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# What can be learned from mathematics teachers' experiences who teach an interdisciplinary STEM course

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*In the Netherlands, it is common that teacher training courses for upper secondary education educate for a single school discipline, such as mathematics. At the same time, teachers with a mathematics qualification are also formally competent to teach an interdisciplinary school course called Nature, Life and Technology (NLT), regardless whether it has been addressed in the teacher training programmes. However, teaching NLT is substantially different from teaching mathematics with respect to, for instance, pedagogy and objectives. In this paper we report on a study on experiences of mathematics teachers who, in addition to teaching mathematics, teach NLT. The experiential knowledge is meant to inform mathematics teacher educators who prepare students for interdisciplinary courses such as NLT.*

*Keywords: mathematics teachers in STEM, secondary education, teacher education, interdisciplinary*

## **Introduction.**

In the Netherlands, most teachers in secondary education are trained to teach a specific school discipline, such as mathematics. Although cooperation between and integrating of school courses are frequently encouraged in the Netherlands (Folmer, Koopmans-van Noorel & Kuiper, 2017), teachers collaborate mainly with colleagues of their own discipline, unless there is a need for cross-curricular collaboration within a school, due to thematic project work or a specific course. One course in which this is different is the interdisciplinary STEM course Nature, Life and Technology (NLT).

Nature, life and Technology is an elective course in upper secondary education. The objectives of the course are to strengthen the cohesion between science and mathematics and to increase the attractiveness of science education (Stuurgroep NLT, 2007). In this course, students work on complex real-life problems for which they need knowledge from mathematics, physics, chemistry, biology and physical geography to solve these. The course has a modular structure. With each module, students are working on new problems around a topical issue using teaching materials developed through collaboration between teachers and universities or organizations specialised in the topic. Teachers work within a team of teachers with different competences and backgrounds, mainly mathematics, physics, chemistry, biology and geography. Such team of teachers is called an NLT-team.

Teachers who participate in these kinds of activities are confronted with other learning and teaching situations as in their disciplinary course and as a consequence will have to relate to these experienced differences. For example, NLT requires attention for overarching ideas such as the interplay between

the natural sciences and technology, and not merely attention for specific disciplinary concepts, such as finding an exponential formula given two points. The usual pedagogical approaches in NLT are also different from those in mathematics school courses, since a lot of coaching of group work is done in NLT. In addition, NLT often uses different assessment formats than the exercises that are customary in mathematics (Den Braber, 2020). Knowing that there are such differences between the courses, it can be argued that mathematics teacher training should prepare future teachers for teaching NLT and for dealing with these differences. Especially, when these differences should indeed be dealt with according to mathematics teachers that teach NLT and knowing that it is considered important that mathematic teachers participate (Stuurgroep NLT, 2007).

However, it has become clear that preparation for NLT is marginal in most mathematics teacher training programmes. Consequently, dealing with the differences will in most cases have to be learned after the teacher training course, during working life, if a teacher chooses to participate in NLT. However, opting for teaching NLT requires some lived experiences in NLT and experiencing the differences with teaching mathematics. However, it is known that mathematics teachers do not seek such experiences in working life easily. Mathematics teachers participate less in NLT than teachers of the other related disciplines such as physics or biology (Den Braber et al. 2020). Mathematics teachers indicate that they do not always see a role for themselves in NLT. Teachers who are unfamiliar with NLT may find it difficult to envision what is required to teach NLT and compare teacher requirements to their own knowledge, skills and attitude to determine whether participation is even feasible, let alone appealing. Teachers who have taught NLT will have formed an image of what is required to teach a course such as NLT and will have found ways to act accordingly.

Despite the fact that mathematics teachers currently participate less in NLT than teacher of sciences, there are some mathematics teachers who are successfully part of an NLT-team. The fact that it is possible and can be successful raises the question whether we can learn from the experiences of these mathematics teachers to help prepare future mathematics teachers. It is this question that led to a study with the underlying research question: How do qualified mathematics teachers shape their role within a NLT- team and deal with mathematics in NLT?

In this paper we will describe results regarding to what the experiences teach us about the possibilities for mathematics teacher training programmes to enable lived experiences in teaching NLT for future mathematics teachers.

## **Conceptual framework**

Analysing the experiences of a teacher within NLT requires a framework that describes a learning process of a teacher in his or her work in the broadest sense. It is not only about the knowledge of the teacher but also about the actions, feelings, motives and foresight within the context of a person's working environment. Roth & Lee (2007) indicate that cultural-historical activity theory (CHAT), because of its focus on processes and individual and collective agency, can be the analytical lens for learning processes in lifelong learning, both in formal and informal (work) situations as well as in educational settings.

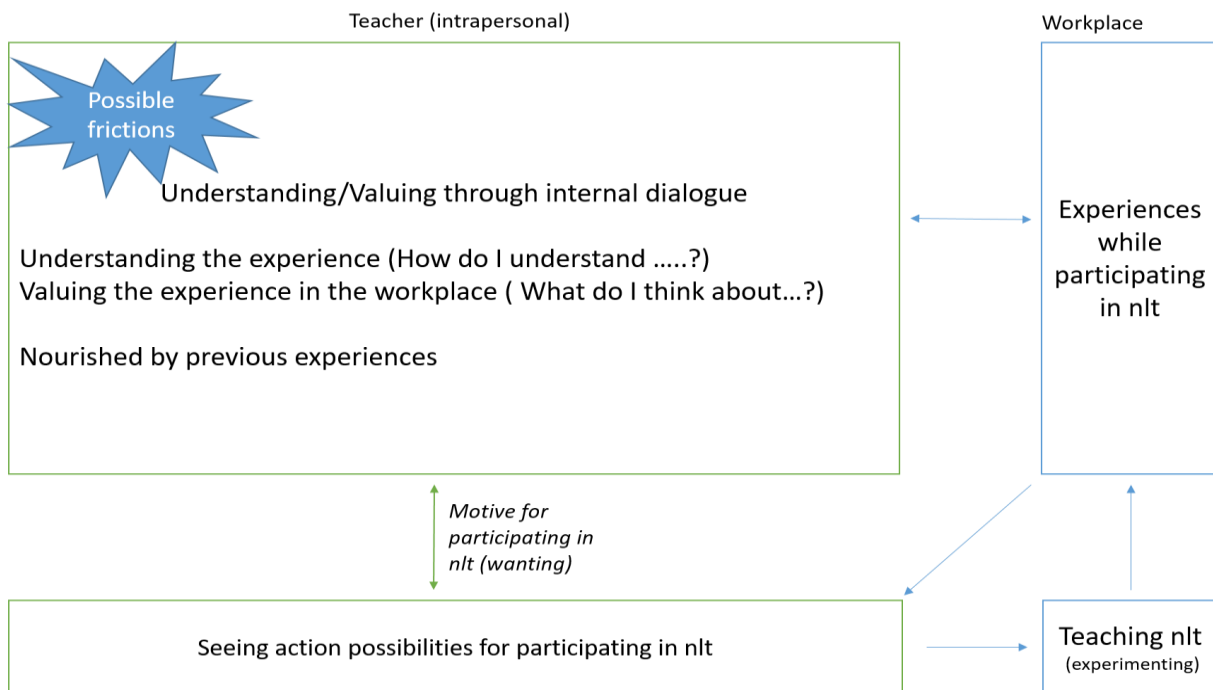
It is for this reason that we make use of a CHAT-based analytical perspective on learning processes while engaged in work processes (Mazereeuw, 2020). This perspective depicts a process in which

experiences at the workplace are internalised (Zittoun & Gillespie, 2015) and, depending on the interpersonal dialogue are stimuli for envisaging new action possibilities and actions within the work process. Acting on these new perspectives and action possibilities through experimenting can also create new experiences. Hence, experiential learning processes are not linear. Because of the reciprocal nature of the interpersonal process and the social and material consequences in context it is much more dynamic. To emphasize the reciprocal nature of the process we included insights of the Dialogical Self Theory (Hermans, 2001).

The idea of the dialogical self is that a person mirrors experiences with ones knowledge, perspectives, norms and values in an internal dialogue and that these experiences can be re-lived and re-framed beyond the actual experience itself. So, the internal dialogue is an interpersonal process -within the mind- in which a person relates to the lived and re-lived experience. CHAT emphasizes that an internal dialogue can result in the desire to act, especially when frictions are experienced. For instance, a person perceives that contributing to the work calls for knowledge and skills that the person does not feel confident about. When that person wants to continue to participate in the workplace, new action possibilities will be sought out. Therefore, frictions, or the commonly used term contradictions, are often a source of change and development as described by Engeström (2011). We tried to capture the internal dialogical process in four compact questions someone asks aware or unaware. The first question is 'How do I understand what is going on (with me, others in the environment)?'. Understanding includes ones own perceptions of knowledge of the workplace, division of labour and workplace goals, norms, emotions and values. The second question is 'How do I value this?'. Here a person mirrors this conception of the experience with what matters to the person, what the person finds important. The third question is 'Should I do something about this or not?'. This question refers to the motive to become an actor and to contribute to the workplace. The fourth and final question reads 'What can I do to contribute and/or to engage the friction?'. This question refers to the way a person depicts his or her own role in the situation and how that person envisages action possibilities that might help to contribute to a solution or to engage the friction.

The questions above show that this process may well be influenced by previous work and teaching experiences. That is probably also the case for NLT teachers who have experiences in another school course or have worked in different fields before entering the educational system. Figure 1 schematically represents the dialogical processes when interpreted for teaching NLT.

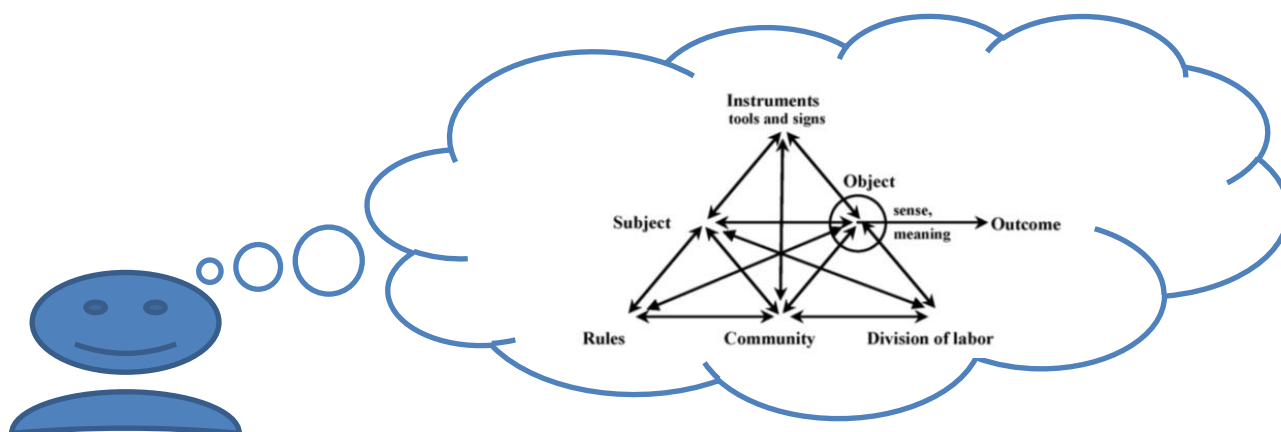
In order to provide insight in the possible frictions that initiate internal dialogue in teachers we conceive teaching of NLT as an activity within an activity system. To portray the activities we make use of the commonly used model of Engeström (1987), which builds on the ideas of Vygotsky and Leont'ev. The model shows that human action can be seen as an interaction between a person (*subject*), a certain goal (*outcome*) and cultural artefacts that support and shape this action (*mediation*). Furthermore, the goal-directed actions of an individual cannot be separated from its social and material context. An activity system consists of relevant others (*community*), with values and norms (*rules*) and with a division of labour.



**Figure 1: Processes of learning through experiences, based on Mazereeuw (2020) exemplified for teaching NLT**

Unlike Engeström, we use the model as a means for portraying a teachers' thinking about the activities in which they participate, shown in figure 2. As indicated above, a person ones social and material work environment and places oneself within it. In this study Engeström's model is used to guide the data collection and analysis and find out how teachers think about their own discipline and NLT and the frictions therein. Teaching NLT in a secondary school can be conceived as a goal-oriented activity in an activity system in secondary education. This is done by using certain teaching materials and supportive (digital) resources (*instruments*) which are in accordance with a national examination program and a plan for assessment, etc. (*rules*). Teachers are part of a professional group of teachers. They have to deal with parents, colleagues within the school who all want NLT to be taught (*community*). Mathematics teachers can be part of an NLT-team which is another community with another set of (informal) rules, and another division of labour compared to the activity of teaching mathematics.

The outcome of the activity deserves a closer look because the outcome of the activity system NLT is still ambiguous. Even though there is an examination programme, it leaves a lot of room for teachers and NLT-teams to formulate their own objectives, objectives that they feel are fitting for NLT. Moreover, Braber et al. (2019) made clear that the general aims of NLT are still debated on and when it comes to mathematics in NLT are not clear to both mathematics teachers and students. So, looking at the way teachers view NLT we can assume that the outcomes pursued are diverse. It is therefore of interest to find out what mathematics teachers view as the outcome of teaching NLT especially with regards to the role of mathematics. In school mathematics learning mathematical skills is seen as the outcome of the activity system. Within NLT mathematics can be described as an instrument, a means to an end. William and Roth (2019) claim that the more disciplinary courses are a goal by itself, the more difficult it becomes to work interdisciplinary.



**Figure 2: The envisaged activity system by the NLT teacher of the activity in which the teacher participates.**

We started with the idea that through an internal dialogue a person mirrors experiences with ones knowledge, perspectives, norms and values. We portrait the envisaged activity using the model of an activity system where the teacher is the subject.

### **Data collection and analysis**

In order to find out how qualified mathematics teachers shape their role within a NLT- team and deal with mathematics in NLT six male and four female qualified mathematics teachers all teaching NLT were interviewed. The teachers varied in age, work and teaching experience and work in different schools around the country. Following the first interview, an additional interview was conducted with a second member of the same NLT-team to triangulate the data of the first interview and evaluate the interview set-up. This led to small changes in the preferred order of the interview questions.

The interviews were meant to provide insight into how mathematics teachers conceive their role within NLT and what thoughts existed about the role of mathematics within NLT. Questions were asked about frictions that teachers experience when teaching NLT, and whether or not these were due to possible differences with the teaching of mathematics. We also asked how they have dealt with these frictions.

The interviews had the character of a conversation about NLT in which the interviewer also provided information about NLT and gave background information when needed. For example, sometimes the teachers asked questions about the organisation of NLT in other schools. The interview can best be characterized as a semi-structured interview. The interview set-up contained a number of topics and questions related to the conceptual framework. The order in which the questions were asked depended on the course of the interview. However, it always started with a few practical questions about background, teaching experiences, current teaching tasks and past work experiences. This was followed by questions about the experience with NLT, their role in the NLT-team and the possible differences between activities when teaching mathematics and NLT. For example, they were asked whether they experience differences in the use of teaching materials or teaching methods (*instruments*), collaboration with colleagues (*division of labour*) and which agreements concerning NLT have been made within the school (*rules*). When frictions were put forward by the teachers,

questions were asked about the teachers' views of knowledge, skills and attitude towards interdisciplinary teaching and NLT. The role in the NLT-team and the connection between curricula of mathematics and NLT were also addressed. The interview ended with questions that invited the teachers to talk about their thoughts on the role of mathematics in NLT.

The recorded interviews were transcribed. Semantic units (Aviv, 2001) were categorised using elements of the activity system, and the labels (personal) beliefs, knowledge and skills and attitude towards NLT based on a division by Ernest (1989). For instance, a teacher stating which teaching materials are used in the classroom is labelled under *instruments*. Frictions experienced by teachers were noted as well as previous experiences when stated by a teacher. For instance, the following semantic unit illustrates an experienced friction concerning the subjects knowledge for teaching NLT compared to teaching mathematics.

Teacher: Mathematics, you can just ask me about that, I know it, but with NLT I sometimes doubt my answers are completely correct. [...] makes me less comfortable.

Data analysis further focused on the role of each mathematics teacher within NLT. First, we looked at their view on the role within the NLT- team to see if there are similarities or differences. Then we looked at the relationships between how teachers describe their own teaching in NLT and what they see as objectives for NLT. i.e. the subject-instruments-object/outcome relationship. A third analysis focussed on each teacher's orientation towards the objectives of NLT. The emphasis was the teachers' views on intended objectives of mathematics within NLT and views on the overall objectives of teaching NLT. A fourth analysis concerned the frictions each teacher experienced. All frictions mentioned by the teachers were gathered and positioned in an activity system to see if there were similarities or differences in the experienced frictions. Peer-debriefing was used in the process of coding and interpretation.

## **Results**

When we look at division of labour in the NLT-teams, the role of the mathematics teachers vary from teaching a statistical module by themselves, to teaching a science module with a physics teacher. Some are teaching modules with a strong biological component involving the brain or navigation of birds which they had to make their own. With the exception of one, the teachers seem comfortable with what they do because of earlier experiences in which they have acquired knowledge or skills before teaching NLT. The one teacher that was not comfortable assisted teachers from other disciplines only for a few lessons. She was asked to help students with differential equations and modelling with in a spreadsheet. This teacher felt a friction due to her view of her own knowledge of science and the lack of overview of the teaching module.

NLT is seen as a course where mathematics is applied and where mathematics can be useful, especially with regard to mathematical modelling to help solve the problem at hand. So the view of most teachers seems to be consistent with the objectives of NLT. However, often the teachers thoughts of these objectives themselves and their personally desired outcomes do not always correspond with the intended curriculum of NLT. Teachers seem to formulate their own objectives as the formal objectives of NLT are not really known. The latter is specifically the case when it comes to the use of mathematics or the reflection on the role of mathematics in the examination program.

Most teachers are not familiar with objectives in NLT that focus on the importance of mathematics. The ones that do report difficulties translating this for students.

The frictions teachers experience also seem to vary. Much of these frictions have to do with conditionalities. In some schools it is hard to have meetings with the NLT-team because disciplinary faculty meetings are held at the same time and require a teachers attention. Nevertheless, working with other colleagues is viewed as worthwhile and desirable even though it can take some getting used to. Working with and preparing the teaching materials of lessons in NLT generally takes more time than preparing mathematics lessons. On the other hand, teachers also seem to appreciate the freedom they get as they are free to adjust materials, add or skip parts of the content and assignments. Some experience difficulties with the motivation of students because students seem to give priority to the disciplinary courses for which they also take exams. Some teachers indicated that seeing that they only teach one or two modules a year, building a relationship with students can be more difficult than in mathematics lessons.

What stands out in the analyses is that teachers with previous experiences in actual interdisciplinary work environments or with mathematical modelling experience less frictions teaching NLT. In fact, two of those teachers commented that they experience frictions with the way they have to teach mathematics instead of with teaching NLT as it is so different to what they are used to.

## **Discussion**

The freedom to find ways to teach NLT that align with a teacher's personal point of departure has been important for teachers. Especially, since this freedom has been a way for teachers to deal with frictions they experience while teaching NLT. This may indicate that teacher training should focus on the flexibility of working with teaching materials and to encourage experimenting with their pedagogical choices. Even though this is also encouraged in mathematics teacher training, research shows that mathematics teachers are still mainly focused on the textbook (Woldhuis et al., 2018). This is not possible within NLT if a teacher wants to feel comfortable teaching. NLT offers a lot of freedom to make pedagogical choices and many different roles are possible as a teacher, but a teacher has to be aware of the objectives of NLT. Specifically, when it comes to the role of mathematics and the idea of interdisciplinary work. This may have consequences for teacher training programmes, knowing that we saw differences between teachers in dealing with interdisciplinary objectives depending on their background and work experience. This could mean taking into account the different personas in teacher training and take advantage of the lived experience with applied mathematics when present. Teacher training should also support reflection on the role of disciplinary mathematical knowledge when working on an interdisciplinary problem. Seeing mathematics more as an instrument than a 'product'. Something that the some interviewed teachers found difficult to do. Training programs could therefore pay attention to beliefs on mathematics in relation to the sciences. Starting, for instance, with one discipline that is closely connected to mathematics, like physics (Nguyen & Krause, 2020), but perhaps ending with letting students experience mathematics or mathematical modelling in corporate life or interdisciplinary working environments. This could support teachers in letting their students experience how mathematics can help with real-life interdisciplinary questions and discuss the contributions mathematics can make in solving real-life problems.

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