Chapter 11
Mathematics in an Interdisciplinary STEM Course (NLT) in The Netherlands

Nelleke den Braber, Jenneke Krüger, Marco Mazereeuw and Wilmad Kuiper

Abstract Mathematics is one of five disciplines in the successful interdisciplinary STEM course ‘nature, life and technology’ (NLT) for upper secondary education in the Netherlands. In this study the way mathematics manifests itself in the course is examined at the intended, implemented and attained curriculum. The results show that students often don’t recognise mathematics in the course or that they consider the level of mathematics in the course as too low, not interesting. Besides this, mathematics teachers seem to struggle more with their role in interdisciplinary teaching than science teachers. Some feel that there is no need for their mathematical expertise, due to the extent to which mathematics is used. Even though the course has many positive outcomes when it comes to mathematics in the course NLT not only shows diversity in practice but also raises questions we need to address if we want mathematics to be part of interdisciplinary education.

Keywords Mathematics · Interdisciplinarity

11.1 Introduction

An interdisciplinary STEM (Science, Technology, Engineering and Mathematics) course can provide opportunities for teachers to collaborate, show students cohesion between the disciplines and use real-life problems as the starting point of investigation. In the Netherlands, such a course exists with many good practices that utilize

N. den Braber (✉) · M. Mazereeuw
NHL Stenden University of Applied Sciences, Leeuwarden, The Netherlands
e-mail: nelleke.den.braber@nhl.nl

M. Mazereeuw
e-mail: m.mazereeuw@nhl.nl

J. Krüger · W. Kuiper
Freudenthal Institute, Utrecht University, Utrecht, The Netherlands
e-mail: jenneke.kruger@gmail.com

W. Kuiper
e-mail: w.kuiper@uu.nl

© The Author(s) 2019

B. Doig et al. (eds.), *Interdisciplinary Mathematics Education*,
ICME-13 Monographs, https://doi.org/10.1007/978-3-030-11066-6_11

these opportunities. However, when it comes to mathematics, in the course NLT, research not only shows diversity in practice but it also raises questions that need to addressed if we want mathematics to function within interdisciplinary education. In this paper, we describe the case of NLT to discuss these issues.

11.1.1 Background of NLT

In 2007 the course 'Nature, life and technology' (NLT) was introduced in the curriculum of upper secondary education in the Netherlands for students aged 16–18. The general aims of this interdisciplinary STEM course are to increase the attractiveness of science education for students and to let students experience the importance of interdisciplinary coherence in the development of science and technology (Stuurgroep NLT, 2007). The course is intended to supplement the existing disciplines in the Dutch curriculum: physics, chemistry, mathematics, biology and physical geography. It aims to offer both a broader and more in-depth educational programme for science and mathematics and is not meant as a replacement of other courses.

Schools are not obliged to offer NLT. About 230 schools do at the time of research (2015), which is approximately 40% of the schools in the country. For students, it is an elective course, chosen additionally to other courses and assessed by a school-based exam. More than 6000 students finish the course each year.

NLT is designed to offer more freedom for teachers and students. It allows them to choose what they find interesting and to use the potential of their local region with relevant contexts for learning, for instance, in visiting research institutes or local industry. Within the boundaries of the examination programme, teachers can select teaching materials from a wide range of compact booklets. These materials are called *modules*. Each module introduces a contemporary science problem that can only be solved by involving different (disciplinary) perspectives resulting in a context-orientated and interdisciplinary course. As a consequence, it is desired, and necessary, that the course is taught by a team of teachers, called an NLT team. Preferably one of each of the intended disciplines is represented in the team.

As described by Michels and Eijkelhof (2014) all modules were specifically developed for the course through co-operation of secondary school teachers and experts from universities, colleges, research institutes and, or, industry. The rich variety of modules is meant to contribute to student awareness of the possibilities for further education in a scientific or technological area.

During the first ten years (2006–2015) the development and implementation of NLT was funded by the Dutch department of education. In 2016 schools formed an association of NLT schools to promote further development and to maintain the quality of the course.

11.1.2 Focus of the Study

From the start of NLT, it was made clear that

> Attracting mathematics teachers to participate in such a team has priority because mathematics plays the rôle of language and/or tool in many sciences. (Stuurgroep NLT, 2007, p. 8)

In the examination programme of NLT, the nature of the course is made explicit by formulating four characteristics that should be visible throughout the curriculum (Krüger & Eijkelhof, 2010). The nature of NLT characterizes itself by 'interdisciplinarity', 'the relationship between science and technology', 'the orientation on higher education and occupations', and 'the rôle of mathematics in science'.

By denoting the rôle of mathematics as one of the main characteristics of the course a unique situation occurs. Although NLT aims to make clear to students that many different disciplines are needed to solve a problem without suggesting that any one discipline is better than another, the rôle of mathematics seems to need more emphasis. Research activities in the last few years, such as interviews with teachers, students, and developers, show that mathematics often has an exceptional position. Examples can be found in the development and use of the teaching materials and the participation of mathematics teachers in an NLT team. In interviews with NLT teachers, mathematics in NLT is often described as a 'different' story. The study presented in this paper focuses on that story.

11.1.3 Research Question

In this exploratory study, we investigate whether the objectives of the course, as described in the formal vision document (Stuurgroep NLT, 2007) and examination programme (Krüger & Eijkelhof, 2010) are met when we concentrate on the mathematics in the course and the participating of mathematics teachers. It aims to depict how mathematics functions in NLT by means of examining the current situation at different representations of the curriculum.

The underlying question is

> How are the objectives related to mathematics reflected in the curriculum of the course NLT?

11.2 Conceptual Framework

Rationales for interdisciplinary STEM courses are often based on the fact that the problems we face in today's world call for perspectives and knowledge from many different areas. The possibilities for mathematics in such a course is described by Williams et al. (2016, p. 13) as

> interdisciplinary mathematics education offers mathematics to the wider world in the form of added value (e.g. in problem solving), but on the other hand also offers to mathematics the added value of the *wider world*.

At the same time they mention that some interdisciplinary literature points out that it seems mathematics is gaining the least from integration.

Evidence for learning gains from interdisciplinary work mainly concerns students' engagement, motivation and problem solving skills (Czerniak, 2007). Even though some results show gains in achievement scores (Czerniak & Johnson, 2014) the outcomes *that will likely be affected by interdisciplinary working will be non-traditional, and non-standard* (Williams et al., 2016, p. 17). For NLT, compared to the examination programmes of the mathematics school curriculum, non-traditional and non-standard outcomes are formulated. For instance, there are no learning outcomes that describe the learning of specific mathematical concepts but they do describe the use of concepts relevant to the interdisciplinary context (Krüger & Eijkelhof, 2010). The same can be said for concepts from physics, chemistry, biology and geography. Also skills and methods required in interdisciplinary working are formulated in the examination programme. This is consistent with the fact that NLT is a context-orientated course in which authentic professional practices, or problems, are the starting point of a module. Something students seem to find meaningful (Dierdorp, Bakker, Maanen, & Eijkelhof, 2014) but is very different from the way mathematics is taught in the Netherlands in general.

When mathematics teachers start teaching NLT they are confronted with differences in the teaching practice between NLT and their familiar mathematics course. Aims, course structure, learning activities, pedagogy, and content can all be different from what they are used to working with. Moreover, knowledge of other school courses and pedagogy is required, such as practical work.

There are various factors that have an impact on attempts to implement interdisciplinary curricula (Czerniak & Johnson, 2014; Venville, Rennie, & Wallace, 2012). Some factors, such as curriculum and testing constraints, and lack of suitable materials, have little impact on NLT, or are not specific to the manifestation of mathematics in NLT. However, teacher content knowledge, and teacher beliefs and attitudes, seem to need consideration when implementing NLT as NLT teams consist of teachers with very different backgrounds.

This is supported by the study of Rıordain, Johnston and Walshe (2015). Teacher perspective, teacher knowledge of the 'other subject', technological pedagogical content knowledge (TPACK), and teacher collaboration and support, were found to be key aspects that have an impact on the integration of mathematics and science teaching and learning. Strategies for collaboration and team work as well as a deeper understanding of content across STEM, that can boost such integrations, are also mentioned as something that should be included in teacher education programmes (Berlin & White, 2012).

In accordance with the teachers' perspectives, students perspectives on NLT and the position of mathematics in NLT is relevant, as NLT aims to show students how mathematics is used in science and technology (Krüger & Eijkelhof, 2010). One of

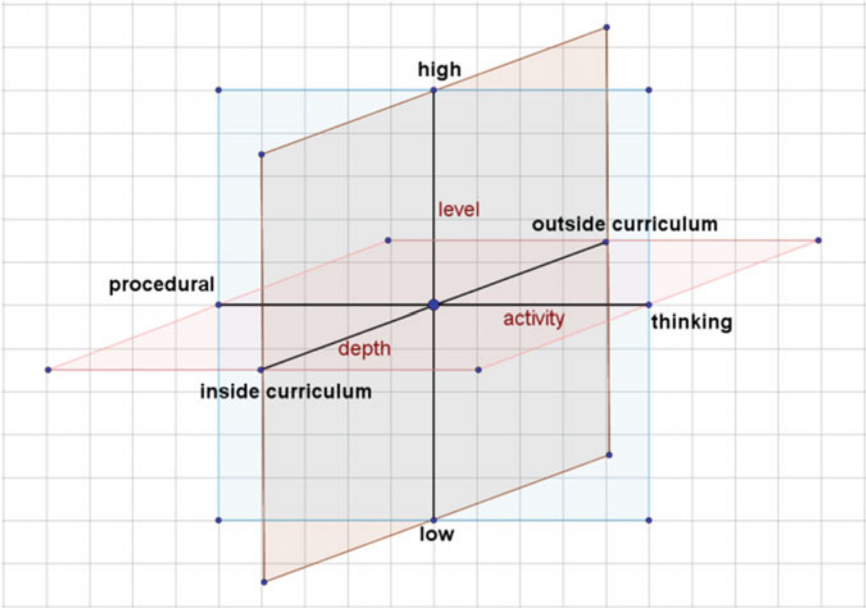

Fig. 11.1 Possibilities of mathematics encountered by students in NLT

the factors that influence students' perspectives is the characteristics of the teaching materials. We need an analytical framework to see how mathematics manifests itself in the teaching materials and to position the perspectives of the students. The framework we have constructed is shown in Fig. 11.1 where three axes represent three aspects of the possibilities of mathematics a student can encounter in the teaching materials when mathematics is required to solve a problem.

The view that NLT should contain both the use of known and unknown mathematics (Stuurgroep NLT, 2007) is reflected in the horizontal axis *(measure of) depth*. When mathematical fields are required that are not part of the school mathematical curriculum, for instance graph theory, this is characterized as *outside the curriculum*. Related subject matter is presumably unknown for students. This also applies to additional content on a known topic such as differential equations as an extension of calculus. The encountered mathematics is positioned on the axis by the frequency in which content is presented in the mathematics curriculum or the connectedness to the existing curriculum (cTWO, 2012).

Mathematics encountered in a module can also involve that which is taught in the mathematics curriculum at a higher or lower grade. The vertical axis *level*, is used to position the offered mathematics compared to the current mathematics curriculum of the student (cTWO, 2012).

Since 2012 new examination programmes for the sciences and mathematics courses have been implemented in the Netherlands. The development of these programmes resulted in a renewed focus on mathematical thinking in the Dutch curriculum (cTWO, 2012; Drijvers, 2015), specifically on problem solving and modelling. The NLT examination programme does not address this distinction explicitly, except for the phrase '*that a student can reason consistently with mathematical and scientific data inductively and deductively*' (Krüger & Eijkelhof, 2010, p. 38), and the statement that modelling is one of the main activities in NLT along with design and research. The type of mathematical *activity* by the student is reflected in the third axis that represents the extent to which the problems concerned require mathematical procedural knowledge or mathematical thinking.

Perspectives of students about the mathematics they are using can be positioned on the axes as well as the characteristics of mathematical subject matter in the modules. For instance, in the module *Logistics* a student is asked to apply new mathematics to a modelling situation (mathematical thinking) in which mathematics is required at a level appropriate for the student in the required grade. This statement is made based on the average knowledge and skills that an average NLT student should have at a certain grade in the Dutch mathematics curriculum.

Obviously, each student has her, or his, own trajectory of development which could mean that personal perceptions of encountered mathematics can differ from the characteristics of the modules. For instance, a student can perceive something as unknown mathematics when in fact it has been offered to the student in the mathematics curriculum.

11.2.1 Method

The different representations of the curricula are used as a framework to explore the current NLT curriculum. The distinction between intended, implemented, and attained curriculum (Goodlad, 1979; van den Akker, 2003), has shown to be especially useful in the analysis of the processes and the outcomes of curriculum innovations (SLO, 2009). At the different representations, data collection has focused on teachers, students, content, and teaching materials.

11.2.1.1 Data Collection

To answer the question on how the mathematics objectives are reflected in NLT, data was collected on the intended, implemented, and attained curriculum. Data on the intended curriculum has been derived from an analysis of (non) official documents from the period of early development of the course, teacher examination guides, as well as from interviews with developers.

Data on both the implemented and attained curriculum was collected through interviews, surveys, and a content analysis of modules. All teaching materials are available for research as well as user data through an on-line user database. Interviews with NLT teachers and students (27 teachers, 50 students) were held while visiting nine NLT schools in 2013. During these school visits many NLT related topics were covered, and the relationship between mathematics and NLT was one of them. There were three interviews with teacher educators in 2014. In 2014 and 2015, students were asked to complete a survey. These students were all in their final school year to increase the probability that they had a good overview of the whole course. All in all, 914 student surveys were completed. Finally, in 2015 two teacher surveys, one among NLT teachers and one specifically for mathematics teachers provided data from 254 teachers, 70 of whom taught mathematics.

Additionally, data for the attained curriculum consists of NLT registration forms of 202 schools and the grades of all NLT students from the national school administration organization (DUO). The registration forms contain specific information about the number of teachers that participate in an NLT team.

11.2.1.2 Instruments

The questions in the semi-structured interviews and the teacher surveys focused on the perceived relationship between mathematics and NLT, reasons for participating in an NLT team, and the importance of mathematics in NLT. Questions corresponding to these categories were for example '*how do you see the rôle of mathematics in NLT?*' or '*why should a mathematics teacher (not) participate in NLT*?' and '*do you think it is important that mathematics is a part of NLT and state your reasons*?'. Students were asked to describe NLT, which disciplines they perceived as a part of NLT, and what their opinion of the course was. They were also asked about the mathematics in NLT. The questions were related to the possibilities in Fig. 11.1 as they focused on the occurrence of unknown mathematics and the difficulty of the mathematics. They were also asked if they could give examples of used mathematics, the visibility of the mathematics, and if they were taught by a mathematics teacher during the NLT course. The two student surveys were identical except for one aspect. Students that did not perceive mathematics as a discipline in NLT were only asked one more question in the first survey, namely why they thought mathematics was not a discipline in NLT. In the second survey students were asked to complete all questions to see whether they were consisted with their perception of mathematics not being a discipline in NLT.

11.3 Data Analysis

The data on students and teacher materials was categorized using the different ways of the occurrence of mathematics in NLT, as shown in Fig. 11.1, and the knowledge of both the mathematics and NLT curriculum and practice of two of the authors. For instance, when a student claims that he only encountered basic calculations this is categorized as low *level* mathematics or when a student describes that he needed to know how to solve linear equations this is marked as a procedural *activity*. The responses of students from both surveys were combined and counted on specific questions related to our framework; for instance, if they encountered unknown mathematics.

The teacher surveys and interviews were analysed by examining teachers' perspectives on participation in NLT teams as well as their perspectives on NLT, the position of mathematics in it, working with the materials and collaboration with teachers from other disciplines.

11.4 Results

Below, we present a few results of our analysis. Starting at the objectives of the course we gathered data on the different representations of the curriculum by looking at course and teaching materials and the view-point of teachers and students. Results are ordered accordingly.

11.4.1 NLT Curriculum

In the examination programme (2010) descriptions referring to mathematics were added to each of the examination domains e.g. *the student can apply relevant science and mathematical concepts to* […]. However, additional documents such as the teacher examination guide show that the rôle of mathematics is limited to a list of techniques that students can encounter in the modules, many of these techniques have already been taught in lower secondary education. That is, these techniques are mentioned in objectives and explained in course materials of lower secondary education.

NLT, and thus the mathematics within it, is intended to supplement the mathematics curricula. However, NLT students have different backgrounds in mathematics, depending on which mathematics programme they have attended when entering the course. Some have experienced no statistics or advanced calculus. Others have attended an advanced mathematics course, called math D, which covers topics like dynamic modelling and complex numbers, and is also an elective school based examination course. As intended by the developers of both NLT and math D, modules were developed that could be used in both courses. In some schools these modules are indeed part of the NLT curriculum, although sometimes presented as isolated math D modules and not as NLT. This could be a way to ensure that more mathematics is offered to students if the school has decided not to offer math D.

11.4.2 Teaching Materials

Given that the modules are context-based, the required disciplinary knowledge varies between modules. Some require more mathematical skills than others. Every school has its own selection of modules and therefore school curriculum. The only condition is that the examination programme of each student is met by the selected modules. To help schools to arrange their curriculum a group of experts has described all used disciplinary concepts in all modules (voorbeelden en gereedschappen, n.d.). This data shows that there are 21 (out of 72) modules that require minimal mathematical knowledge or only mathematics from lower secondary education (4 out of 72 modules). Comparing the educational materials of NLT with the examination programme has shown that it is possible to build a suitable curriculum with a selection of these modules.

There are 18 modules that use concepts which are not part of the compulsory school mathematics curriculum; e.g. linear programming, graph theory, logic, or differential equations. Eleven modules use statistical, or probability theory, which is not in the basic curriculum of the majority of the students.

Procedural activities involving solving equations, working with formulae and calculus are more common than activities involving mathematical thinking.

Modules that have a strong mathematics component are not represented in the five most popular modules (in 2014), except for one, dynamic modelling. This module deals with a topic that is not part of the mathematics school curriculum and was developed to be used in the advanced mathematics course mathD as well. In Fig. 11.1 such a course is positioned on the end of the axis *Depth* and on the procedural side of the axis *activity* near the centre. Depending on the mathematical courses students take, the level of mathematics varies from average level to high level. This means that encountering new mathematics does not necessary mean that a high level of mathematics is required.

11.4.3 Teachers in NLT

Mathematics teachers are allowed to teach NLT. However, not all mathematics teachers are familiar with NLT, or they are not aware that they are allowed to participate in a team of NLT teachers. Interviews and informal conversations with teacher trainers show that this is also true for teacher trainers. There doesn't seem to be a general focus on NLT under mathematics teachers. This is supported by the fact that even though 200 (20%) of NLT teachers responded to the first teacher survey only 18 of them were mathematics teachers. And only a small number of mathematics teachers completed the second survey sent to more than 4000 recipients of a popular educational newsletter, most of them mathematics teachers. The completed surveys combined with the interviews do, however, provide insight into the participation of mathematics teachers.

Table 11.1 Number of teachers in NLT of the mono disciplines from 202 schools

Course	Percentage of schools with teacher(s) of mono discipline in NLT-team (%)	Total number of teachers in NLT teams
Geography	40	93
Biology	95	291
Physics	98	288
Chemistry	98	255
Mathematics	50	121
Other (e.g. computer science, physical education)	9	19

The reasons mathematics teachers have to participate vary. Teachers who wish to participate in NLT indicate that NLT shows attractive applications of abstract mathematics, and ways to make mathematics and its use, visible for students. As one mathematics teacher says:

> The question ‘where do you use mathematics’ is finally answered.

Also, working together with other NLT teachers is mentioned as a positive aspect of NLT. Some of the mathematics teachers recommend participation in NLT, for the course itself, but also for their own professional development; ‘*it broadens your own view*’. Others feel less strongly about the necessity to participate. On the contrary, the opinion that science teachers are sufficiently able to help with the mathematics in the course is mentioned as a reason for not wanting to participate. As described by a teacher and shared by others:

> Mathematics is actually quite scarce in the course and when you encounter it, is superficial. Often a teacher of a science subject can also explain it to the students.

Other reasons for not participating are that teachers feel insecure about their science knowledge, that they want to concentrate on mathematics lessons, or that they are not allowed by their school administration, because of a shortage of mathematics teachers.

On average, five teachers participate in an NLT team. But in only 50% of the teams a mathematics teacher is present, as shown in Table 11.1. In contrast, in 98% of the NLT teams at least one physics teacher is present. Even though teacher formation in schools may vary every year, great shifts in numbers are not to be expected.

The low participation of geography teachers in NLT can be explained by the availability of geography teachers with knowledge of physical geography, which is only a small part of the geography curriculum.

Some schools ask teachers to participate in NLT for specific modules because of their expertise in certain fields like computer science, engineering, or physical education. In Table 11.1 these teachers can be found under *Other*.

The question *do you think it is important that mathematics is a part of NLT and why* was answered positively in the surveys by 56 of 64 mathematics teachers. Not all explicated their answer and reasons for finding mathematics important, and even though the answers vary, they seem to coincide with the reasons to participate.

Some answers to illustrate the diversity:

> Mathematics is necessary to fully comprehend scientific models. Mathematics is used everywhere but that is not visible in the mono-disciplines. There is no point because it is such a small part. Mathematics should be stressed more as a separate discipline.

11.4.4 Students

Analysis of the student surveys show that students have very different opinions about mathematics in NLT. Although most students recognize mathematics as a discipline within NLT, 22% don't mention mathematics when asked about the disciplines that play a rôle in NLT. In contrast, 98% mention physics as playing a rôle. When asked why mathematics is not mentioned, students say that mathematics plays a smaller part than the other disciplines. They also say that only low-level mathematics is required, or that it is not similar to what they do in mathematics class. Several students mention that it coincides more with what they do in physics lessons.

> Question: You didn't choose mathematics as one of the disciplines in NLT. Can you describe why not?
>
> Student 1: Because there is little maths in it. If it is there, it's basic calculations that you apply in physics or geography.
>
> Student 2: You never get maths questions. I didn't even have to differentiate once in the NLT course.

From the 131 students in the second survey who say that mathematics is not a discipline in NLT, 101 say that there was no mathematics teacher part of the NLT team, or that they don't know if that was the case. Also, 22 (out of the 131) say they have encountered mathematics they hadn't learned before.

At the same time, there are students who are very positive about mathematics in NLT. Two examples are:

> Due to NLT I now know that mathematics is a lot more than what is done in mathematics class and now I think about studying mathematics.
>
> Within NLT chemistry, physics and mathematics come together and now I see the use of the three mono disciplines.

A majority (85%), of the students who say mathematics is part of NLT, also indicate that mathematics is important in NLT and that NLT gives them insight in real-life applications of mathematics (73%). About 50% of the students indicate that they have learned mathematical skills and topics that they hadn't learned before in mathematics courses.

11.5 Summary

This exploratory study tried to answer the question how the objectives of the course related to mathematics in NLT are reflected in the curriculum of NLT. Taking the objectives of the course we gathered data on the different representations of the curriculum by looking at course and teaching materials, and the view-point of teachers and students. Data was analysed by looking at how the students encounter mathematics in NLT, and the perceptions and participation of mathematics teachers related to the course objectives.

In the examination programme of NLT, the ‘rôle of mathematics in science’ is formulated as one of the four characteristics that should be visible throughout the curriculum. However, how this should manifest itself in the course is not clear, and perspectives on mathematics in the course vary both from teachers and students.

The intention of NLT is to offer both a broader, and more in-depth, educational programme than the mono disciplines in school. On the one hand, data shows that NLT calls for a lot of low level procedural knowledge, and that only half of the students encounter mathematics they haven’t seen before. Most modules in which new mathematical concepts and techniques are needed do not seem popular among students and teachers, or these are not presented as NLT modules, but as advanced mathematics modules. This may have to do with the fact that NLT students have different mathematical backgrounds. However, that is also the case when it comes to knowledge of physics, biology, or geography.

At the same time, there are students and teachers who feel that NLT is a way to show how mathematics is used, which could be related to the *added value of the wider world,* as mentioned in the conceptual framework.

One of the objectives of the course is to strengthen the cohesion of science disciplines. Although many students see mathematics as an important part of NLT, this is not recognised by all students. Some students feel the mathematics in NLT is not similar to what they encountered in mathematics courses.

At the start of NLT, the participation of mathematics teachers was named as a priority. In practice, we see that, after 10 years, in 50% of the NLT schools no mathematics teacher is present in the NLT teams.

The results call for strengthening the aims of NLT by working towards a well-defined rôle for mathematics in NLT. Further study will address this issue.

11.6 Discussion

The case of NLT provided us with an example of an interdisciplinary STEM course in which teachers from different disciplines collaborate to show students the cohesion between the disciplines, and in which they use real-life problems as the starting point of investigation. The development and implementation structure, government support, and the fact that it is not meant as a replacement of other mono-disciplinary courses, lowers the number of obstacles for integration, as mentioned in literature (Czerniak & Johnson, 2014; Venville, Rennie, & Wallace, 2012). However, when it comes to mathematics in the course, NLT not only shows diversity in practice but the way in which mathematics is manifest also raises questions that need to be addressed if we want mathematics to be a relevant part of interdisciplinary education.

Firstly, the question of whether mathematics teachers should be stimulated to join an NLT team considering that mathematics teachers seem to struggle with their rôle in the course when compared to science teachers. In light of the developments in the field of mathematics, and the general aims of NLT, we argue that the assumed quintessential contribution of mathematics teachers to an NLT team needs to be elaborated.

In 2013, the National Research Council of the United States (NRC, 2013) published a comprehensive analysis of the field of mathematics in which they describe that:

> Mathematical sciences work is becoming an increasingly integral and essential component of a growing array of areas of investigation in biology, medicine, social sciences, business, advanced design, climate, finance, advanced materials, and many more. This work involves the integration of mathematics, statistics, and computation in the broadest sense and the interplay of these areas with areas of potential application.

For the Dutch situation, a similar report was published (PWN, 2014).

NLT teachers have the opportunity to let their students experience *how the mathematical science topics they are teaching are used and the careers that make use of them* (NRC, 2013 p. 11). Here the rôle of the mathematics teachers may come to the surface. By participating in an NLT team, teachers do not only give the example of mathematicians working together with other disciplines to solve problems, they are also the experts on the mathematics curriculum who are able to design learning and teaching processes that take prior knowledge and skills of students into account. Participation provides them with the opportunity to raise the level of mathematics used in the modules, reflect on the functionality of mathematics, and enable the transfer between mathematics and other science disciplines in the NLT curriculum.

Secondly, as described in the conceptual framework, when mathematics teachers begin to start teaching NLT they may be confronted with a teaching practice that, for them, has unfamiliar goals, pedagogy, course structure, and content. The mathematical exercises from mathematics text books are not often seen in NLT. This confrontation requires a change in thinking about the position of mathematics, collaboration with teachers from other disciplines and the use of materials with various natures.

We tend to refer to this ability to change as *agility*. Although all NLT teachers have to be agile in some respect, NLT may ask for more agility of mathematics teachers. When this is the case, support of mathematics teachers in gaining such agility is required.

Visser (2012) described a professional development programme for teachers in a school that can boost team teaching and the professional growth of the teachers in an NLT team. Furthermore, currently some steps are made to describe the competencies of a NLT teacher (Competentieprofiel docent NLT, 2013). However, the best way to help future teachers and specifically mathematics teachers to participate in NLT has not yet been the subject of research. This is not only the case for NLT. Czerniak and Johnson (2014) state that there are still few models about effective ways of preparing teachers to deliver integrated instruction.

Several useful models can be found in studies on the knowledge, beliefs, and attitudes of mathematics teachers, a common division used by Ernest (1989). The focus of these models is on the mathematics teacher in a mathematics classroom. However, in NLT a mathematics teacher with all his, or her, knowledge, beliefs and attitudes is asked to teach in an interdisciplinary course in addition to mathematics courses. Because of this, we wonder what part of the known models can be used to describe the interdisciplinary knowledge, beliefs and attitude required.

Ernest declared that knowledge of the other school courses should be part of the knowledge of a mathematics teacher to provide an opportunity to use other courses to facilitate the learning of mathematics and to show the use of mathematics. In the model describing mathematical knowledge for teaching (Ball, Thames, & Phelps, 2008) it is not clear where this knowledge is positioned. The new component to the existing model *horizon knowledge* described by Jakobsen, Thames and Ribeiro (2013) may well be considered to also include interdisciplinary knowledge but is not yet well-defined. We consider interdisciplinary knowledge as more than knowing where and when mathematics is used in other disciplines, but also how disciplines relate to each other (Repko, Szostakm, & Buchberger, 2014). An NLT teacher should provide an answer to questions like *why is it important that mathematics is a part of NLT, in what way should mathematics be used in NLT* or *what connection to the mathematics taught in mathematics class can be highlighted with this topic?*

This requires not only interdisciplinary knowledge but also relates to personal beliefs about the rôle of mathematics in real-life and in relation to other disciplines. In studies on beliefs, teacher statements related to interdisciplinary teaching are scarce. We argue that the application related view on mathematics teaching (Grigutsch, Raatz, & Törner, 1998; Feldbrich, Muller & Blömeke, 2008), or the utilitarianism in teaching (Tang & Hsieh, 2014), do not cover the complete spectrum. We can use the distinction between beliefs on the nature of mathematics, mathematics teaching and students learning (Cross, 2009) to describe the beliefs concerning mathematics within NLT. For instance, a mathematics teacher in NLT needs to reflect on the importance of mathematics in NLT with respect to the nature of NLT (*nature*), how a mathematics teacher can contribute to NLT, and collaborate with other teachers (*mathematics teaching*), and how students should perceive the rôle of mathematics in NLT (*students learning*).

Attitude towards interdisciplinary teaching also influences participation. In this study teachers gave ‘broad interests’ or ‘preferred focus on mathematics’ as reasons to participate in NLT.

Even though we discuss knowledge, beliefs, and attitude, in relation to our case study, we believe that our findings may show similarity to other interdisciplinary STEM courses.

Consequently, further research should focus on how to equip future mathematics teachers for teaching NLT and to meaningfully collaborate in NLT teams. In the end, mathematics teachers in NLT should be able to help students experience the functionality of mathematical sciences in real-life. An extended analysis framework using the concept of functionality in relation to interdisciplinary knowledge, beliefs, and attitude, will be elaborated on in our further research.

When looking back at the results of this study and the discussion above there is one aspect that we have not addressed properly that emerged when reflecting on the outcomes of our study. This is the value of mathematics. Ng and Stillman (2007) describe that value of mathematics as well as mathematical confidence, and the interconnectedness of mathematics are three affective domains directly associated with interdisciplinary learning involving mathematics. They measure the value of mathematics by looking at the perceived usefulness of mathematics by students, i.e. current relevance, usefulness for further education or society. Williams (2012) distinguishes between practical use, purchasing power and enjoyment of mathematics as different themes associated with value. Other themes are social empowerment e.g. learning ways of thinking or having knowledge of our culture (Ernest, 2010).

The way mathematics teachers value their subject is probably closely related to the values mentioned above. The metaphors of mathematics as a servant and queen of other disciplines come to mind. However, the dichotomy of mathematics as queen, or as servant, not only illustrates the problem, the use of this metaphor is in itself a cause of the problem. When mathematics teachers see their own discipline as the queen it is hard to accept that others are perceived to treat it as a servant. Evidently it is not helpful to position disciplines hierarchically. It is more useful to know and appreciate what each discipline contributes to solving real-life problems, and how to get the most out of the characteristic ways of thinking, used methods, and culture of a discipline. For mathematics this could include acknowledging modelling and problem solving strategies, or logical reasoning, next to procedural fluency. Repko, Szostak, and Buchberger (2014) describe this as part of *interdisciplinary perspective taking* where *taking on other perspectives often involves temporarily setting aside your own beliefs, opinions, and attitudes*. (p. 125)

It would be useful for future studies to address interdisciplinary perspective taking specifically how to include this as a part of teacher education. It would be recommended to include aspects of interdisciplinary teaching in national standards for teacher education in countries, like the Netherlands, where such standards exist.

The goal is not marginalising one discipline, or promoting another, but to value each discipline and use the possibilities each discipline brings to the table in a real-life situation.

References

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching what makes it special? *Journal of Teacher Education, 59*(5), 389–407.

Berlin, D. F., & White, A. L. (2012). A longitudinal look at attitudes and perceptions related to the integration of mathematics, science, and technology education. *School Science and Mathematics, 112*(1), 20–30.

Competentieprofiel docent NLT. (2013). Retrieved May 23, from http://www.ecent.nl/artikel/2682/Competentieprofiel+docent+NLT/view.do.

Cross, D. I. (2009). Alignment, cohesion, and change: Examining mathematics teachers' belief structures and their influence on instructional practices. *Journal of Mathematics Teacher Education, 12*(5), 325–346.

cTWO. (2012). *Denken & doen; wiskunde op havo en vwo per 2015*. Utrecht: Universiteit Utrecht.

Czerniak, C. M. (2007). Interdisciplinary science teaching. In *Handbook of research on science education*, pp. 537–559.

Czerniak, C. M. & Johnson, C. C. (2014). Interdisciplinary science teaching. In *Handbook of research on science education* (pp. 395–411). New York: Routledge.

Dierdorp, A., Bakker, A., van Maanen, J. A., & Eijkelhof, H. M. (2014). Meaningful statistics in professional practices as a bridge between mathematics and science: An evaluation of a design research project. *International Journal of STEM Education, 1*(1), 1–15.

Drijvers, P. (2015). *Denken over wiskunde, onderwijs en ICT*. Utrecht: Universiteit Utrecht.

Ernest, P. (1989). The knowledge, beliefs and attitudes of the mathematics teacher: A model. *Journal of Education for Teaching, 15*(1), 13–33.

Ernest, P. (2010). Why teach mathematics? *Professional Educator, 9*(2), 45–47.

Feldbrich, A., Muller, C., & Blömeke, S. (2008). Epistemological beliefs concerning the nature of mathematics among teachers educators and teacher education students in mathematics. *ZDM Mathematics Education, 40,* 763–776.

Goodlad, J. I. (1979). *Curriculum inquiry. The study of curriculum practice*. New York: McGraw-Hill.

Grigutsch, S., Raatz, U., & Törner, G. (1998). Einstellungen gegenuber Mathematik bei Mathematiklehrern. *Journal für Mathematikdidaktik, 19,* 3–45.

Jakobsen, A., Thames, M. H., & Ribeiro, C. M. (2013). Delineating issues related to horizon content knowledge for mathematics teaching. In *Proceedings of the Eight Congress of the European Society for Research in Mathematics Education.*

Krüger, J., & Eijkelhof, H. (2010). *Advies beproefd examenprogramma NLT: eindrapportage Stuurgroep NLT*. Enschede: Stuurgroep NLT.

Michels, B., & Eijkelhof, H. (2014). Professional development of teachers by developing, testing and teaching curriculum materials of an interdisciplinary STEM-course (NLT) for senior high school. In *Conference Proceedings Educating the Educator*, pp. 288–233.

Ng, K. E. D., & Stillman, G. (2007). *Interdisciplinary learning: Development of mathematical confidence, value, and the interconnectedness of mathematics*. Paper presented at the 30th Annual Conference of the Mathematics Education Research Group of Australasia Incorporated (MERGA 2007) on "Mathematics: Essential research, essential practice", Tasmania, Australia, 2–6 July 2007.

NRC. (2013). *The mathematical sciences in 2025*. Washington: National Research Council.

PWN. (2014). *Formulas for insight and innovation. Vision document 2025*. Amsterdam: PWN.

Repko, A. F., Szostak, R., & Buchberger, M. (2014). *Introduction to interdisciplinary studies*. London: Sage.

Ríordáin, M. N., Johnston, J., & Walshe, G. (2015). Making mathematics and science integration happen: Key aspects of practice. *International Journal of Mathematical Education in Science and Technology, 47*(2), 233–255.

SLO. (2009). *Curriculum in development*. Netherlands Institute for Curriculum Development (SLO). Enschede: SLO.

Stuurgroep NLT. (2007). *Contouren van een nieuw bètavak; visie op een interdisciplinair vak: natuur, leven en technologie*. Enschede: SLO.

Tang, S., & Hsieh, F. (2014). The cultural notion of teacher education: Future lower secondary teachers' beliefs on the nature of mathematics, the learning of mathematics and mathematics

achievement. In *International perspectives on teacher knowledge, beliefs and opportunities to learn.* Dordrecht: Springer.
van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1–10). Dordrecht: Kluwer Academic Publishers.
Venville, G., Rennie, L. J., & Wallace, J. (2012). Curriculum integration: Challenging the assumption of school science as powerful knowledge. In *Second international handbook of science education* (pp. 737–749). Netherlands: Springer.
Visser, T. C. (2012). *Professional development as a strategy for curriculum implementation in multidisciplinary science education*. Enschede, Institute for Teacher Education, Science Communication & School Practices (ELAN), University of Twente.
Voorbeelden en gereedschappen. (n.d.) Retrieved May 23, 2017, from http://betavak-nlt.nl/nl/p/lesmateriaal/leerlijnen/voorbeelden-en-gereedschappen/.
Williams, J. (2012). Use and exchange value in mathematics education: Contemporary CHAT meets Bourdieu's sociology. *Educational Studies in Mathematics, 80,* 57–72.
Williams, J., Roth, W.-M., Swanson, D., Doig, B., Groves, S., Omuvwie, M., et al. (2016). *Interdisciplinary mathematics education: State of the art*. Cham: Springer. https://doi.org/10.1007/978-3-319-42267-1.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.