Ways of constructing competence – the cases of ”mathematics” and ”building and construction”

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In this paper I investigate different learning situations in the vocational programme ”building and construction” in upper secondary school in Norway. The aim is to illustrate that what it means to be competent is constructed differently for the same students in (1) the mathematics subject and (2) the building and construction subjects within this vocational programme. Differences are conceptualized in terms of agency, accountability and authority.

The high dropout rate from vocational programmes in upper secondary school is a part of current public debate in Norway. Grade statistics indicate that mathematics is the hardest common core subject for students in vocational education (Utdanningsdirektoratet, 2015), and the subject can thus be determining for the students' completion of vocational education. There is currently a national emphasis on making common core subjects *more relevant* for vocational students in order to decrease dropout (Utdanningsdirektoratet, 2014).

Several international studies have focused on mathematics in school and at the workplace, showing differences in the use of mathematics in the two environments (e.g. Williams, Wake & Boreham, 2001). In Norway some studies have focused on how students in vocational upper secondary education work on workplace related tasks in mathematics (e.g. Sundtjønn, 2013). However, I have not so far been able to find studies that have inquired into what it really *means* to make mathematics more relevant for students in vocational upper secondary education in Norway.

The data and analysis in this paper draw on a case study directed towards the educational programme ”building and construction” in the first year of upper secondary school in Norway. In this case study, I explore learning situations in both (1) the mathematics subject and (2) the programme subjects (meaning subjects directly related to building and construction, for instance the subject ”production” at the school's workshop). I refer to these two environments as different learning communities. Early in the investigation I noticed that the

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way competence was constructed seemed to be different in the two learning communities. The analysis of learning situations in the two learning communities showed that differences in what it means to be competent are seen in: (1) How new knowledge or new ideas enter the community, (2) how students work on tasks in order to be considered competent and (3) how competence is measured in the end products. In this paper I will focus on the part of the construction of being competent that has to do with how new knowledge or ideas enter the community. I will discuss the following question: In learning situations in ”mathematics” and in ”programme subjects”, what characterizes the student role in the process of constructing competence?

Theoretical framework

My framework for analysing competence draws on Gresalfi, Martin, Hand and Greeno (2008). This framework differs in substantial ways from e.g. Kilpatrick, Swafford and Findell's (2001) *strands of mathematical proficiency*. These strands are associated with desirable cognitive changes *in* children so that they can be successful in mathematics. The framework presented by Gresalfi et al. (2008) takes a more collective view. Here competent participation can be seen in “what students need to know or do in order to be considered successful by the teacher and the other students in the classroom” (p. 50). It is important that what counts as *being competent* gets constructed in each classroom, and can be very different from one classroom to another. Thus competence is not only seen as something the student ”has”. Gresalfi et al. (2008) imagine that a *system of competence* exists in classroom activities, and that this system is constructed by negotiation of three aspects:

> [W]e refer to a *system of competence* that is constructed by participants in their practice. This system of competence gets constructed as students and teacher negotiate (1) what kind of mathematical agency that the task and the participation structure afford, (2) what the students are supposed to be accountable *for* doing, and (3) whom they need to be accountable *to* in order to participate successfully in the classroom activity system.
>
> (Gresalfi et al., 2008, p. 52)

Gresalfi et al. (2008) use the term *agency* to refer to how students act, and how they are getting opportunities to act, in the classroom. They draw on Pickering (1995), who proposes different kinds of agency. *Human agency* is associated with attributes such as choice and discretion. *Disciplinary agency* is associated with human passivity, and is characterized by series of manipulations. For instance a person is exercising disciplinary agency in the phase of using well-established procedures (from the discipline) and following predetermined steps. Boaler (2002) uses Pickering's (1995) disciplinary agency to characterize

”traditional classrooms”, where students follow standard procedures of the discipline. She associates ”reform classroom” with students exercising an interplay (or *dance of agency* (Pickering, 1995)) between human agency and disciplinary agency. Here students use their own ideas and methods, and they are positioned to critique others' ideas in addition to using more well established methods from the discipline (Boaler, 2002).

The concepts *accountable for* and *accountable to* are the other dimensions that Gresalfi et al. (2008) use to analyse systems of competence. I will make use of their concept *accountable for* in this paper. This concept refers to what students are accountable for knowing or doing in the community.

Another relevant concept is *authorship.* Who are the authors of ideas and knowledge in a community? Povey, Burton, Angier and Boylan (1999) separate between two epistemological perspectives important when analysing pedagogical practices in classrooms, *external authority* and *author/ity.* They claim that viewing classroom experiences through this lens will help us understand how students experience pedagogical practices. *External authority* is associated with experiences of the authority as external to the students and belonging to experts.

> Meaning is taken for given and knowledge is assumed to be fixed and absolute rather than contextual and changeable. The knower is deeply dependent on others, especially authoritative others.
>
> (Povey et al., 1999, pp. 233–234)

The contrasting perspective is that of *author/ity.* This perspective is associated with students experiencing themselves as “members of a knowledge-making community” (Povey et al., 1999, p. 234). The power here is more distributed, and the students' voice is given primacy. Knowledge is not seen as given, but constructed in the community. External sources are consulted, but students are responsible for being critical of these ideas. The students in the community are themselves *authors* of ideas and knowledge. Knowledge in this perspective is contingent and contextual (Povey et al., 1999).

Methodology

The research is situated in a constructionist paradigm where social phenomena and meaning are continually constructed by the social actors involved (Bryman, 2008). The design used is multiple case study (Stake, 2006), where intrinsic interest in exploring present cases is of importance. The study is of an exploratory character, and the aim is to represent the cases explored, not the world (Stake, 1994). Students in one class enrolled in the educational programme ”building and construction” are the subjects of the study. The units of analysis are these students' *participation and their experiences related to participation*

in the mathematics classroom, and in the programme subjects. The two contexts are considered as different cases, even though the same students are present in both. There are different teachers in the two communities.

The school was chosen because it was a large upper secondary school having both university-preparatory and vocational programmes. It was of importance that its location made it possible for me to spend substantial time on site, offering more opportunities to learn (Stake, 1994). The school's willingness to participate was also crucial. The class in the study consisted of 14 boys at the age of 15 to 16. I have no indication that this class was outstanding in any way. The class was followed for one year, in both the programme subjects and in mathematics. Data were collected mainly by use of participant observation and semi-structured interviews. I also collected students' work. Mathematics lessons and interviews were audio taped. Audio recording was however not practically possible in the workshop where there was a lot of noise and students were constantly moving. Data from lessons in the programme subjects were therefore gathered by taking notes and pictures during observations, and by audiotaping discussions and interviews with students and teacher during or directly after the lessons.

In the analysis I have followed Postholm (2010) in separating between a *descriptive analysis* where the data are structured, and a *theoretical analysis* where substantive theory is used to analyse parts of the material. In the descriptive analysis, each case was analysed individually by use of constant comparison (Corbin & Strauss, 2008). The aim was to explore what it meant to be competent in the two different communities. This part of the analysis was highly inductive, trying to set aside preconceptions. One core category that emerged from each community concerned how new knowledge entered the community. This was "Use the teacher's method" from the mathematics classroom, and "Giving ideas and being critical" from the programme subjects. In the following I will use the theoretical framework described in the previous section to interpret some of the data from these core categories. This is then a part of the theoretical analysis.

Constructing competence: different learning situations

Use the teacher's methods: an example

The examples in this section are taken from audio taped observations in the mathematics classroom. The mathematical theme for the lessons chosen for illustration is percentages. The teacher's aim for the lessons is presented to me in an interview the day before class as follows.

> When I calculate with percentages, I often think that you have the percentage, the part, and the whole. [...] [The aim is] to teach them three methods

> for finding how much it is if you have a certain percentage of something, and to teach them to find the percentage ... and to teach them to find the whole if you have the part and the percentage. [...] The aim is that after the two lessons tomorrow they are able to separate between those three ways to calculate.

When the teacher formulates that the aim is "to teach them three methods" this says something about *authority*. It lies with the teacher, and is thus *external* to the students. Meaning is also fixed, and the three fixed methods are what the students are *accountable for* knowing.

The first method is introduced to the students in the following way:

Teacher: We have three operations related to percentages that we have to learn. One of the methods, one of the things we have to figure out [...] is to find how much for example 20 % is out of 200 kr [Norwegian kroner, NOK]. [...]

Students: 40

Teacher: Yes, some sees this quite easily, and some needs a way to do it. What I think is best, is to find the percentage factor.

Here it is evident that a few students have solved the mathematical task, but the teacher shows no interest in how the students thought to come to this solution. The teacher claims the *authorship* for the mathematical idea by showing the class what he thinks is the best way to proceed. The students' voices are silenced. *Authority* is *external* to the students. The teacher continues (following directly from the excerpt above):

Teacher: What is the percentage factor in this case? How can I find the percentage factor?

Student A: Divide or multiply?

Teacher: Yes, how to get from percentage to percentage factor?

Student A: Divide ... or ... Multiply!

Teacher: No, what have I done here? [Points to an example for calculating percentage factor on the blackboard.]

Student A: Then I divide.

Teacher: Yes! Then ...

Student A: You reacted so I switched!

In this section the teacher is guiding the students through his own method for finding how much a certain percentage of an amount is. When the students can't answer the question about how to find the percentage factor, the teacher points to an earlier example and a procedure authored by the teacher himself on the blackboard. Again authority is external to the students. The *agency* can be termed *disciplinary*. Instead of giving attention to the meaning of the concept "percentage factor", the teacher forces the attention back to the predetermined steps on how to perform the calculation. The last utterance from the student

"You reacted so I switched" is reinforcing the epistemological perspective of *external authority*. The student is not sure how to find the percentage factor (or what percentage factor really is) and is using the teacher's reaction to decide whether the right operation to use is dividing or multiplying. This indicates a view that knowledge is fixed, and that the teacher holds this knowledge.

The teacher goes on presenting the steps in his method:

Teacher: Yes, that's fine. But it's only you [still in conversation with Student A] who are responding. I would like others to participate as well. [...] Divided by 100, right? Make the percentage factor. So the percentage factor is 20/100 (writes on the blackboard) and that is 0.20. [...] And then we are going to use this further on, because we have the percentage factor. And if we are going to find how much 20 % is out of 200 kr [...]. We find it by taking the 200 kr and multiply [...] multiply by the percentage factor. [...] Now, someone has given the answer several times. What is it?

Students: 40

Teacher: 40 kr, yes. [...] One of the methods we should know is to find how much a certain percentage is out of something. If you are going to find how much 70 % is out of the students in this class, you should be able to find that.

Student B: Then we divide by 100 and multiply by 70.

Teacher: Yes, take the amount – you have to know it. Then it is just to take the amount you have and multiply it by the percentage factor. Then you find how much it is.

As the teacher says, the answer to the teacher's original task has been given several times. But the main purpose has not been to find a solution. It has been to present the *teacher's method*. In the last excerpt the teacher is formulating a similar task as the one given before, but one student (Student B) shows another way of thinking. The teacher acknowledges this way of thinking weakly by saying "Yes, [...]", but quickly draws the attention back to his own solution path. Again he claims authority, and reinforces the epistemological view of *external authority* in this learning situation. The student who presents an alternative way of thinking is silenced.

In this lesson the teacher first presents his three "methods" in the same manner as shown above. For the rest of the lesson, the students are occupied with solving tasks related to use of the three methods. This approach is typical for the lessons observed in mathematics.

Giving ideas and being critical: an example

An agro-technical exhibition was arranged in the school's neighbourhood and the class was asked to construct some equipment for this exhibition. The order was to construct a stage, rail fences and signboards. The activity was quite complex. I have constructed narratives of how students worked, building

on observations in the workshop and interviews with both students and the building and construction teacher.

The order from the customer is presented to the students, and the teacher engages the whole class in making strategies for how to build the stage. The order is to make it 6 m long and 3 m wide. The teacher suggests that they make the stage using Euro-pallets that they put close together in layers. Then they will cover the Euro-pallets with plates on the top and on the sides. It is emphasized by the teacher that it is important to cut as few plates as possible for economic reasons (make it possible to reuse plates). How many Euro-pallets do they need to order? How are they going to put the Euro-pallets together to make the stage as stable as possible? How are they going to join together plates on top to make the stage stable, and at the same time cut as few plates as possible? The whole class is divided in groups, and they are asked to come up with possible strategies.

When groups are asked to come up with solutions they are given *authority* in the form of *author/ity*. Engaged in teamwork, students discuss ideas or strategies. Here more students get a voice, compared to full class situations.

The different groups' solutions are presented to the class. Every idea is acknowledged and considered. All students are responsible for evaluating the different solutions, being attentive to economics and stability.

In terms of agency in general, this phase of the work can be characterized by *human agency*. The students are engaged in processes of presenting solutions, being critical and making decisions. The activity requires more from the students than following a procedure. They are trusted to contribute with their professional knowledge, strategies and critique. Here it is not the teacher who holds the (one) solution. Authority for making solutions is distributed to all the students, and the activity is guided by students' voices and *students' author/ity*. In this activity students are *accountable for* providing professional knowledge, making suggestions for possible solutions, being critical and participating in decision making about which plan to follow.

When the class had decided how to make the stage, agency is shifted more towards *disciplinary agency*. The plan is made, and the students have to get hold of Euro-pallets, put them together, cut plates and assemble the stage.

Work continues on the stage, but more planning and work is needed elsewhere. The teacher teams up four students to make the fence components. One of the students in this team explains:

> We were provided with one of those rail fences that we were supposed to make more of. So it was eight that we had to make. So we had to find a way to make them, the easiest way possible.

The students are given the template, but as they say, they have to "find a way to make them". The students are given time and responsibility for making the fences, including finding out how to do so. In this activity the students are given *author/ity* to author their own solutions to a given task.

Figure 1. *The rail fence component template given to students (in front), and fence components in progress made by students (behind)*

One practical problem was that the students did not have a milling machine to make the trace seen in the bottom board in figure 1. One of the students explains how they used available tools and materials to find an alternative solution:

Student C: [...] So we came up with a solution to bind it together in another way.

Student D: We used 2" x 8" [Student H: For the bottom.] and then we cut ... So we put one of the poles down, and then we used a compass saw to cut around it. [...]

Christina: Who was it that ... Did you figure this out all by yourselves?

Student C: The teacher was there, of course, but ...

Student D: We came up with this. That we could use 2" x 8" and… Was it 3"?

Student C: 2" x 8" here and there is 2" x 3" on the top, which we made the cuts in. In this way we are building upwards on this [refers to the 2" x 8"]. [...]

Student D: Yes, so this one [refers to the fence rail made by the students] is way more stable than the one we got [refers to the template].

The students here claim *author/ity* for finding the solutions in saying "We came up with this". The knowledge is locally constructed by the students, under local conditions. It follows that the activity can be characterized by *students' agency*. At the time students were given the task, there were no predetermined steps to follow. They had to find the best way to deal with the practical challenges. At the same time they had in mind professional standards (stability) when doing this work. The students were *accountable for* finding solutions or make a plan, and to make a good product. They had to make use of their own knowledge about tools, materials and constructions to so. The last utterance from student D, shows pride and ownership to the solution.

After solving the practical issues and after having made the first rail fence component, the activity shifts character to more *disciplinary agency*. The

students claim that they used four hours to make the first component, and used less than a day to finish the last seven.

Not all activities in the programme subjects have the same authentic degree as the ones described and the students are not always given this much responsibility. Students have to learn to use tools, for example, and are involved in activities where the teacher is more instructive. However, I have tried to illustrate that in the workshop I see students being involved in activities were they are positioned to exercise a considerable degree of freedom and discretion.

Conclusion

The tasks and the ways that the teacher is leading the communication in the mathematics classroom leave little room for human agency such as opportunities for students making choices or showing or sharing insights. *Agency is disciplinary* and for the students "associated with human passivity and characterized by series of manipulations" (Pickering, 1995, p. 115). I have argued that students are *accountable for* knowing the teacher's method, and that the *authority is external* to the students in this learning situation.

In the episodes from the building and construction workshop I will characterize agency as a *dance of agency*. As described above both elements of *human agency* and *disciplinary agency* are in play. Responsibility for authoring solutions is to a large extent given to students, so the community have a high degree of students' *author/ity*. The students were *accountable for* making plans and critically finding solutions according to both professional standards and local conditions.

During the whole study it became clear that making the mathematics subject more relevant to students, can be more than giving content a vocational flavour. It can also be about changing the classroom interaction to support identities of autonomous future workers, giving room for students' agency and author/ity. This can be important for two reasons: (1) In mathematics the students' observed identities can be associated with roles as "received knowers" and a lack of agency (Boaler, 2002). This can be problematic and alienating especially when students' experiences with what it means to be competent in building and construction (their preferred profession) is connected to their ability to exercise agency and *author/ity*. (2) Boaler (1998) inquired into two schools where one used a traditional, textbook approach and one used open-ended activities in mathematics. She showed that in the school with the open approach, students needed to think for themselves, interpret situations, choose, combine and adapt different procedures. These characteristics give me associations to *human agency, author/ity* and the "programme subjects". Boaler (1998) concludes that this kind of working and thinking gives students an advantage when they need to solve problems in new settings. This is highly relevant for future workers.

A consideration of how mathematics in vocational education can be more supportive for the students' professional identities as autonomous workers and better prepare the students for the demands of problem situations in the real world could be an interesting avenue for future research.

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