Four ways pre-service teachers teach virtual pupils

Abstract
This study contributes to our understanding of how pre-service teachers (PSTs), studying to become middle school teachers, teach virtual pupils in a simulation setting. Such settings provide an opportunity for PSTs to practice teaching skills in a safe environment with the support of their teacher educators. It also enables researchers to study in detail how PSTs handle classroom interaction and teach content. The data comprises 102 recordings from teaching sessions, analyzed using qualitative analysis. The results show that the PSTs handle content and interact with virtual pupils in different ways. Four teaching styles were identified: (a) a confusing way of teaching, distinguished by misleading explanations in an IRE (Initiation-Response-Evaluation) structure; (b) an improvising way of teaching, distinguished by messy explanations following pupils’ questions; (c) a lecturing way of teaching, distinguished by consistent explanations in an IRE structure; and (d) an orchestrating way of teaching, distinguished by consistent explanations and instances of exploratory talk. The results also identify areas where the PSTs need further support in their development. Teacher educators can use the results as a starting point when they organize and plan the content of their teacher education programs.

Keywords: Pre-service teachers, Simulations, Teaching, Interaction, Teacher training

Lärarstudenters undervisning av virtuella elever

Sammanfattning
Denna studie bidrar med kunskap om hur lärarstudenter, som studerar till 4-6-lärare, undervisar virtuella elever i en simuleringsmiljö. Simuleringen erbjuder lärarstudenter möjlighet att träna på och utveckla sin undervisningsförmåga i en trygg miljö, med stöd av sina seminarielärare. Det ger också forskare möjlighet att detaljerat studera hur lärarstudenter hanterar klassroomsinteraktion och ämnesundervisning. Dataunderlaget består av 102 inspelade undervisningssessioner. Inspelningarna analyserades genom en kvalitativ, induktiv analys. Resultaten visar att det finns en variation avseende hur
lärarstudenter på samma lärarprogram hanterar ämnesinnehållet och interaktionen med de virtuella eleverna. Fyra undervisningsstilar identifierades: (a) en rörig undervisningsstil som kännetecknas av att läraren ger vilseledande förklaringar och främst använder sig av IRE-strukturen (initiativ-respons-evaluerande), (b) en improviserande undervisningsstil som kännetecknas av att läraren har ostrukturerade förklaringar och har mycket interaktion med eleverna, (c) en föreläsande undervisningsstil som kännetecknas av att läraren ger sammanhängande förklaringar och använder IRE-strukturen och (d) en interaktiv undervisningsstil som kännetecknas av sammanhållande förklaringar och drag av utforskande samtal. I resultaten identifieras också områden där lärarstudenterna behöver stöd i sin utveckling till att bli lärare.

Nyckelord: Lärarstudenter, simuleringsutbildning, undervisning, interaktion, lärarutbildning

**Background and rationale**

It is well-established that teachers' ability to teach is the most critical factor for pupils' success at school (Hattie, 2009; Hanushek, 2011; Hamre et al., 2013). Teaching is complex and complicated, and demands both analytical and practical skills (Anthony et al., 2015; Ball & Forzani, 2009; Grossman, 2009). The foundation for teachers' teaching skills is established in the teacher training program. Hence, it is crucial for teacher educators to create situations where pre-service teachers (PSTs) can develop their teaching skills. To do so, teacher educators need to understand (a) what constitutes good teaching (Grossman & Dean, 2019), (b) how PSTs teach and what challenges they face (Ryberg, 2018), and (c) how to create powerful learning sessions for PSTs' teaching (Grossman et al., 2009). Knowledge of PSTs' teaching and their qualities will help teacher educators develop effective teaching strategies for PSTs, as the foundation for all teaching is an awareness of the learners' abilities (Marton, 2015). Thus, understanding PSTs' teaching provides an important foundation for interventions designed to help students become teachers. Previous research has shown that PSTs face challenges in handling core teaching practices (Grossman et al., 2009; McDonald et al., 2013), including communication skills (Rosati-Peterson et al., 2021) and managing subject content (Anthony et al., 2015).

In addition to traditional modes of investigating PSTs' teaching, today's teacher educators can also use simulations (Badiee & Kaufman, 2015; Kaufman & Ireland, 2016; Samuelsson et al., 2021). Semi-virtual simulations, such as TeachLivE, include virtual characters with different pre-programmed personal traits but also require a human in the loop who will decide what the characters will say and do (Dieker et al., 2014; Ersozlu et al., 2021). PSTs who practice teaching with semi-virtual simulations provide the research community with unique opportunities to study how they approach specific content and interact with virtual pupils (cf. Dieker et al., 2019). In this study, we use the context of semi-virtual simulations to examine the teaching styles of PSTs who are preparing to...
become teachers of pupils aged 10-12 years. Our investigation is guided by the following research questions:

- How do pre-service teachers handle content when teaching mathematics to virtual pupils?
- How do pre-service teachers handle classroom interaction when they teach mathematics to virtual pupils?

Central teaching skills
Teaching is about intentional actions designed to make someone learn something (Marton, 2015). This study focuses on two important areas of teaching with respect to pupils’ learning: (a) handling content, and (b) classroom interaction (cf. Maunula, 2018; Mercer et al., 2009; Emanuelsson & Sahlström, 2008). When teachers explain and represent the subject, they handle content. The handling of content is an issue of what content is presented during instruction and which aspects of the content are brought to the foreground (Marton & Booth, 1997). The handling of content could occur in qualitatively different ways with respect to how the teacher represents the subject. Venkat et al. (2019) assert that pupils’ learning is connected to whether the teacher can provide a structural approach in their teaching. Teaching with a structural approach involves the systematic organisation of items in examples. The activities in relation to items draw pupils’ attention to sufficient relationships with respect to the object of learning, and thereby help the pupils to see local relationships. Teaching with a structural approach means focusing on pupils’ awareness of similarities and differences, and their ability to reason about parts and wholes simultaneously (Davydov, 1982; Zhou & Peverly, 2005). It also includes being aware of possible misconceptions about the content, and identifying aspects of the object of learning that are critical to clarify in the teaching (Marton, 2015). A competent teacher chooses tasks and examples and connects them in a way that highlights central aspects of the content to provide an internal logic and progression in the lesson (Venkat et al., 2019; Marton, 2015).

The way teachers interact with pupils affects the pupils’ learning opportunities (Pianta et al., 2012; Hufferd-Ackles et al., 2004; Mercer & Dawes, 2014; Park, 2015). Pupils are offered different sorts of agencies in different interaction patterns. Agency includes teachers’ and pupils’ opportunities as individuals to act and have control over their actions, in interaction with others (Andersson & Valero, 2016). Agency consists of the opportunities individuals have to make their voices heard and influence what happens in the classroom; it is not a specific characteristic of individuals (cf. Biesta & Tedder, 2006; Norén & Anderson, 2016). A common interaction pattern in the classroom is known as IRE: initiation, response, and evaluation (Henning et al., 2012; Sinclair & Coulthard, 1975). In this kind of communication, the teacher asks a question that has one correct answer. When a pupil answers, the teacher evaluates whether it is correct. This
kind of conversation is strictly led by the teacher; pupils are only involved when giving short answers, which leads to low pupil agency. A ‘contract’ is established between the speakers: the teacher as the one asking questions and the pupils trying to respond (Hundeide, 2003). In contrast, Wegerif and Mercer (1997) argue that a classroom characterized by exploratory talk increases pupils’ learning and their agency. In exploratory talk, also called dialogic teaching, the teacher uses interaction to make pupils develop their thoughts about the content being taught. In a dialogic classroom, pupils are encouraged to share their thoughts and discuss them with peers and the teacher, and the pupils engage critically but constructively. Statements and suggestions are presented for shared consideration (Alexander, 2006, 2018; Mercer, 2010). To provide such an environment, the teacher presents challenging questions and tasks in which pupils should interact with each other and explore the content to be learnt. Ideas from pupils are valued and used to further explore the learning content (Hufferd-Ackles, Fuson, & Sherin, 2004). According to Hacker and Tenant (2002) and van der Veen et al. (2017), it is difficult to change established communication patterns in the classroom. It is therefore important to identify PSTs’ interaction patterns so that they can receive early training on how to interact with pupils in a powerful way.

**PSTs’ teaching skills**

The process of becoming a teacher is influenced by many factors, such as major discourses about teaching and learning, the classroom practices the novice teacher take part in, prior experiences, and participation in other social contexts (Skott, 2013). Central teaching skills, such as leading classroom interaction and teaching subject content, are unnatural in everyday life, and therefore PSTs often struggle to master them (Ball & Forzani, 2009). PSTs’ previous experience can be more of a hinderance than an asset, since it often is based solely on their perspectives of themselves as pupils and from their everyday lives (Ball & Forzani, 2009). To become successful teachers, Timperley (2013) argues that novice teachers need to shift focus from themselves to the pupils, which includes the ability to see each learner, understand their needs and abilities, and give agency to the pupils. They also need to shift from seeing teaching as routine to seeing it as adaptive expertise. Using Timperley’s theories when analysing PSTs’ teaching, Anthony et al. (2015) showed that PSTs start at different levels, but what they have in common is that they tend to focus more on themselves than on the pupils. They also show that it takes a lot of time and practice to see teaching as adaptive expertise, and to be able to use various teaching tools in a flexible and responsive way.

In teacher education, PSTs are introduced to several theories about teaching and learning, but they often find it challenging to connect these theories to practice (Grossman et al., 2009; MacDonald et al., 2013). Even if they have studied theories about how to handle classroom interaction (Rosati-Peterson et al., 2021), and how to handle challenging pupils (Cohen et al, 2020), novice teachers often
need support to act in a powerful way. Another area that is challenging for PSTs is teaching in a variety of subjects.

For PSTs to develop their teaching skills, they need to be given plenty of opportunities to practice, not only during field work but also on campus (Ball & Fonzani, 2009; Grossman, 2005; McDonald et al., 2013). Rawlins et al. (2020) have shown that the ability to teach mathematics can be developed through guided rehearsal sessions before teaching the content to real pupils (cf. Dieker, et al., 2019). To provide more practice-oriented opportunities within the teacher training program, various kinds of simulations can be used. In a review about simulations in teacher education, Ade-Ojo et al. (2022) show that simulations can offer a complement to the practice PSTs do during field work. Semi-virtual simulations, such as TeachLivE, are especially powerful since it has virtual students controlled by a human in the loop. This makes it possible to create complex scenarios, and provide an authentic experience for the PSTs (McGarr, 2021) in which they can practice commonly occurring situations (Ade-Ojo et al., 2022; Dieker, et al., 2014; Piro & O’Callaghan, 2018).

Cohen et al. (2020) found that PSTs who practiced teaching in a semi-virtual reality and then received feedback on their interaction with the virtual pupils successfully developed their ability to handle challenging pupils. Similarly, Rosati-Peterson (2021) found that PSTs who received feedback on their communication skills after teaching virtual pupils also improved. Bautista and Boone (2015) studied PSTs’ self-efficacy before and after a mixed-reality simulation, and the results showed that in nine out of ten, this significantly increased after conducting the practice; Gundel et al. (2019) and Thorsten et al. (2021) concur with these findings. These studies show that simulation training is an effective way to support PSTs’ teaching skills. A reason for this might be that the PSTs experience the simulations as realistic (Dieker, et al., 2008; Brown, 2014; Badiee & Kaufman, 2015; McGarr, 2021; Samuelsson et al., 2022a). Another reason might be that simulation training offers PSTs the opportunity to practice action-oriented aspects of teaching (Grossman et al., 2009; Anthony et al., 2015; Thorsten et al., 2021), and can be helpful in bridging the theory-practice gap (McGarr, 2021).

Methodology

This study includes 102 PSTs enrolled in teacher education. The program spans eight semesters, and the study was conducted during their fifth semester, during a course about mathematic didactics. One group of students (41) took part in the course one year, and the other group of students (61) took part in the same course the next year.
**Research ethics**
All students in both cohorts were informed that a specific part of the didactics course included teaching virtual pupils in a simulation. They were also informed that the simulation training was part of a research project that they were invited to take part in. All students voluntarily agreed to be part of the study and be recorded while teaching the virtual pupils. No names or years are included in the paper to ensure confidentiality. No one other than the researchers have seen the recordings, which have been stored securely on portable hard drives (Swedish Research Council, 2017).

**Preparation before the simulation training**
The simulation training was conducted as part of a ten-week course about mathematics for PSTs attending teacher education for upper elementary school. Prior to the simulation training, the PSTs had participated in a seminar about teaching fractions. They were also asked to read course literature about mathematic didactics, and more specifically the parts about fractions. For example, they read Bentley & Bentley (2016), which gives rich descriptions of pupils’ challenges in learning mathematics, and of how these can be addressed in teaching.

Before the simulation, the PSTs were divided into groups of three and asked to jointly plan three teaching sessions where they should introduce fractions to 11-year-old pupils who had a basic knowledge of fractions. They should teach one session, and observe their peers in the other two. Hence, each PST participated in the simulation three times.

**Simulation setting**
The simulation was set up in a small classroom. The PSTs had a desk for their lesson plan and materials in front of them, and a whiteboard behind their back. In front of their desk, the virtual pupils were shown on a screen, appearing at a normal size for 11-year-old pupils. Communication with the virtual pupils took place using a conference sound system. All PST groups came to the room at a scheduled time. In the classroom, the PSTs met two instructors; a specialist in mathematics didactics and another specialist in classroom management, who led the simulation training. Support was given when a PST chose to pause the simulation. They could then direct questions to their fellow peers and the instructors, and use their responses to find ways to handle a situation, to understand a question, or figure out ways to explain specific content. As the PST taught, they met five virtual pupils with different personalities and abilities: Ava, Dev, Ethan, Jasmine and Savannah, see Figure 1.
The simulation is semi-virtual, which means that some traits for each virtual pupil are programmed, while others are created by a simulation specialist who orchestrates the virtual pupils in relation to the content (Chini et al., 2016). The simulation specialist has equipment that makes it possible to choose between seven facial expressions and several movements for each virtual pupil. All the pupils are voiced by the specialist. The voices are morphed, resulting in different voices for each virtual pupil.

The teacher on the course, the instructors, the simulation specialist, and the researchers in the project created the scenario that the PSTs used. The scenario consists of a plan for how each virtual pupil could represent different possible misunderstandings (about fractions in this scenario), and how they will interact socially with the other virtual pupils and the PST (Reynolds & Muijs, 1999). During a session, the simulation specialist uses the scenario description as a basis for the interaction with the PST. Although the basis is the same in each simulation, each session will be different since the simulation specialist will let the virtual pupils’ reactions emanate from the ways PSTs teach.

Each session was followed by reflection and feedback. First, the PST was asked to reflect on their teaching experience. This was followed by feedback from peers, who had made notes based on a protocol focusing on (a) teaching mathematics, and (b) classroom management (Samuelsson, et al., 2022b). The two instructors then provided feedback, which connected what took place in the simulation with the theoretical content of the course. In this way, the simulation training made it possible to connect theory and practice, in line with Grossman et al. (2009).
Analysis
The researchers conducted a qualitative, inductive analysis, inspired by thematic analyses (Braun & Clark, 2006). To familiarize themselves with the material, each researcher individually watched randomly selected recordings from the total of 102. At this point, the researchers had an open mind, searching for phenomena in the material that varied in relation to the PSTs’ teaching. The researchers compared and jointly discussed their impressions, focusing on the teaching phenomena that occurred among the PSTs. They aimed to identify “repeated patterns of meaning” (Braun & Clark, 2006, p. 86). During this process, various phenomena were tested against new recordings before two recurrent phenomena were identified: (a) PSTs’ handling of content, and (b) their interaction with pupils. These two phenomena became the focus of the following analysis. In the next phase, two researchers jointly coded five recordings that represented various ways of teaching, focusing on how the two identified phenomena were handled by the PSTs. Initial codes were, for example, “following the pupils’ ideas” or “incorrect explanation”. In relation to the codes, various patterns of how PSTs taught were identified. The patterns were used as the basis when the rest of the recordings were analysed. The researchers then compared their coding and validated their interpretation. In the next phase, the codes were compared and connected to each other as four themes. Each theme described various ways of teaching regarding handling of content and classroom interaction. The third researcher – who had not so far analysed all the recordings – then analysed them to validate the identified themes. This researcher came to the same conclusion as the previous researchers, and no further themes were found. The identified themes are not attributed to individual PSTs.

Results
The results will be presented thematically, as four ways of teaching in a semi-virtual environment. We found that the PSTs taught the virtual pupils in (a) a confusing way, (b) an improvising way, (c) a lecturing way, and (d) an orchestrating way. Each will be described with respect to the handling of content – more precisely, reflecting which aspect of the content is brought to the foreground during instruction – and how the PSTs interact with the virtual pupils, with a focus on the extent of opportunities they give the pupils to influence what happens in the classroom.

A confusing way
When the PSTs teach in a confusing way, the enacted object of learning is unclear. They give misleading explanations and force the teaching process. The interaction pattern is characterised by the teacher talking most of the time, with the pupils only included through the use of short questions.
In the following excerpt, PST1 is teaching equivalent fractions. She mixes her explanation with respect to different subgroups of numbers in fractional form, sub-whole, and as the result of a division.

PST1: Does anyone know what equivalent fraction expressions are? (Dev raises his hand.) Dev.

Dev: Equivalent fraction expressions means that they have the same value, but the numerator can vary, and the denominator can vary. I can give an example: a third is equal to two sixths.

PST1: Yes, that’s a good example. I’ll go through it now. Here we have an example. We can start by drawing a pizza (draws a ring and divides it into three parts). Like this. The number of pizzas we have is one pizza (points to the numerator) and there will be three people sharing the pizza (points to the denominator). Then each person gets a third of the pizza (colours in one third of the pizza).

In the excerpt above, the PST asks a question to the pupils. She confirms the answer given by the simulated pupil Dev, and then moves on. She explains that the numerator represents the number of pizzas, which is not in line with the correct mathematical description. The PST handles the fraction expression as a division instead of what should reasonably be a sub-whole expression. She continues with another example, now showing two sixths. She uses the same explanation as before.

PST1: Then, here we have two sixths (draws two rings). It is therefore the number (points to the rings and then points to the numerator). The pizzas are thus two pizzas. And then each person will share here (divides the two pizzas into thirds). Each pizza is shared between three people (writes “3” under the pizzas) and each person gets a third of each pizza (writes “1/3” next to it), which is equal to two sixths.

Based on this explanation, real pupils would possibly have problems understanding what the numerator and denominator represent. Thus, this kind of explanation might lead to pupils’ misconceptions.

The interaction between PST1 and Dev in this session is characterised by an IRE (initiation-response-evaluation) structure. PST1 and Dev interact through short questions and answers. The PST is interrupted by questions from the pupils on a few occasions. For example, Dev asks if it matters whether the pieces of the pizza are equal in size. PST1 responds “Yes, the pieces should be equally large”, but does not explore it further. Throughout the session, PST1 has a high degree of control over the content, and decides what content is brought to the foreground. When Ethan questions an explanation – “What? The people increase as much as the pizzas? Is that what you said?” – PST1 does not explore it; instead, she repeats what she said before. She does, however, ask a couple of questions – for example: “Do you see that it is just as much?”, “Has everyone understood?” – during the
session. These questions address whether the pupils understand the instruction. In relation to the first question, the pupils do not react. The second question is posed later, and is answered by Ava, who makes a denigrating comment about Ethan probably not understanding. PST1 does not follow up on how any of these questions are received, and does not comment on Ava’s answer. In other words, the questions do not affect the teaching; they are of a more rhetorical nature. Thus, the pupils’ opportunities to influence what happens in the classroom are few.

Another example of PSTs teaching in a confusing way is when the teaching includes big steps in level of difficulty. The PST then forces the teaching in a way that is not in line with the pupils’ ability. This leads to a lack of internal logic in the lesson. In one session, PST2 starts the lesson by writing 1/3 and 1/4 on the board, followed by a question: “Which one is the biggest? 1/3 or 1/4?” In this task, fractions with a numerator of one and different denominators are compared. When one pupil responds incorrectly, she does not ask her to explain her thinking. Instead, PST2 immediately gives the following explanation: “If four people share a pizza, each of them gets less than if three people share the pizza.” She also draws a picture of two pizzas divided into pieces. After this, PST2 proceeds with a task where the pupils are asked to compare 3/4 with 5/7. In this case, both the numerator and the denominator vary, which is much more complicated than the first example given. This leads to unclear connections between the examples given by the teacher and the tasks that the pupils are supposed to manage by themselves. The pupils are given few opportunities to influence what happens in the classroom. They are given questions and tasks, but their answers are not explored, and when they give an incorrect answer, they are not asked to explain their thinking. The session is characterised by the IRE structure.

To sum up, when PSTs teach in a confusing way, they have a high degree of control over the content during the lesson, but it is still taught in an unstructured way. This is due to them having low knowledge about the mathematical content and/or being insecure about how to teach it, and about how to create an internal logic in the lesson. The teacher talks most of the time, and the pupils are only included through short questions. Therefore, the pupils’ opportunities to influence what happens in the teaching process are few.

**An improvising way**

With improvised teaching, the object of learning is handled in an unstructured manner; the PST does not appear to have a clear plan and improvises extensively. There is a lot of interaction with the pupils, who are given several opportunities to influence what happens in the classroom. When PSTs improvise, they reason with themselves and use questions from and to pupils to guide the lesson.

In the following example, the object of learning is equal fractions. PST3 enters the classroom wearing a cap. This is immediately questioned by one of the pupils, and PST3 throws the cap away. He then looks at three fraction circles (one with six pieces, one with four pieces and one with three pieces) on the board.
PST3: Aha … but … yees … I’m thinking like this (looks at the different fraction circles on the board) … er … to go on like this from this subject (fiddles a bit with a fraction circle) and see if you can … er … yes … (look at the fraction circles) er, we’ll take it easy a bit. If we say this, we can start with these (points to the fraction circle with sixths). How …? This is sixths. If you recall. I write this (writes “⅙” under the fraction circle).

PST3 has no written lesson plan, and when he introduces the topic, it seems as if he is thinking about how to start the lesson. He then interacts with the pupils, asking if they remember what one sixth is, and has a short dialogue with Ava (who does not remember) and Dev (who remembers). He looks at the board and continues to talk about sixths, explaining that one third is the same as two sixths. Savannah says that she does not understand. PST3 uses the prefabricated fraction circles to explain it, but since he cannot put them on top of each other he accidently drops them on the floor. PST3 changes strategy. Instead of only using fraction circles, he continues the lesson by also writing on the whiteboard.

PST3: We can do this (draws a ring). We draw that (points to the circle with sixths) and divide it into sixths (draws parts). Now we have six equally large pieces. And if we colour in two of them (fills in two parts). So. Then we’ve coloured in a third. Because then we can look at these (puts together thirds from the fraction circle with thirds). And then we see that all the pieces … if we have pieces, this shape (points out the circle), then we have thirds. Ava?

Ava: Wait a moment now … Now I think this is a bit confused. Just now you were talking about sixths, and now you’re talking about thirds. Are we talking about sixths or are we talking about thirds? What are we actually talking about?

PST3: We’re actually talking about both. Perhaps it’s getting too much. But …

Ava: You just showed everyone those sixths and then you divided up, divided it up into six parts and then suddenly you said thirds.

PST3: Yes, that’s because I coloured in two of them. If we say here, here I have a third (holds up a third). And if we then take two of the sixths (takes two sixths and puts them under) then we’ll have the same shape and the same size as one third. Which means that they make up the same amount of this symbol … or this shape (puts together thirds and sixths).

Ava: I understand, of course … But I’m wondering about something else. If you take a third like this and put it on the drawn third, then it takes up the space of, like, two of the ones you drew.

PST3: (Puts a third on the drawn circle.) Yes, I drew it a little larger.

Here, PST3 notices that it is difficult to use the fraction circles. He therefore draws a picture instead. He also tries to give an explanation to Ava’s question. When PST3 is focusing on the form of the third, and not its size, it is confusing for the pupils.
pupils, which can be seen when Ava concludes that two of the prefabricated thirds can be placed on two sixths. The PST has access to mathematical materials that can help him to show fractions in pieces that are exactly the same in size. However, when the materials are supplemented with self-made circles, the representation of the mathematical content becomes unclear. He combines two pictures of different sizes to represent the same fraction.

The lesson proceeds and PST3 draws two rectangles to give another example. When Ethan does not understand the examples, the PST pauses the simulation and says to his student peers: “What do I mean?” This shows that he is insecure about his own explanations. He pauses the simulation and is given support by his fellow peers, and he continues the lesson. Later, he pauses the simulation once again and says: “I don’t know what to do.” Throughout the entire session, it seems that he is making up the examples and explanations on the spot, which leads to him sometimes appearing to be puzzled about his own way of teaching the mathematical content.

In other words, when PSTs teach in an improvising way, the teaching is characterised by a lot of interaction with the pupils. The questions and comments from the pupils guide how the teaching session proceeds. This leads to a lack of internal logic and low control of the mathematical content. The structure of the session is not based on the logic of the mathematical content; instead, it is based on the content raised by the pupils. This gives the pupils who ask questions several opportunities to influence what happens in the classroom. However, pupils who are quiet are not involved in the discussion at all, since it is the questions asked by the other pupils that guide what is being taught in the lesson.

A lecturing way
When PSTs teach in a lecturing way, the object of learning is handled systematically. They give consistent explanations by using representations and examples that highlight the critical aspects of the content. The sessions have a clear internal logic, with a progression that is grounded in the pupils’ ability and the logic of the content. The PST has high control of the content and gives the pupils few opportunities to influence what happens in the classroom. The excerpt below shows how PST4 teaches equivalent fractions, such as $1/3 = 2/6$.

PST4: Listen, now we have to concentrate a little. Now we’ll concentrate on the board and look at the figures here. So now we’ve drawn a pizza here, and we’ve drawn a line right through it. So we’ve divided it up into two parts (points), OK? And if now we were to write a fraction, it would look like this. We’ve divided the pizza into two parts, so we write a two in the denominator. And now we decide we’ll eat one of these two parts.

Ethan: (Mumbling).

PST4: (Speaks up a little.) We choose that we’ve eaten this part (points to a half). So then the question is how much of the pizza have we eaten? (Short pause.) We’ve eaten
a half, haven’t we? So then the question is, what will we write in the numerator (points to where the numerator should be).

PST4: Ava?

Ava: There it’s a one, of course. We’ve eaten one of two parts.

PST4: Yes, good! We’ll draw another pizza next to it, but we’ll divide this pizza up into more parts.

Ethan: So then we won’t be full up.

PST4: What will we write here then, in the denominator, if we divide up the pizza into four parts? What figure will we write then?

Ethan: Because there are four parts, we write a four. And then we won’t be full up, then.

PST4: (Laughs a little.) Yes, how many parts of this pizza (points at the circle that is divided into four parts) do we need to eat to get as much as we’ve had on this pizza (points to the circle that is divided into two parts)? How many parts do we need to eat then?

PST4 starts with a concrete example and connects it to mathematical symbols, using correct mathematical concepts. She is in control of the mathematical content and engages the pupils through short, guided questions, using the IRE structure. The questions are asked after PST4 has given an explanation, meaning that the questions function as a means of knowledge control rather than finding out how the pupils think. When Ethan comments on things other than the mathematical content, this is ignored and the PST proceeds by focusing on the object of learning, sometimes by slightly raising her voice and continuing to talk. Later in the session, PST4 continues to teach about equivalent fractions by connecting pictures of fractions with a mathematical operation.

PST4: We can look here, too. What have we actually done with this two (points to the two in the “1/2”)? We can multiply, so take something times this two. It should be as big as this four (points to the four in “2/4”). What do we need to multiply this two by so that it’s as big as this four?

Dev: So when you multiply the two so that it becomes a four, so you multiply by two.

PST4: To make this two as big as the four, so we’ve multiplied – or timed by – two. OK? Now we’ll look at the numerator instead. Here, we have a one (points) and here we have a two (points). What must we times one by?

PST4: What must we times one by to make it this two? What must we multiply by, then? A one that needs to become a two. What do we need to multiply by, then?

Savannah: Yes, then you multiply by the same thing. You multiply by two.
PST4: Just as you say, now we’ve also multiplied it by a two (writes “x 2”). And it’s actually like this: if you multiply the numerator and the denominator by the same number, you can get an equivalent fraction. So we could multiply by anything, actually. We could multiply by three or four or ten, and no matter what we choose to multiply by, we would get an equivalent fraction.

The questions and the answers are used to highlight what the PST wants the pupils to understand regarding the object of learning. Throughout the session, the PST repeats correct answers from pupils, sometimes slightly rephrasing them and emphasising the central mathematical content. PST4 finishes the session with a new example about a chocolate bar that will be divided into three parts. She tells them that they are now going to try the method they just learned. She leads them through multiplying both the denominator and the numerator by two. She starts by writing question marks in the fraction, and when the pupils give the correct answer, she erases the question marks and writes the right numbers in the fraction. Then she does the same with a rectangle to convince the pupils that 1/3 is equal to 2/6. In this part of the session, PST4 uses her previous examples to guide the pupils through using a mathematical operation to calculate equal fractions.

In sum, when the PST teaches in a lecturing way, the object of learning is handled systematically, and the session has an internal logic, including a logic progression where examples are used to clarify and explain the mathematical content. The PST gives consistent and correct explanations for the mathematical content. The concrete and the abstract are connected through several representations (words, pictures, and written symbols). The PST gives all the pupils the opportunity to answer one or more questions. This leads to pupils being engaged in the lesson, but it is based on issues from the PST. When there are disruptions or issues that are irrelevant to the object of learning, the PST mainly handles them by proceeding with the lesson. Hence, the pupils’ opportunities to affect what happens in the classroom are few. However, the handling of the mathematical content shows an awareness of possible misconceptions and critical parts that need to be clarified for the pupils to learn.

**An orchestrating way**

When PSTs teach in an orchestrating way, the object of learning is handled systematically, with consistent explanations that use examples, and tasks which draw attention to the object of learning. The sessions have a clear internal logic, with a progression that is grounded in the logic of the content and pupils’ questions. The difference compared to the lecturing way is that the pupils are given more opportunities to affect what happens in the classroom. They are given tasks that demand interaction, and pupils’ questions and misconceptions affect what content is taught during the lesson. The sessions have some traits of exploratory talk.

In the following example, the object of learning is understanding equal fractions. PST5 has started by giving an example (1/2 = 2/4) by drawing a picture.
and combining it with the mathematical symbols. In the next part of the session, the PST invites the students to discuss and explore the object of learning. He writes \( \frac{1}{4} = \frac{2}{8} \) on the board and asks: “I wonder whether these fractions are equivalent fractions?” He divides the pupils into groups. During the discussion, he notices that some pupils direct negative comments at other pupils. He starts the whole class discussion with a brief comment about the climate before proceeding with the mathematical content.

PST5: We can deal with other things later, and everyone should do their best. Are these two fractions equivalent? What do you say? Put your hand up if you want to answer. Savannah.

Savannah: Yes, they are actually. I thought we could times it, by the same for both, because otherwise it won’t be right and you’ve done that there. Because one times two is two, and four times two is eight.

PST5: So you want to extend a quarter there, so that it makes the same as two eighths.

Savannah: Yes, it was called extending.

PST5: Yes. Extending, yes, great. And then the denominator is the number down here, under the line. And so we extend the four by two (writes “x 2”) and extend the one, the numerator, by two, and then we get … I’ll write it under here. Two out of eight is equal to two out of eight. Then the numbers are equivalent.

In this session, he uses Savannah’s explanation and expands it by using correct mathematical concepts (extend) and connecting it to a written mathematical operation. In the next phase, Ethan asks a question.

Ethan: Do you have to times by two? Because it’s been that all the time.

PST5: Yes, it has actually been that all the time. We’ll see if we can find another example. But it’s because these two denominators should be the same thing, and then because the four there should be as big as the eight, so we have to multiply by two. Because four times two is eight.

Ethan: So you can also take two billion if you want?

PST5: If you have fractions that big, but we won’t deal with that today, it’s this size we’re dealing with today.

Ethan’s question draws attention to the fact that the chosen examples only vary by two. This leads to PST5 first explaining mathematically why it is multiplied by two. After that, he continues with a concrete example that shows that the fractions are equal. This is followed by another example that shows that it does not have to be multiplied by two:
PST5: We’ll take another example and do it the same way (writes “1/6 = 3/12”). Then I wonder: Are these fractions equivalent? Discuss it with the same friends as before, and you at the back, remember that we’re talking about maths now.

The pupils discuss and focus on solving the task.

PST5: I think I’ll stop there. Then we can push the focus forward again. I just want to say that I think it’s great when you explain to each other, because you improve that way yourselves. When you help a friend and explain step by step, then you also learn something yourself. So that’s great to see. (Mumbling.) Did someone say something, put up your hand.

During the session, the pupils are given opportunities to affect the content. When Ethan asks a question, PST5 first explains it by going back to the first example, and then creates a new example where the numbers are not multiplied by two. This leads to an internal logic of the lesson where examples and explanations are connected. During the session, PST5 also comments on the interaction and why it is important to support each other’s learning.

To sum up, when the PST teaches in an orchestrating way, consistent explanations are given. Mathematical explanations are connected to both mathematical symbols and pictures, which illustrate that the fractions are equal. Using the examples, the PST can connect the different representations to each other, and at the same time be precise about what the parts of the fraction represent, and how the parts relate to the picture. During the sessions, the PST and the pupils share control of the content. The PST organises the session and alternates between group discussions and teacher instruction, which leads to high pupil participation and many opportunities for exploring the object of learning through discussions with peers. There are some traits of exploratory talk and there are several opportunities for pupils to affect what happens in the classroom. The pupils are given some opportunities to explain how they think, but different ways of thinking are not used as a basis for teaching. The PST also gives instructions and encouragement for behaviour that will strengthen a mathematical discussion with peers. The PST interrupts when the pupils veer off topic, and praises them when they explain the mathematical task to each other. Thus, when the PST teaches in an orchestrating way, pupils’ opportunities to influence what happens in the classroom are greater than when the PST teaches in a lecturing way. The interaction between the PST and the pupils ensures that the lesson proceeds, regarding both the content and the structure of the lesson.

Summary
The results are presented as four different ways of teaching, highlighting qualitative differences in how the PSTs handle content and interact with the virtual pupils. Notably, the PSTs’ handling of content varied in terms of explanations, internal logic, and control over the content taught. Additionally, interaction patterns exhibited variations in pupils’ opportunities to influence
classroom events, types of interaction, and the functions of questions. A comprehensive summary of these findings is provided in Table 2.

Table 2. Teaching styles with respect to handling of content and interaction patterns.

<table>
<thead>
<tr>
<th>Teaching style</th>
<th>Handling of content</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A confusing way</td>
<td>Misleading explanations</td>
<td>Pupils are given few opportunities to affect the lesson</td>
</tr>
<tr>
<td></td>
<td>Lack of internal logic</td>
<td>IRE structure</td>
</tr>
<tr>
<td></td>
<td>High control of content</td>
<td>PST gives short answers to pupils’ questions</td>
</tr>
<tr>
<td>An improvising way</td>
<td>Messy explanations</td>
<td>Pupils are given several opportunities to affect the lesson</td>
</tr>
<tr>
<td></td>
<td>Lack of internal logic</td>
<td>Follows pupils’ questions</td>
</tr>
<tr>
<td></td>
<td>Low control of content</td>
<td>Pupils’ questions guide the lesson</td>
</tr>
<tr>
<td>A lecturing way</td>
<td>Consistent explanations</td>
<td>Pupils are given few opportunities to affect the lesson</td>
</tr>
<tr>
<td></td>
<td>Internal logic</td>
<td>IRE structure</td>
</tr>
<tr>
<td></td>
<td>High control of content</td>
<td>PST’s questions function as knowledge control</td>
</tr>
<tr>
<td>An orchestrating way</td>
<td>Consistent explanations</td>
<td>Pupils are given several opportunities to affect the lesson</td>
</tr>
<tr>
<td></td>
<td>Internal logic</td>
<td>Traits of exploratory talk</td>
</tr>
<tr>
<td></td>
<td>Shared control of content</td>
<td>PST organises classroom discussion</td>
</tr>
</tbody>
</table>

Discussion

The results of this study provide important insights into how pre-service teachers teach and interact with simulated pupils in a virtual environment. The four teaching styles identified show that there is variation between PSTs with respect to how they handle the content and interact with pupils. Compared to earlier studies using surveys and quantitative approaches (Bennett, 1976; Grasha, 1994; Marbán & Mulenga, 2019), this study, using a qualitative approach focusing on PSTs, expands our knowledge about teaching skills. The study also identifies areas where the PSTs need further support in their development, and teacher educators can use the results as a starting point for a nuanced and qualified discussion about how to organise teacher education programs.

The four ways of teaching witnessed in this study identified four areas in which the handling of content seem to affect PSTs’ teaching of mathematics. The results indicate that focusing on the following aspects can be crucial in a teacher education program: (a) PSTs’ content knowledge, (b) PSTs’ ability to choose examples that highlight the content, (c) PSTs’ ability to create an internal logic in the lesson, and (d) PSTs’ ability to elaborate on the content of the lesson.

To become knowledgeable, there are several concepts that PSTs need to learn (Shulman, 1986). First, content knowledge can be seen as a foundation for specific
teacher knowledge (Blömeke & Delaney, 2012); the present study shows how PSTs who taught in a confusing way were uncertain about the mathematical content being taught, which led to indistinctly enacted objects of learning. Creating an internal logic for the lesson was difficult for PSTs who taught in a confusing way or an improvising way, and how to choose examples and how to organise them were major challenges for these students. In contrast, PSTs who taught in a lecturing way had a clear internal logic within the lesson when presenting the mathematical content. This is important with respect to the quality of PSTs’ teaching, since both Venkat et al. (2019) and Marton (2015) argue that successful teaching is characterised by a systematic way of organising the content, and by using examples that highlight critical aspects of it.

The results also show how PSTs interacted in qualitatively different ways with the virtual pupils. PSTs who taught in a confusing way and in a lecturing way interacted with the virtual pupils in a manner that could be described as following the IRE structure (Henning et al., 2012). However, there was a significant difference between the two teaching styles of confusing and lecturing. The PSTs who taught in a lecturing way structured the mathematical content with regard to aspects that needed to be clarified, and used questions to scaffold the virtual pupils’ learning. The PSTs who taught in a confusing way did not use questions to clarify the object of learning. In this context, the PSTs created a situation where the teacher was the one asking questions and the virtual pupils were trying to respond (Hundeide, 2003).

PSTs who taught in an improvising way used the virtual pupils’ questions to guide the direction of the lesson, which gave pupils several opportunities to influence what took place in the classroom. The virtual pupils were also given several opportunities to affect what happens in the classroom when the session was handled in an orchestrating way; the PSTs gave the virtual pupils several opportunities to make their voices heard and influence actions in the classroom, which offered them opportunities of agency (cf. Biesta & Tedder, 2006; Norén & Anderson, 2016). However, there was a difference between these two teaching styles. Orchestrating PSTs were in charge, and organised the session to allow pupils to interact in connection with the mathematical content, whereas improvising PSTs interacted more spontaneously with the virtual pupils. PSTs who taught in an orchestrating way also involved the virtual pupils more, and were attentive to their questions and answers. These sessions have traits of exploratory talk, as described by Wegerif and Mercer (1997), but there are some important features missing. Hufferd-Ackles et al. (2004) emphasise that pupils’ learning opportunities will increase if the teacher creates a space for learning where ideas about the object of learning are explored. This was not the case in any of the analysed sessions in this study. As previous research (Hacker & Tenant, 2002; van der Veen et al., 2017) has pointed out that established interaction patterns are hard to change, this is most likely an area in which PSTs need considerable practice.
Becoming a skilled teacher is a dynamic process, where novice teachers’ meaning-making in teaching situations is central to their development (Skott, 2013). Therefore, PSTs need to be part of processes where they are given opportunities to practice teaching, and to reflect upon what went well and what could have been done differently (McDonald et al., 2013). The semi-virtual reality is a setting where PSTs can practice teaching at campus. It gives the opportunity to focus on selected aspects of teaching, followed by immediate feedback from peers and instructors (Cohen, 2020). Moreover, the orchestrating of the virtual pupils by the simulation specialist was based on research concerning misconceptions about fractions, and this appeared to increase the sense of realism among the PSTs (cf. Dieker, et al., 2008; Badiee & Kaufman, 2015; Samuelsson et al., 2022a)

Overall, the semi-virtual simulation made it possible to investigate how PSTs teach, providing detail that made it possible to identify and classify their different behaviours. It enabled the identification of qualitative differences regarding how PSTs explain and control content, create – or fail to create – an internal lesson logic, their use questions and answers, and about whether pupils are offered any opportunities for agency.

Conclusion and further research

The results give important insights into PSTs’ challenges with respect to the knowledge they require to be effective teachers, as well as about how they act when teaching. Drawing on our results, teacher educators can nuance and qualify their discussions about how to arrange teacher education programs with respect to students’ different qualities and challenges. For PSTs, teaching virtual pupils can provide an opportunity to practise specific teaching skills in a safe environment (Dawson & Lignugaris/Kraft, 2017).

This study has its limitations regarding generalisability, and three important issues need further investigation to strengthen this aspect. First, researchers need to continue to investigate PSTs’ ways of handling the content and the interaction when teaching virtual pupils. Second, they need to investigate PSTs’ behaviour with real pupils to see if there are similarities in different contexts, and third, they also need to investigate PSTs’ enacting with respect to subjects other than mathematics to see whether or not there are similarities with teaching different subjects.
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