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# COMPLEMENTING THE GUIDANCE PROVIDED BY A SIMULATION THROUGH TEACHER QUESTIONING

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*The interaction between the teacher and the learners when using simulations is in need of research. This study concentrates on two questioning approaches, series of probing and series of guiding questions that teachers use to guide learning with simulations. These two approaches are contrasted with non-directive and directive guidance provided by the simulation. The data was collected through screen capture videos of pre-service primary teachers teaching physics with a PhET simulation. Two cases were selected for further analysis of teacher questioning and its adaptation to the learners. Even though teachers might use the spaces for explanations created by the simulation to probe for learners' explanations, it is possible that the guidance provided by teachers is still not based on these ideas and explanations.*

## INTRODUCTION

Computer simulations can be used as a part of inquiry-based science teaching in supporting development of hypotheses, collection of data and revising theory (Rutten, van Joolingen, & van der Veen, 2012). Unguided inquiry-based learning is ineffective while providing guidance e.g. feedback, worked examples or elicited explanations during inquiry learning benefits learners (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). The need for guidance is even greater with simulations which contain a lot of information that can be hard to perceive (Zacharia et al., 2015). Without proper guidance, the learners have difficulties with generating hypotheses, interpreting data and regulating their inquiry learning with simulations (de Jong & van Joolingen, 1998). Research into the learning support and guidance concerning learning with simulations has been focused on the guidance provided by the simulations themselves and not the role of the teacher (Rutten et al., 2012). This paper studies guidance provided by the teachers during learning with simulations and its interplay with guidance provided by the simulation.

Key factors of successful guidance are the same for teacher-learner interaction and for guidance provided by the simulations: adaptation to the learner, fading out and support for self-regulated learning (de Jong & Lazonder, 2014; van de Pol, Volman, & Beishuizen, 2010). Of these three characteristics, the ability to adapt the guidance to the learners' needs is the focus of this paper. The development of adaptive learning analytical tools which guide learners based on their learning products is still under way (de Jong & Lazonder, 2014). On the other hand, teachers can monitor and probe learners' needs and

knowledge through questioning and act upon the information gained (Ruiz-Primo, 2011). Probing questions can be used to e.g. elicit hypotheses from the learners before they start to experiment or encourage learners to reflect on their actions (Chin, 2007). Teachers' questions also can be used to guide learners or ask for factual information (Sahin & Kulm, 2008). Hähkiöniemi (2015) found that pre-service mathematics teachers who asked series of guiding questions directed learners towards an answer through a specific path whereas those who asked series of probing questions elicited learners' thinking and directed them towards forming explanations. These two approaches for questioning bear a resemblance to *directive guidance* and *non-directive guidance* provided by simulations (de Jong & Njoo, 1992). Directive guidance steers the learners into a certain direction through e.g. hints or direct feedback. Non-directive guidance helps learners in completing certain action but doesn't steer them into any direction.

The aim of this paper is to understand how teacher guidance complements the guidance by a simulation by two questioning approaches: one emphasizing probing questions and another emphasizing guiding questions. These approaches are presented through two cases from pre-service teachers who use questions differently in similar teaching situations involving simulations.

## METHOD

### Data collection

The two case study pre-service teachers were selected among 33 pre-service primary teachers (PSTs) who were participating in a science methods course. The PSTs were assigned to teach an inquiry-based physics lesson (length 45 mins) to which they had to integrate a given PhET simulation. (University of Colorado Boulder, 2016) These lessons were planned and taught in groups of five PSTs to learners from grades 3 to 6. The PSTs and the learners' guardians agreed voluntarily to take part in the research. Lehtinen, Nieminen and Viiri (2016) describes the planning and execution of the lessons. The learners used the simulations in groups of two to five with a PST guiding them. The actions with the simulations and the talk by the learners and the PST were recorded using screen capture software. The data for this paper comes from these recordings.

This paper focuses on teaching physics to learners from grades 5 and 3 with the "Balancing Act" (University of Colorado Boulder, 2016) simulation. This particular simulation was chosen because of the high amount of probing and guiding questions used by the PSTs with this simulation. The excerpts come from the "Game" section of the simulation where the learners were given assignments concerning balancing the seesaw. Before this section they experimented more freely with the simulation.

**Data analysis**

Teachers' questions were divided into four different categories: probing, guiding, factual and other questions. These categories are based on Sahin and Kulm (2008). The shortened definitions for the categories are as follows:

- Probing questions (code 3): Asking the learners to elaborate and extend their answers. The learners can also be asked about how they would solve the task at hand in a different situation or to make a hypothesis.
- Guiding questions (code 2): Suggesting some procedure for the learners or otherwise aiding in the task at hand with a question. The learners can also be told to pay attention to a particular event in the simulation through questions.
- Factual questions (code 1): Asking for a specific fact, a definition or an answer to an assignment. Series of factual questions are interpreted as guiding if it is clear that the teacher has a guiding aim in mind.
- Other questions (code 0): Asking non-subject related questions e.g. about classroom management.

Teacher utterances were considered questions if they invited the learners to produce an oral response. The question types were coded by author 1 using Atlas.ti video analysis software from the transcribed group activities. Part of the data was also coded by author 2. Inter-rater reliability for a sample of 101 questions (12% of all the questions) was 90% and $\kappa$ = .832 (95% CI .733 to .931), $p < .001$. Questioning diagrams were produced in order to study how the questions appeared in series. Similar graphs have been used to study pre-service teachers' questioning in inquiry-based mathematics lessons (Hähkiöniemi, 2015). Transcripts were divided into event segments which were marked by a change in topic, contrast in behavior or transition to the next type of conversation or activity (Jordan & Henderson, 1995). Questions asked in the same event segment are connected by a line in the diagrams.

**RESULTS**

The cases of two female pre-service teachers (PST A and PST B) are presented. The case of PST A demonstrates how series of probing questions are used to elicit information and to openly invite learners from grade 3 to share their ideas. The case of PST B on the other hand shows how series of guiding questions direct the learners from grade 5 towards an answer via a predetermined learning path. Figure 1 shows the questioning diagrams of PST A and B.

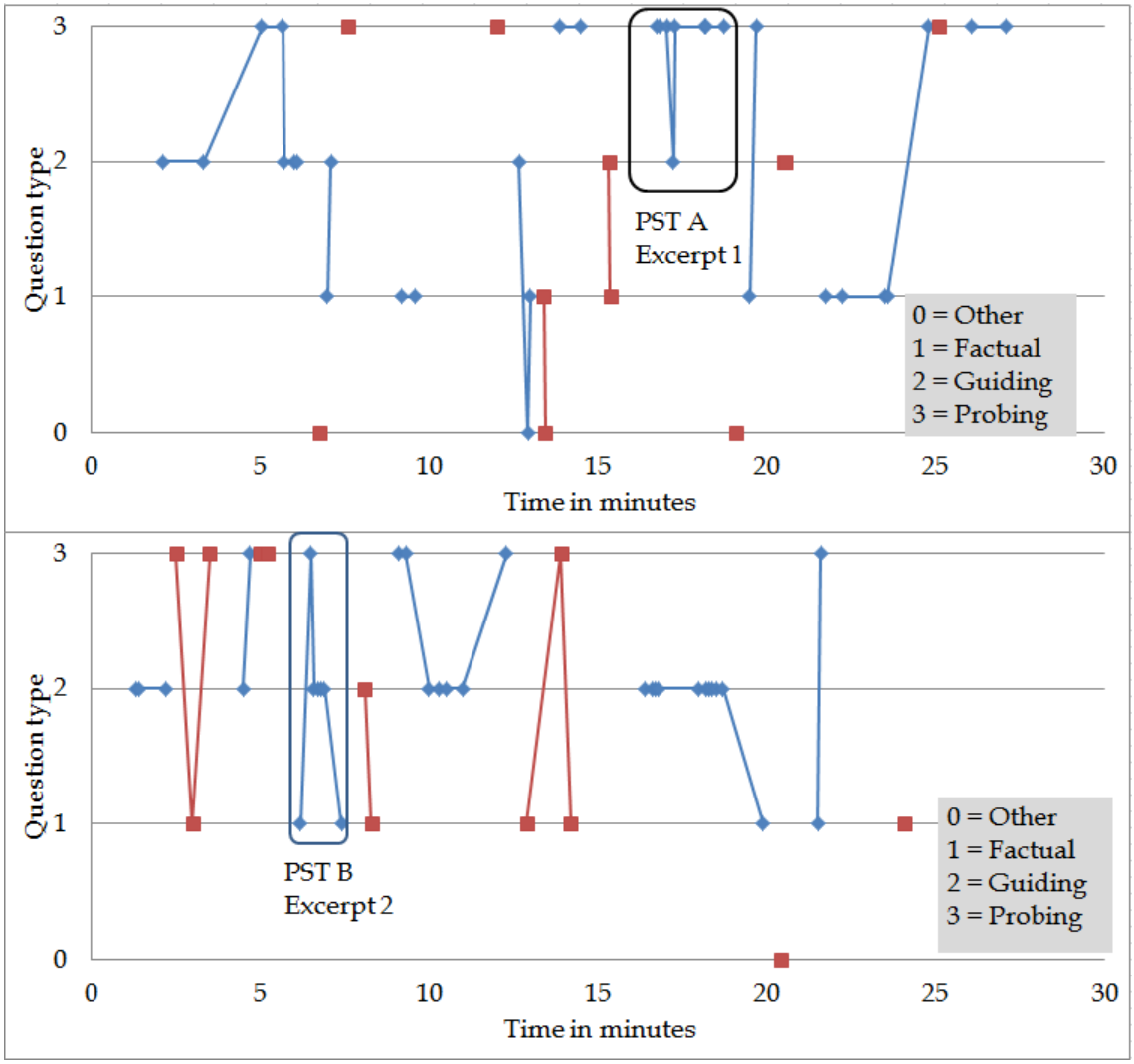


Figure 1. Questioning diagrams for PST A (upper) and PST B (lower). The episodes presented are circled.

Both pre-service teachers asked series of questions including both guiding and probing questions. Yet probing questions were more prevalent in PST A's questioning whereas guiding questions were more common in PST B's questioning. In the following sections we analyze one questioning series from both of the teachers.

**The episode of pre-service teacher A – series of probing questions**

The assignment asks the learners to find the mass of a trash can which is in a fixed position on the seesaw 1 meter away from the fulcrum. They do this by balancing the seesaw using a brick which weighs 15 kg. The learners have placed the brick 2 meters from the fulcrum and the seesaw has balanced itself.

1 PST A: OK, now it balanced itself so how can we deduce how much does the trash can weigh? [probing]

2 Learner 1: It weighs at least more than the other one.

3 PST A: Yes, why does it weigh more? [probing]

4 L 1: Because it's more to that direction.

At the start of the episode the simulation gives the pupils information that the seesaw is balanced but it does not show the masses of the objects. In turns 1 and 3, PST A poses probing questions which request the learners to think about the masses and reasons for them before proceeding to submit the answer. The learners have manipulated the simulation and created an interesting situation and the teacher stops the learners to think. Thus, the interplay of the guidance by the simulation and by the teacher creates a potential place for learner explanation of the phenomena. Indeed the learners articulate the qualitative idea of the relation between the masses and their distances from the fulcrum. After this qualitative idea, PST A starts to draw the learners' attention to the quantities of the masses.

5 PST A: If it was here on the same spot, then what would it weigh? [probing]

6 L 1: 15

7 PST A: That's right. So now that it is half as far as the other one- here is two one and zero- it's on top of the one so how much more should it weigh than 15… its half as far [guiding]

8 L2: Does this weigh 35 kilos?

9 PST A: Why do you think it is 35? [probing]

10 L 1: Yeah right!

11 L 2: I guessed.

12 L 1: I did too.

13 L 2: OK so let's try 35.

(The simulation informs them that their answer is wrong.)

In turn 5, PST A asks learners to hypothesize about the masses in the situation they already know from their previous experiments. This probing question is based on the learners' idea about the distances. PST A also confirms the learners' answer in turn 7. In this case, the guidance by the teacher complements the guidance by the simulation as PST A asks them to think about the simpler situation which draws the learners' attention to what they already know.

After this, in turn 7, PST A turns back to the quantities in the situation at hand in the simulation. Although the teacher is hinting about "half" in turn 7, she is not pressing it much and lets the pupils guess even though they are not able to answer the probing question in turn 9. The pupils submit 35 kg into the simulation and get the feedback that their answer is incorrect. In this case,

PST A lets the simulation provide the guidance by giving feedback that the answer is incorrect. After this, the learners start suggesting other values.

14 Learner 3: What about twenty?

15 PST A: So who thinks that why the answer- why do you think so? [probing]

16 L 1: Because well well there goes three and then one.

17 PST A: Hmm so what if the trash can would be on the same line what would it weigh? [probing]

18 L 1 and L 2: 15.

19 PST A: Yeah and now that the trash can is half as far from the fulcrum it is half way-

20 L 1: 30!

21 PST A: Try that.

22 L 2: Are you trying 20?

23 L 1: No but- yeah 20.

(The simulation informs them that their answer is wrong.)

24 L 2: It not that one either- do I have to show the correct answer?

25 L 1: It's 30.

26 PST A: Now you can't try it anymore- here comes the correct answer.

(The simulation informs them that the correct answer is 30 kg.)

In turn 15, PST A again probes for reasons for learners' answers and in turn 17 again directs their thinking towards the simpler situation. Thus, the teacher's guidance complements the guidance by the simulation by adapting to the situation in which the learners should move from guessing to reasoning. In turn 19, PST A hints again about "half" but does not press for it and does not even formulate a question about it. She lets the learners to submit a wrong answer. The discussion continues after the correct answer has been shown.

27 L 1: It would have been 30.

28 PST A: Yeah why was it 30? [probing]

29 L 2: Because 15 is half from 30.

30 PST A: That's right OK the next one.

The simulation reveals the correct answer, but doesn't provide any reasoning for it. PST A complements the guidance provided by the simulation by

probing one more time about the reasons and learners explain that the weight is half.

In the episode above, the interplay of the guidance provided by the simulation and by the teacher gets the learners to find the reasoning for their answer. The simulation created a space for explanations and the teacher's probing questions stopped the situation and elicited learners' explanations. The guidance was mainly non-directive basing on learners' own ideas. The dialogue continued based on their answers and the teacher did not steer the learners towards a pre-determined and structured learning path. The most directive guidance happened towards the end of the episode when the teacher hinted about "half" and when the simulation gave the correct answer.

**The episode of pre-service teacher B – series of guiding questions**

The assignment asks the learners from grade 5 to find a place where a weight of 40 kg balances the seesaw when a weight of 20 kg is fixed 1 m from the fulcrum.

1 PST B: Where should you put the weight of 40 kilos if the weight of 20 kilos is there? [factual]

(The learners discuss where to place weight and move the weight of 40 kilos to the correct position. The simulation informs them that their answer was correct.)

PST B starts the episode with a factual question in turn 1 that is aimed at finding out the answer to the assignment. She doesn't probe the learners for their reasoning before they check their answer. The teacher's question and giving the correct answer make the guidance received thus to be directive i.e. guiding towards an answer.

2 PST B: How did you figure out that you were supposed to put it there? [probing]

3 Learner 4: This is a bit heavier than that- this is 20 kilos heavier.

4 Learner 5: The heavier it is-

5 Learner 6: The more in middle it should be.

In turn 2 PST B probes the learners for their reasoning for their answer. The learners articulate the relation between the masses and their distances from the fulcrum qualitatively as did the learners in the previous episode. Again, an interesting situation has been created through manipulating the simulation and the teacher stops the learners to think. Thus the non-directive guidance provided by PST B complements the guidance provided by the simulation.

6 PST B: Yes, how many times is 40 kilos than 20 kilos? [guiding]

7 Learners: 20.

8 PST B: Yes and how many times? [guiding]

9 Learner 4: Two times.

With guiding questions in turns 6 and 8, PST B guides the learners to think about the relations of the weights. In turn 7 it is clear that the learners are having difficulties in doing so. Their initial qualitative idea is not being taken into account but instead PST B directively guides the learners based on her own strategy.

10 PST B: Yes two times heavier- well how much closer do you have the weight of 40 kilos than the weight of 20 kilos? [guiding]

11 Learner 4: One step.

12 Learner 6: One step closer.

13 PST B: Yeah and if the other one- well how far away is this other one? [guiding]

14 Learner 6: Two steps.

15 PST B: Well and-

16 Learner 5: Three steps all together.

17 PST B: Yes if this is the center of the balancing beam and this weight is one step this way and the other one is two steps that way but what is it… There is the distance but how- if this is two times heavier than that then how many times is this distance longer than that? [factual]

18 Learner 5: One step.

19 PST B: Ok… you can take a look at the next assignment.

In turns 10 and 13 PST B asks guiding questions aimed at finding the distances of the objects from the fulcrum. She is following the same strategy as before by directing the learners towards using the ratios of the weights and their distances from the fulcrum. In turn 17 PST B asks the final factual question about the ratios. When learners still can't give a correct answer PST B simply instructs them to move on in turn 19.

The guidance was mainly directive based on the PST B's own strategy. The dialogue advanced on a path laid out by the teacher which consists of structuring the task with multiple guiding questions. Even though PST B used the space for explanation created by the simulation to ask a probing question, her guidance did not take these explanations into account. Instead she used guiding questions to direct the learners towards using a specific strategy.

## DISCUSSION

Both of the episodes discussed show how the simulation created spaces for explanations. PST A used probing questions to elicit these explanations from the learners and mostly non-directively guided them based on their answers.

The teacher's guidance complements the simulation's guidance by using the spaces created by the simulation to provide adaptive, non-directive guidance for the learners. PST B also elicits explanations from the learners but doesn't use these explanations to adapt the guidance. Instead her guidance is based on structuring the task by directive guiding questions that are aimed at making the learners follow a pre-determined learning path. She doesn't deviate from this path even though the learners have difficulties following it.

Questioning diagrams reveal the teachers' emphasis on probing or guiding questions as in Hähkiöniemi's (2015) study. However, the diagrams do not give information about how the questions are adapted to the current situation. For this microanalysis is needed as done in this study. The two episodes show that even though guidance provided by teachers can complement the guidance provided by the simulation by eliciting explanations, the adaptation to the learners' actions is not self-evident. By eliciting the learners' knowledge and ideas through series of probing questions, the teacher gets information about the learners' knowledge and can adapt the guidance. This type of guidance can be compared with non-directive guidance (de Jong & Njoo, 1992) as it supports the learners to come up with their explanations. On the other hand series of guiding questions lead the learners through a pre-determined learning path towards the answer which can be compared with directive guidance by de Jong and Njoo.

Adaptation is an essential concept in describing all kinds of guidance (van de Pol et al., 2010) Use of simulations adds a new dimension to guidance by the teacher as it needs to adapt both to the learners and to the simulation. Through adaptation the teacher acts as orchestrator who chooses when to step in to complement the guidance provided by the simulation or when to step out to let the simulation provide guidance. Even though the simulation itself may provide directive guidance toward the answer the teacher may change the nature of guidance to non-directive. Thus the guidance provided by the teacher and the simulation have synergy with one another by interacting and working in tandem to support learning (Tabak, 2004).

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