on the teacher education activity system if teacher educators take note of what the MSs state they were missing.

Quaternary level of contradictions

Quaternary contradictions occur when there are tensions between two or more neighbouring activity systems to do with a range of constituent components. An example of this could be when the MSs discussed how they could work collaboratively when they became Grade 1 teachers. They were asked about this because all three MSs described how valuable they had found working together on their research projects, "I thought it was very positive, because it was very nice to have several master students together as well" (MS1, Utterance 62). MS3 indicated that the MSs had already thought about how they could do this:

We are talking about having these Google docs sites of all the (master's) students that are working together now, to just share ideas. And I think it will also be possible to – like take some parts of this project and try it out, absolutely. And we are in so different parts of Bergen as well, so it will be nice to see. (Utterance 40)

In the interviews, there were no reference to multivoicedness or historicity to do with either activity system, except to the other MSs' voices about their experiences of their collaboration. The traditions about teachers working together in schools, which perhaps could have had some connection to what they were suggesting, was not referred to. Without knowledge of how collaborations are expected to

occur in the school mathematics teaching activity system, the MSs did not articulate any potential contradiction in trying to collaborate across schools. On the other hand, as teacher educators, we were aware that a contradiction could arise if this form of collaboration that had occurred during research were implemented when the MSs worked as teachers. It did provide us with information that we could take into consideration in designing our future teacher education.

Contradictions that have aspects of both tertiary and quaternary levels

Some discussion topics, raised by the MSs, seemed to be between the tertiary level and the quaternary level of contradictions. One such discussion topic, which appeared in all three interviews, was when the MSs reflected on how asking students about their mathematical thinking provided them with other kinds of information than when teachers usually asked children questions in mathematics classrooms. For example, MS1 described that by showing curiosity about the students' thinking, the students talked to the MSs in a different way, "(we) said that we just want to know what you think, and in a way started talking a little bit about the number story they had, then they started talking a little more freely" (Utterance 11). MS3 discussed how this led her to understand the importance of asking the students about their thinking:

Just to talk with the students, like ... Yeah, just ask the student "oh, what were you thinking here?" That I also think is an important starter to do, and then maybe it will be easier to talk about regnefortelling together afterwards. It will start with saying it's okay to explain how you're thinking, and it's okay to not have the right answer, but it's better to know how to explain it than to have the right answer and not explaining it. (Utterance 79)

This indicated that interviewing skills from her data collection changed her ideas about what was important when talking with students. MS3 seemed to consider that the mediating artefact of doing research interviews could support her to achieve the goal of improving her teaching mathematics in school by moving beyond just being interested in the correct answer. The multivoicedness about this discussion topic can be seen when MS3 used "you" to refer to the students. There were also traces of historicity in that there is a sense that traditionally mathematics teaching has focused on the correct answer and not on the students' thinking.

Although this discussion topic is about the object of research interviews being integrated into teaching, it is difficult to know if the contradiction with traditional classroom discussion practices is likely to stay within the object component and thus be at the tertiary level or affect other components of the school mathematics activity system and be at the quaternary level. The object, research interviews, from teacher education activity system, did disrupt the object of classroom discussions in the school mathematics activity system:

I have seen that it is very interesting to talk a little more with students about how they think, than to just stand at the front and question them one by one like that, that you get more out if you ask a few questions where you can dig into a little with each individual student. (MS2, Utterance 47)

However, the complexity of implementing these alternative types of classroom discussion may mean that other components of the activity system would not be affected:

It takes a lot of time, and you have to be so focused on one student, so then you cannot have twenty students sitting there, you have to have control over them as well. So maybe you have to

collaborate with more teachers, divide into stations, do it a little differently so that you can get a little... Yes, a little help from others. Maybe also sign up for some such research projects, and ... Mhm, so you can get help there. (MS2, Utterance 54)

MS1 also suggested ways of getting the same benefits from interviewing students, while managing the rest of the class, “maybe they could have had a conversation with each other and in a way argued with each other, then. But then we must have worked with a lot of argumentation” (Utterance 33). This indicates that even when imagining alternative ways of gaining useful information about the students’ thinking, there were issues in that the students would need to be taught argumentation before they could engage in talking to each other about their regnefortelling.

These quotes indicate that the contradiction raised by valuing the information provided by the interviews was in conflict with the MSs’ understanding of the realities of classrooms, which would not allow for individual interviews and where argumentation needed to be taught before students could use it. At this point in their careers, the historicity to do with mathematics classroom teaching had provided the MSs with a view that their main job was to ensure all students in the class were occupied appropriately, making it difficult to do individual interviews. However, identifying the contradiction between wanting to hear about students’ thinking and keeping all students occupied made the MSs imagine potential solutions. The MSs seemed to say that the contradiction could affect several components of the school mathematics teaching activity system, but their suggestions for implementing alternative approaches seemed uncertain. This could be because the MSs were not yet working as teachers so imagining system level changes was difficult and, as Engeström (2001) stated, transforming activity systems is a collective endeavour, taken over time. Nonetheless, the multiple voices about the school mathematics teaching activity system for these MSs now included the researcher voice, which allowed them to query a focus on the students having the right answer.

The MSs’ suggestions of alternative ways of hearing about students’ thinking suggested that the contradiction was at the quaternary level because more components than just the goal of the activity system were discussed. However, it is not clear if this could lead to school mathematics activity system changing. For the teacher education activity system to change, we as teacher educators need to also reflect upon what the MSs described as difficulties in the implementation of new practices around listening to students’ mathematical thinking.

Conclusion

Although activity theory has been used in different mathematics education projects (Anastasakis et al., 2020; Psycharis & Potari, 2017; Solomon et al., 2014), our analysis had a different purpose. We wanted to determine if it could provide useful insights from MSs’ interviews that could help us to reflect on our work as teacher educators. 3GAT did provide insights on how the MSs considered research understandings and mathematical argumentation using regnefortelling from the teacher education activity system, could be integrated into the other activity system, school mathematics teaching. In Engeström’s (2001) description of a project with Finnish health care system, there was a need for participants to be able to articulate the contradictions across activity systems in order for possible alternative practices to be designed. MSs did not always seem to identify a contradiction between the activity systems. As teacher educators, we could identify the contradictions but the connection to how to change our practices and connect them to the school mathematics activity

system was not clear. Some of these issues may be with the data rather than with 3GAT. As the MSs were not yet in the school mathematics teaching activity system, they may not have been able to imagine difficulties often associated with implementing new practices in schools (see for example, Psycharis & Potari, 2017). The value of 3GAT was that the aspirations, challenges and obstacles, that the MSs identify, are reconfigured from being problems of individuals into what they should be perceived as, i.e., tensions and contradictions in and between activity systems. This provided other insights, which had the potential to contribute to more substantial changes in the activity systems.

Acknowledgment

The data for this project came from the Learning about Argumentation for Critical Mathematics Education in multilingual classrooms (LATACME) funded by the Research Council of Norway.

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