Practices in teacher education for supporting pre-service teachers in language-responsive teaching of modelling

Georgia Kasari, Western Norway University of Applied Sciences, ✉ geka@hvl.no

In this paper, I investigate practices in teacher education for language-responsive teaching of mathematics. I use action-research in a mathematics education course for primary school (grades 1–7), to systematically investigate my practices to support pre-service teachers in identifying language demands of modelling activities. Two sets of practices were identified regarding teaching about supporting communication and supporting multimodality. These practices were associated with pre-service teacher actions of talking, noticing, planning, and applying language-responsiveness. The paper concludes with recommendations for further changes and improvements in these practices. The study contributes to insights on improving teacher education practice for preparing language-responsive mathematics teachers.

Στο παρόν κείμενο διερευνώνται οι πρακτικές εκπαίδευσης εκπαιδευτικών για την γλωσσικά-ανταποκρινόμενη διδασκαλία των μαθηματικών. Αξιοποιώντας την έρευνα-δράση διερευνώ τις πρακτικές που χρησιμοποιώ στο πλαίσιο ενός μαθήματος μαθηματικών για την υποστήριξη των μελλοντικών εκπαιδευτικών (τάξεις 1–7) στην αναγνώριση των γλωσσικών απαιτήσεων δραστηριοτήτων μοντελοποίησης. Αναδεικνύονται δύο θεματικοί άξονες πρακτικών, ως προς την υποστήριξη της επικοινωνίας και της πολυτροπικότητας, καθώς και εμπλοκή των μελλοντικών εκπαιδευτικών σε γλωσσικά-ανταποκρινόμενες δράσεις συζήτησης, παρατήρησης, σχεδιασμού και εφαρμογής. Η παρούσα μελέτη δύναται να συνδράμει στη βελτίωση της πρακτικής των εκπαιδευτών για την προετοιμασία γλωσσικά-ανταποκρινόμενων εκπαιδευτικών των μαθηματικών.

Introduction

As the number of multilingual students in school classrooms increases over the years, teachers need to be prepared to meet their needs in subject areas, like mathematics, in language-responsive ways (Prediger, 2019). Language-responsiveness that is specific to mathematics means that students' needs are to be met through teaching arrangements that support students' languages and diverse backgrounds, with the parallel development of the content language required. In this paper, I investigate a teacher educator's (TE) practices in the topic of mathematical modelling, for preparing pre-service teachers (PTs) for language-

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responsive teaching in their future school classrooms. The research question is: how does a teacher educator support pre-service teachers in identifying classroom language demands in a mathematical modelling activity?

Earlier studies show that many PTs lack formal preparedness for responding to the complexities of teaching mathematics in multilingual classrooms (e.g., Essien, Chitera & Planas, 2016). This is problematic, as it leaves PTs relying on personal experiences and natural inclinations, which are usually insufficient to support students both mathematically and linguistically (de Araujo et al., 2015). Consequently, teacher education programs need to reconsider how they prepare teachers for language-responsive mathematics teaching (Prediger, 2019) and how TEs provide explicit experiences for PTs, as part of the entire mathematics curriculum (Essien et al., 2016).

A reason for the lack of preparation can be that TEs have not developed appropriate practices to support PTs to reflect on language-responsive teaching in systematic ways, or are constrained by contextual and other challenges. For example, Eikset and Meaney (2018) identified situations where the TE prioritised mathematics content over language-responsive practices, despite having awareness of the need for such practices. In addition, Thomassen and Munthe (2020) suggested that teacher education programs might not have yet integrated recommendations from relevant research so that their programs were adapted to raise the responsibility of TEs to prepare PTs.

More knowledge about what practices TEs could use to prepare PTs for language-responsive mathematics teaching is therefore necessary. In this paper, I aim to explore the practices used to support PTs in identifying language demands of a mathematical modelling activity. The paper is part of a wider ongoing action-research project, which aims, first to describe initial practices that I, as a mathematics TE, use to support PTs to consider in issues of language-responsive mathematics teaching; and second, to identify how such practices are adapted to improve PTs' understandings of these issues.

To conduct this project, I draw on Lucas and Villegas' (2013) framework as a stimulus for preparing language-responsive teachers, which includes the element of identifying language demands of disciplines, such as mathematics. The framework describes orientations and types of pedagogical knowledge and skills that PTs could use for teaching language learners responsively, and has been utilised by researchers in mathematics education, such as Prediger (2019) in professional development.

Theoretical background: Language-responsive (mathematics) teaching

Lucas and Villegas' (2013) language-responsive teaching is concerned with taking into account learners' diverse backgrounds and languages as resources for academic learning. Responsiveness to student diversity is a critical equity concern in mathematics education regarding how students understand and participate in classroom communication (Vogler & Prediger, 2017).

Language-responsiveness can be considered related to Moschkovich's (2013) "equitable mathematics teaching practices", which highlights the importance of the role of language in

mathematics by extending the use of content-specific vocabulary to the use of a range of mathematical discourse practices for communicating ideas. Similarly, Barwell (2020) identified that when explicit attention was given to features of mathematical discourse, such as formal and informal language, linked to gestures, representations and body language, the school classrooms tended to be more language-positive for supporting students' learning. Therefore, students should be supported to use the resources they have in their first, second or additional languages in mathematical discussions. Based on Essien et al. (2016), considering students' languages as resources is one of the major challenges for mathematics in multilingual classrooms and, hence, TEs' practices should be structured with systematically supporting PTs to respond to these challenges.

Research by Prediger (2019) on language-responsive teaching in mathematics found that practices drawing on students' linguistic background also need to highlight the content language demands. This is important for teacher education, as many PTs can find it challenging to not equate language-responsive teaching to reducing academic standards for linguistically diverse students (Gay & Kirkland, 2003). It is TEs' responsibility to support PTs to change such beliefs. Developing an ability to identify language demands of particular disciplines is an essential element of teacher expertise in Lucas and Villegas' (2013) framework. Also, it is one the five teacher jobs that Prediger (2019) has described, including noticing, demanding, supporting, developing and identifying language, as part of requirements for classroom teachers to sufficiently support students' language and mathematics learning. For these reasons, this paper focuses on identifying mathematics-specific language demands.

Lucas and Villegas (2013) additionally suggest relevant "tasks for learning" about teaching language learners. For example, they explain that teachers need to be able to analyse language features of the communication and activities that play out in the classroom and would likely challenge multilingual students. In doing so, teachers could support multilingual students' participation and active engagement, in ways that approach what Moschkovich (2013) and Barwell (2020) emphasise for communication in mathematics. The framework with the "tasks for learning" can be used by TEs to inform practices within the teacher education curriculum to prepare PTs.

Methodology

To address the research question, I use the first cycle of my ongoing action-research project, which concerns teaching about modelling. This cycle, like all others in an action-research spiral (Kemmis et al., 2013), involves multiple sub-cycles, from which I use individual examples to identify and investigate my practices. As an action-researcher, I aim to understand my teacher education practices and change them for improvement (Kemmis et al., 2013). The examples described in this paper are about the practices I used in my teacher education work which would contribute to PTs being able to identify the language demands of a mathematical modelling activity.

Mathematical modelling is the focus of the teacher education course under investigation. In the mathematics course for teachers of grades 1–7, mathematics content and didactics are combined. The course included an assignment about the PTs' implementing mathematical modelling into their teaching while on practicum at local schools. The assignment was based on Barbosa's (2006) criteria for a mathematical modelling activity, in that it should be a problem (not an exercise); and it should be taken from everyday or other sciences that are not pure mathematics (p. 294).

The data collection in the first cycle comes from a workshop, at the beginning of the autumn semester of 2020, on modelling with three different groups of PTs, which was physical (first session) or digital (second and third sessions)[1]. Between the workshops, I discussed my practices about language-responsive mathematics with colleagues to consider how I used or could change them. Each workshop was about three hours long and was audio-recorded with the consent of participants, and then transcribed. Interactions between the TE and PTs were primarily in English, as their native languages were not shared, while interactions among PTs were in Norwegian. The TE used power-point slides in Norwegian and/or English as a visual aid and displayed a video of modelling in a school classroom with linguistically and culturally diverse students in which the students spoke English. Video screenshots were used as springboards for discussions about different aspects of language-responsive teaching to do with mathematical modelling into other parts of the sessions.

The analysis of my teacher education practices was done to identify which practices to change and in what ways. Therefore, I adapted Pierson's (2008) model of analysing teacher's follow-up interactions in mathematics classrooms, based on the constructs of "responsiveness" and "intellectual work". In the adapted version, responsiveness refers to how the TE takes-up PTs' ideas, and is not to be related to language-responsiveness. Intellectual work refers to how the TE engages PTs with cognitive work, by giving or demanding it, which draws on Lucas and Villegas' (2013) framework of language-responsive teaching within the context of mathematical modelling.

To do this analysis, I created tables where I categorised my interactions with the PTs in levels of responsiveness and/or intellectual work. Interactions categorised as low responsiveness were those in which I as the TE did not take up the PT's idea. Those classified as medium showed the TE's idea being the focus of the TE's response. High responsiveness was split into two levels: high-I when the TE's reasoning was on display when elaborating on PT's idea, while high-II when the PT's reasoning was displayed. Intellectual work was split into giving and demanding. Low level of giving intellectual work were interactions in which the TE gave information without integrating language aspects in the mathematics content, medium level were interactions in which the TE gave information about students, and high level interactions were when the TE gave information about implications for teachers. About demanding intellectual work, low level interactions were those in which the

[1] The regulations in Norway in autumn 2020 required 50% digital teaching due to the COVID-19 safety measures, unless other force majeure reasons eventuated.

TE did not request the PTs to use their own ideas, medium level were interactions where the request was implicit, and high level when the request was explicit.

A second analysis, in alignment with Pierson's (2008) coding of content/activity, provided deeper insights on the TE's practices about the element of "identifying classroom language demands". This analysis supported me as the TE action-researcher to decide whether my practices were effective for achieving my pedagogical goals, and consequently understand how to improve them. For instance, if the TE's support for "identifying classroom language demands" was in interactions with little or no uptake of PTs' idea (low responsiveness), then there is a need to determine alternative practices that would utilise PTs' own reasoning in future interactions.

As a result of the two analyses, two sets of practices were identified as important foci in regard to improving my work as a TE. The first set was identified as practices to do with "supporting communication rather than single language use", and a second set was about "supporting multimodality related to content-specific mathematical ideas". These results are described in the next section.

Results

In this section, I present representative examples of the two sets of practices related to "identifying classroom language demands" in modelling contexts. The first set of practices were aimed at developing PTs' understandings about the value of teachers moving past a focus on students' imprecise language when discussing a modelling activity. The second set of practices were aimed at developing PTs' understandings of how a teacher could encourage the use of multiple linguistic and non-linguistic modes to make the modelling content accessible to all students. In the examples, I use brackets to indicate the level of {responsiveness} or {intellectual work}.

First set of practices: "Supporting communication rather than single language use"

– Actions of talking about language-responsiveness

The most common practice was connected to PTs' actions of talking about language-responsiveness. For example, in the last part of the second modelling session, the TE asked PTs about what they thought the teacher in the video did to support multilingual students' engagement with modelling ideas. One PT wrote a response in the digital platform chat, shown in quotation marks in the excerpt below. The TE read it and further elaborated with her own reasoning {high-I responsiveness}.

> TE: [PT's name] says, "the teacher focuses on what they (the children) are trying to communicate rather than the words they are using. They are able to get across what they mean, and the teacher accepts it". Yes, the teacher actually does stand by the kids and […] encourages them to move forward. She does not insist on precise language to explain how they solve the problem, […] she does not lower the content that they are working with academically. So, everyone is working on the same content demand. […] Learning math does not need to wait for learning the language of instruction in the classroom. [It] can happen in parallel by learning the language through using the language.

After the TE affirmed PT's idea of accepting students' language when communicating meanings, she continued with how language and content were not reduced for multilingual students in that video. In this sense, the PTs interacted with the TE to explicitly talk about language-responsiveness in a modelling activity. In this action of talking, they shared opinions of maintaining the modelling content demands, without situating language as a problem in mathematics communication.

Another example from that session was after the TE asked PTs to work in groups and plan for supporting multilingual students in a modelling activity using Barwell's (2020) suggestions for language-positive classrooms. In one group, a multilingual PT shared personal stories about the opportunities of mathematics education received in a mainstream school classroom, compared to classrooms where mathematics content was reduced on account of communication skills in Norwegian being a problem. The TE followed up by asking smaller questions to facilitate a discussion focused on planning the modelling activity {low responsiveness}. The PTs continued with discussing the use of symbols, and the ways modelling can support working "across languages". Here, the PTs talked about language-responsiveness in a modelling activity, in a slightly different way than the previous example, as they reflected upon personal experiences and the role of languages other than Norwegian in mathematics education.

– *Actions of noticing language-responsiveness*

Teacher education practices in this theme were also identified in connection to PTs' actions of noticing language-responsiveness in a modelling activity. For example, in the second and third modelling session, the TE showed a video screen shot of a student who explained in a plenary session someone else's modelling strategy as "He minused until he got to the answer of how much are left". The TE elaborated on the creativity of the language involved and compared the expression in English (to minus) and Norwegian (å minusere). She then indirectly requested PTs to rethink their ideas by pointing out that the teacher again did not insist on precision, and that "learning another language provides more resources to think with, to understand the world and to understand the mathematics" {medium demand}. Thus, the TE engaged PTs in noticing language-responsiveness by paying attention to students' language use in a modelling activity, and to the valuable role of multilingualism in mathematics.

– *Actions of planning for language-responsiveness*

Another practice of supporting the identification of language demands was during PTs' planning a modelling activity using Barwell's (2020) suggestions for language-positive classrooms {high demand}. For example, one group of PTs planned a small-group activity, with the aim of encouraging multilingual students' participation. The TE briefly gave feedback by elaborating on the importance of encouraging students to use their existing language skills when working on a modelling activity in groups {high-I responsiveness}. In this sense, the PTs explicitly planned for language-responsiveness in a modelling activity.

Second set of practices: Supporting multimodality related to content-specific mathematical ideas – Actions of noticing language-responsiveness

The most common practice that I used in regard to raising PTs' awareness of the value of multimodality was connected to PTs' actions of noticing language-responsiveness, and in particular using gestures and representations, in students' contributions to interactions with their peers or the teacher. For example, in the third session, the TE showed a video screenshot of a student sharing with a learning partner what was noticed in a short film that the students watched in the school classroom for working with their modelling activity.

> TE: So this kid was using body language, kroppsspråk (body language), to explain, to show how she understands the film that she saw about [film content]. There was the concept of taking away, that something happened, and some [products] were taken away. That is a very central concept in subtraction. And that is the main idea that they were working with, […] and how modelling was used as a tool for them to learn about subtraction. And also her learning partner understood her.

The TE explained {medium giving}, first, that the student's body language was a means to show her understanding of "taking away" in the short film, which was integrated into the students' modelling activity, and second, that her learning partner understood her body language. In this case, the TE engaged PTs in noticing language-responsiveness related to using non-verbal modes to discuss modelling content.

A similar example was when the TE explained (second and third session) another video situation, where a student explained in the whole class the "decomposing" strategy he used in the modelling activity. The TE's explanation was about how the student used signs and symbols that represent how he "decomposed" the numbers and supported his classmates' understanding {medium giving}. In this manner, the TE's practice engaged PTs in noticing language-responsiveness related to using representations to understand content and emerging features of content language.

An example of a student and teacher interaction is when the TE showed a screenshot of the video of a teacher talking with a student about her strategies in doing the activity, at the second and third modelling sessions. The student had written on her worksheet numbers and symbols, represented relations of subtraction, and drawn a number line. Both the student and the teacher were pointing at the representations and supported the language features of the activity while talking about it. The TE gave intellectual work to PTs by explaining this and by stressing that the use of multimodal means to communicate provides students with more opportunities to participate and learn {high giving}. In this sense, the TE engaged PTs in noticing language-responsiveness related to how multimodality can be encouraged and allow students and teachers to discuss and make sense of each other's ideas about the content of the modelling activity.

– *Actions of applying language-responsiveness*
Applying language-responsiveness was identified in PTs' discussions in a multilingual setting. For example, in the first modelling session, the TE asked PTs to share ideas from the modelling activity they planned in groups {high demand}. The PTs, individually and with the help of their peers, switched between Norwegian and English, pointed at pictures they had taken for the activity (e.g., from the cafeteria) or at their written text describing the activity, and used body language about the activity's content, such as comparing (sammenligning) statistical data and finding the average (gjennomsnitt) height of students, or repeating these phrases and using synonyms to ensure understanding. Therefore, content language demands of each activity were met through interactions {high-II responsiveness}. The PTs interacted with the TE and applied language-responsiveness to support their ideas in a multilingual mathematics setting, and their efforts to reinforce others' understanding of the activity encouraged them to identify and utilise extra-linguistic supports.

Discussion and concluding remarks

In this study, I have investigated my own teacher education practices for preparing PTs to work with language-responsive teaching within the context of a mathematical modelling activity. I used Lucas and Villegas' (2013) framework of language-responsive teaching, focussing on the element of "identifying classroom language demands of particular disciplines", to gain insights on how does a TE support PTs identify classroom language demands in a mathematical modelling activity.

Two sets of teaching practices in teacher education emerged as being of interest: teaching about supporting communication rather than single language use, and teaching about supporting multimodality related to content-specific mathematical ideas. Supporting PTs to identify classroom language demands in a modelling activity was to do with preparing PTs to identify, first, when and why letting go of students' imprecise language can be appropriate and, second, to identify what and how multimodalities can be used in mathematics classroom communication.

The TE's practices for this preparation involved engaging PTs in actions of language-responsiveness: talking-about, noticing, planning, and applying. Noticing was the most common action, while planning was the least common action in relation to identifying language demands.

Noticing language-responsiveness was about being aware of language and language forms used by students and relates to Lucas and Villegas' (2013) task for learning through cultivating awareness of language as a focus of analysis. Making the action of noticing language relevant to specific mathematics content in this study aligns with what Prediger (2019) described about noticing being a necessary teacher job that supports the identification of language demands. However, in my teacher education practices, I did not involve PTs in noticing students' language resources and needs, like Prediger (2019) had emphasised as needing to be done. My practices for noticing language-responsiveness were identified either as giving intellectual work, where I gave information about students' language, or as implicitly demanding intellectual work from the PTs. As a result of this analysis, it is

important for me to consider how to change my practices to do with noticing so that I request explicit intellectual work from the PTs to notice language-responsiveness themselves within the context of a modelling activity.

Talking about language-responsiveness was about having PTs reflect on their experiences and share their understandings of teaching and learning in multilingual mathematics classrooms. This PT action is relevant to the first task for learning within Lucas and Villegas' (2013) framework. Talking about language-responsiveness occurred within multilingual interactions with multilinguals, between the TE and PTs as part of considering aspects of language-responsive teaching. However, talking about language-responsiveness should not be considered sufficient in teacher education (Prediger, 2019). In the analysis, my TE practices for engaging PTs in talking about language-responsiveness were identified as low or high-I responsiveness. Therefore, I need to consider how to provide explicit intellectual work so that the PTs will talk about language-responsiveness in a modelling activity and to address questions to the whole classroom so that all the PTs engage in discussion. In addition, I, as the TE, could look for meaningful opportunities to associate talking about language-responsiveness with other actions, such as applying language-responsiveness.

Applying language-responsiveness was about the PTs using the resources that were available in the environment when sharing ideas about a modelling activity in multilingual classrooms. This action was connected to Lucas and Villegas' (2013) task for learning through applying practices and tools in linguistically diverse settings. Thomassen and Munthe (2020) also highlighted that all PTs, especially at the beginning of their education, should be given practical opportunities to participate in multilingual classroom settings, and to then reflect on their experiences. However, as the TE, I did not explicitly provide opportunities for this. Therefore, I need to consider improving practices for applying, so that they contribute to high levels of responsiveness and demand for intellectual work, by making connections to actions of reflecting on language-responsiveness.

Finally, planning for language-responsiveness was about creating teaching arrangements that can support multilingual students and is related to Lucas and Villegas' (2013) task for learning through understanding and applying practices and tools to plan classroom instruction. In regard to mathematics education, this kind of planning seems similar to Prediger's (2019) description of teacher's job to demand language from multilingual students by activating teaching and learning situations that promote student communication. In the data, there was one example of demanding high level of intellectual work. Thus, I, as the TE, could consider how to improve my use of this practice by interacting more with the PTs and engaging with their ideas.

The analysis of the data showed that I, as the TE, used multiple practices for supporting PTs to identify language demands in a mathematical modelling activity. Also, I was able to identify those practices that needed to improve in order to increase the possibilities for the PTs to develop their language-responsive mathematics teaching. However, there remain issues to investigate as a TE to ensure that I continue to improve my own practices in the future.

The findings from this paper can provide information to other TEs, engaging in action-research, about how to attend systematically to preparing PTs for language-responsive teaching of mathematics. Becoming a language-responsive teacher is a process that begins in initial teacher education programs and continues throughout a teacher's professional career development (Lucas & Villegas, 2013). Therefore, it is important to better understand the challenges faced in preparing language-responsive mathematics teachers.

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