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Making sense of student data in teacher professional development

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ABSTRACT

In recent years, the use of student data has become increasingly concerned with management of teacher performance. However, when teachers become aware of specific student data directly related to their approach of teaching, it could inform them about possible strengths, weaknesses or challenges. Unfortunately, teachers generally have little time and encounter significant problems in the interpretation and use of data for change. In this article, we put forward that such problems can be avoided by offering teachers practical frames that are aimed at the interpretation and productive use of student data. We report on an extensive study that was done in the setting of reform implementation where teachers were asked to change their teaching practices. Participating teachers performed multiple PDCA (Plan-Do-Check-Act) cycles in which they designed and taught lessons where student data were collected. To interpret and make use of such student data for change, we provided participants with practical frames. We examined to what extent and in what way participants used these frames and how this influenced professional development. Results showed that participants used frames to both interpret student data and make changes to their teaching practices towards that required by the reform in a stepwise, rather independent way.

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Professional development; practicality; data based teacher learning; educational innovation

Introduction

Data about student learning as indicators of teacher and teaching quality have become increasingly important in the last decades. In most cases, such student data serve as information for school management and accountability purposes (Lingard *et al.* 2015). Student data are also collected at a larger scale, where schools, districts or even state agencies collect and monitor data, which, in turn, are used to map teacher quality by comparison to others. As a result, student data have also become increasingly important in framing the working lives and experience of teachers (Ball 2015, Stevenson 2017). However, when school management uses student data to judge or compare teachers, there are risks involved such as datafication, being the use of data as a management tool in itself, and performativity, that is, a culture or system that is focused on maximization, targets and the worth of individuals for the greater good (Ball 2003, 2015, Lloyd and Davis 2018). This, in turn, can lead to teachers feeling low trust and stress which can result in the ethics of competition, individualism, performance and inauthenticity ('I am doing this because it will make me look good') instead of the ethics of professional expertise, authenticity and co-operation (Ball 2003).

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Student data can, however, also be used to contribute to the development of teachers' professional expertise. Linking outcomes in student learning to teacher learning is known to be an important guideline for effective professional development programs for teachers (Desimone 2009, Borko *et al.* 2010). As the primary objective of teaching is to promote student learning, it is important for teachers to have insight into specific effects of their actions on student learning (Fishman *et al.* 2003). On the basis of data about student learning, teachers could adjust and/or expand their knowledge, beliefs, attitudes and teaching repertoire (Desimone 2009). In practice, most teachers make nonetheless insufficient use of strategies in which they productively use student data to inform teaching practices. Student data and how to use them to improve teacher effectivity, therefore, are underutilized (Stecker *et al.* 2005, Schildkamp and Kuiper 2010) and there is a need for initiatives and support to assist teachers in how to use student data for change (Mandinach 2012, Marsh and Farrell 2014). Studies on teachers who did try to perform data-driven decision-making by using student data for improvement in their classrooms show significant problems. A first problem is that many teachers report practical issues, such as struggling with time constraints and encountering technical problems such as using management information systems (Young 2006). A second problem is that, generally, teachers report trouble understanding what the large numbers of student data mean and how they can use these data to propose change (Ingram *et al.* 2004, Schildkamp and Kuiper 2010). A third problem is that, when thinking about change, teachers often experience that they do not have enough knowledge or prior experience to propose change (Bransford *et al.* 2005). Teachers willing to change thus face serious problems in data use and are at risk of ending up in a vicious cycle of teaching lessons and trying to make use of data without significant improvement. The primary focus in this study should therefore be to understand ways in which teachers can both adequately *interpret* and *use* student data to propose change. To this end, we studied the development of teachers who followed a PD program with multiple cycles in which they (a) collected student data in their classes, (b) made sense of these student data by interpretation and (c) tried to use these student data for changes to their teaching practices. Support in both steps was based on ideas from Minsky (1985) and Klein *et al.* (2006) who state that new information is always examined through 'frames' that act as lenses or perspectives that give meaning to information. We designed three practical frames and we explored to what extent and in what way participants used these frames. We also monitored participants' professional development in terms of influence of data use on changing teaching practices in line with the reform.

Theoretical framework

In principle, data based improvement procedures can be understood as an application of the well-known quality improvement cycle; the Plan-Do-Check-Act (PDCA) cycle (Shewhart 1931, Deming 2000). When this cycle is applied to improve the quality of teaching, teachers would design a lesson (Plan), which they teach in their own class (Do). Next, teachers collect data on those student outcomes of interest and compare them to standards or expectations set beforehand in order to determine whether a change was successful or not (Check). After this, teachers can propose a new change (Act) and incorporate this in their new lesson design (Plan). To understand how teachers can be assisted in successfully interpreting and making use of student data within a PDCA cycle, we first need to deeper understand how people give meaning to experiences and propose change. From the field of cognitive science, it becomes clear that whenever people encounter new experiences, they activate mental frame-structures that were acquired in the course of previous experience (Minsky 1985). Using such frames, a new experience can be connected to the subjective knowledge already present in that frame and hence give meaning to the new experience. Already more than 30 years ago, such frames were defined to be a sort of skeletons, somewhat like application forms with many blanks or slots to be filled or a fixed set of named slots whose values vary across applications, which resemble the concept of mental schema (Bartlett

1932, Minsky 1985). An example of a frame could be a tree-like structure used for the concept *car*, having attributes like driver, fuel and different engine parts. Within the frame, all attributes have relations to one another and can be filled differently to design many different cars. Also, when a car is malfunctioning, one can schematically examine the attributes to find the part that is broken. Barsalou (1992), who built upon the work of Minsky, states that frames are the main representations of knowledge in human cognition. They provide both a strong conceptual tool to give meaning to new experiences and a powerful productive mechanism for generating specific combinations of parts within a certain field. However, frames are drawn from past experience and sometimes do not fit new situations perfectly. Therefore, frames have to be adapted to particular experiences in specific settings (Minsky 1985). As Klein *et al.* (2006) wrote, 'Making sense of data is the process of fitting data into a frame and fitting a frame around the data'. Translated to education, this provides valuable insight into the problems of teachers having trouble in understanding and using student data. For, if teachers want to overcome the previously mentioned problems of not being able to interpret and make use of student data, we can point towards the use of specific frames. Frames, however, are made up of a broad factual and theoretical knowledge in a certain setting, which in education would be pedagogical content or specific teaching approaches. Research by Bransford *et al.* (2005) shows that precisely such broad factual and theoretical knowledge was often found to be lacking, resulting in a situation where teachers often have frames that can be considered inadequate.

Frame design

In order to design effective frames for teachers usable in multiple PDCA cycles to interpret student data and propose new change, designers need to consider the specific settings in which the data based improvement procedure takes place as well as the intended goals for teachers. Coming back to the earlier mentioned frame example for *car*, it is clear that this frame is only suitable to assist practitioners involving car design, maintenance, etc. When we, in this specific study, want to design frames that can assist teachers in changing their teaching practices in single lessons towards context based education, it is implied that frames should focus on the primary teaching-learning strategy within a single lesson. Effective frames in this study should therefore offer factual and theoretical knowledge about the primary goal of the change process at hand. Frames should, however, not be limited to concrete actions that cannot be replicated in other classes or offering fixed solutions, which requires a level of abstraction that is not too generic and not too specific or limited.

As teachers are known to have little time or options for using new tools, frames will only be used properly if they are perceived as being functional within the teacher´s own environment, time and settings (Doyle 2006). In their teaching practices, teachers have to meet several goals simultaneously (e.g. student learning, keeping up the momentum, covering the textbook) with limited time and resources (Fullan 2007, Janssen *et al.* 2013). As a result, teachers will only use something new if it is perceived as being practical (Doyle and Ponder 1977). Three criteria can be used to determine the level of practicality of any change proposal in educational settings: it should be *instrumental* for teachers to use, it needs to be *congruent* with what a teacher normally does, and it must be easy to implement (*low cost*). Thus, to further design and fill the subparts of the frames, we not only need to take the main goal of the change process (the primary teaching-learning strategy within a single lesson) into account, but also need to focus on practicality demands. With these practicality demands in mind, we adopted the ideas of Merrill *et al.* (2008), who showed that teaching-learning strategies for single lessons can be decomposed into smaller segments like presentation, practice or demonstration. In our research, we built upon his work and designed frames based on the concept of smaller segments of single lessons that can be ordered and reordered particularly to represent single lessons as teachers give many every day (see Figure 1). The use of specific segments in understanding and attaining innovation has earlier been

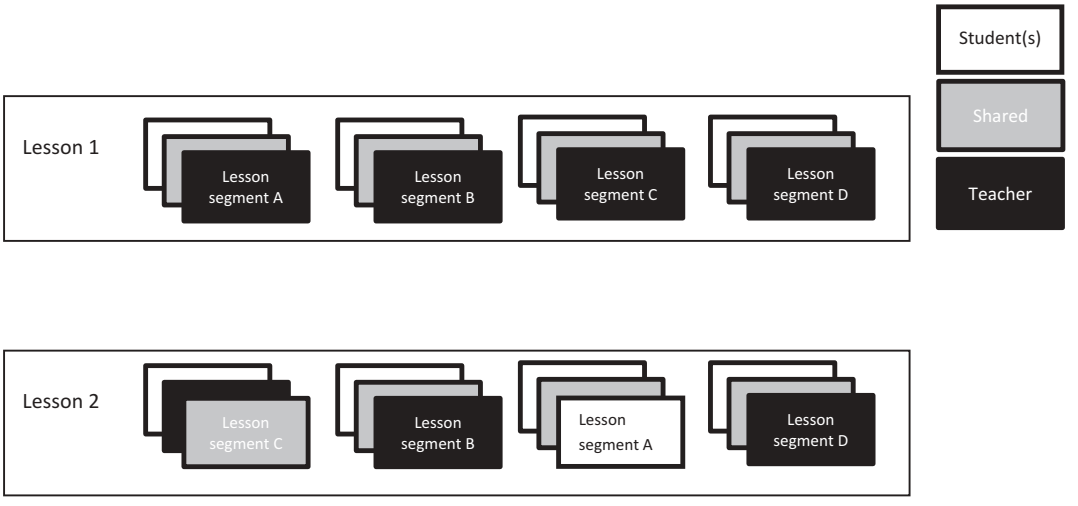

Figure 1. Graphical display of frames based on the concept of lesson segments.

described by Holland (2000), who defined innovations as, 'the rearrangements of already existing building blocks'. Whenever trying to propose innovations, the first step is to come to know the predominant building blocks in a certain area and then re-arrange them to propose an innovation. The concept of lesson segments has also been used in previous research by the authors (Janssen *et al.* 2013, 2014).

We expect that the set of lesson segments will illustrate to teachers how a change proposal such as context-based education in this study would work out in a concrete lesson design and how this relates to their regular instructional approaches. Using lesson segments, we expect teachers to also stepwise approximate the proposed reform with their own teaching practice as starting point, which can help them to understand how a change proposal connects with their regular teaching practice (congruency). Finally, all of this must be possible within limited time and resources available to teachers. Such low cost is accounted for by lesson segments being in place already as part of regular practices and the expectation that they are easily understood, so that teachers do not have to spend much time and effort on designing something completely new.

Frame use

From the previous sections, it becomes clear that frames could provide both a strong conceptual tool to give meaning to new experiences and a powerful productive mechanism for generating specific combinations of parts within a certain field. The specific frames used in the present study are based on lesson segments that can be combined to make up a single lesson and serve as a tool to make sense of student data. So how can lesson segments assist in making sense of specific student data? Suppose that a teacher expects 60% of the students to answer a test question correctly and he/she finds that only 40% answered the question correctly. He/she might then use a frame based on lessons segments to make sense of this problem by pointing to, for example a specific non-functioning order of lesson segments in the lesson (sequence of lesson segments) or a badly-structured explanation phase (content of one lesson segment). Asked which change would increase the student learning outcomes in a PD setting, the teacher might again choose to use a frame based on lesson segments to predict that when he/she aims to organize, for example the explanation phase better, the outcomes will increase as well. In this way, frames could be used in the setting of data based improvement initiatives to interpret student data and to propose change

in a specific or desired direction, in this study the arrangement of lesson segments that constitutes context-based education.

In the present study, participants were instructed to collect, interpret and make use of student data obtained in their own classes to inform their change processes. The PD program specifically offered assistance in the two crucial steps of the process: interpretation of student data and productive use of student data and the objective was to explore to what extent and in what way these frames were used, and to monitor participants' professional development in how their teaching practices changed upon using data. This research therefore aims to answer the following research question: How do practical frames contribute to teachers' interpretation and use of student data in the setting of a PD program, and what are influences of this PD program on changing teaching practices?

Methods

Participants

The PD program examined in this study was performed in the setting of a national biology education reform in the Netherlands; that is, the introduction of a context-based curriculum in secondary biology education (Grades 7–12 in which teachers were asked to change their teaching practices according to the reform). Because of the explorative nature of this study, we purposively invited biology teachers both known to the Institute's network of schools and varying on teaching experience, age and gender. None of them had previous experience in data based decision-making or teaching according to the goals of context-based education. Participants (n = 5) worked at four different secondary schools in the west of the Netherlands (see Table 1). Four participants taught grades 10–12 and one participant grades 7–9. Two participants taught in general secondary education and three in pre-university education (see Table 1).

Context-based reform

This research took place in the setting of implementing a reform-based curriculum in secondary biology education in the Netherlands. Context-based education is an approach to education in which subject matter is organized and taught by using contexts. The use of a context to teach subject matter is thought to bridge the gap between the often abstract and difficult scientific concepts and the world the students live in (Gilbert 2006). It was proposed as a solution to students' seeing school science as disconnected from the real world, leaving them with little interest in science, little understanding of the role of science in society and little awareness of career possibilities in the field of science (Bennett *et al.* 2007, Boersma *et al.* 2007). At the classroom level, the teaching-learning process of context-based education typically focuses on a meaningful context that is presented at the start of a lesson. From this context, a problem or question naturally follows that develops a 'need-to-know' for scientific concepts. Following, students have to gain insight in the concepts that are needed to answer the question or solve the problem (Gilbert 2006, Bennett *et al.* 2007, Wieringa *et al.* 2011). Several phases can be divided according to three forms of regulation: student self-regulation, shared regulation or

Table 1. Survey of participants.

Participant	Age	Teaching experience (years)	Grade Level [a]	Grades
Bob	28	3	GSE	10–12
Kimberley	49	12	PUE	10–12
Paula	52	4	GSE	7–9
George	40	10	PUE	10–12
Vincent	49	11	PUE	10–12

Note. [a]PUE = Pre-university education, GSE = General secondary education

a teacher's regulation (e.g. Vermunt 1998). If applied to the phase of finding answers, a first option could be to have students perform certain learning activities themselves to answer the question or solve the problem. In the second option, students and teacher work together to find answers, mostly in questioning-based classroom discourse and in the third option, the teacher regulates learning by presenting the information needed for answering. In more general terms, the regulation of the lesson segment 'answering questions' can be done by either the teacher, or the students, or shared. In the same way, all lesson segments can be regulated by either the teacher, shared or students. The answering phase is then followed by a final reflection on the content and the process of learning. The introduction of a context-based curriculum with new objectives and examination requirements will be introduced nationally, but the implications of the reform proposal in terms of instructional approaches are largely up to teachers themselves. It is precisely here that teachers are required to reconsider their instructional approaches and that is where we performed the present PD program.

Structure of the PD program

Participants in the present study followed a PD program that was aimed at the development of their instructional approaches towards proposed context-based education. Foundations of the PD program were data-driven steps of the PDCA quality improvement cycle (Shewhart 1931, Deming 2000). Participants were instructed to perform certain actions in each step of the PDCA cycle (see Table 2, left column). In the Plan phase, participants set learning goals for a single lesson, designed a lesson on the basis of their intention, and made up a small test questionnaire for students (SQ1) aimed to determine the extent to which students met the learning goals. Also, they set expectations for effects on learning. A second questionnaire (SQ2) was designed by the researcher and aimed at determining the perceived regulation of learning processes. SQ2 was constructed as follows: each time participants designed a lesson, they emailed their lesson plan to the researcher (first author). On the basis of the lesson plan, the researcher provided the participant with a short questionnaire to investigate student views on the sequence of lesson segments and the regulation for each of the lesson segments (see Figure 2 for an example). Next, in the Do phase, participants taught the designed lesson during which they collected students' data by administering SQ1 and SQ2. In the Check phase, the participants summarized their student answers to SQ1 and SQ2 and compared these to their expectations set in the Plan phase. The guiding question in the PD program for this comparison was, 'Did the student data match the expectation you set beforehand?' and the important question for interpretation: 'Do you think that your specific lesson design has had influence on the outcomes of SQ1, and if so, how?' Participants then completed the PDCA cycle by proposing change (Act), which we named 'intentions' after Fishbein and Ajzen (2010). The guiding question for eliciting these intentions was, 'Which next change in your practice would increase the student outcomes?' Participants then designed a new lesson (Plan phase) on the basis of this intention and moved on in their next PDCA cycle. In the last two steps of the PDCA cycle (Check and Act), we provided participants with frames that could assist them in understanding the outcomes of the questionnaires and proposing changes (see Table 2, middle column). Participants completed four PDCA cycles in total, in which they designed, taught and reflected on four lessons. Participants worked independently and wrote down all the above-mentioned steps in an online structured reflection format. Researchers (first and second author) and participants only met at the start and the end of the PD program. In the first meeting, one of the researchers and individual participants jointly compared the participants' regular practice with the proposed reform, both represented in lesson segments. The researchers then asked: 'What change would take your regular teaching practice one step towards the reform proposal?' This change proposal was rephrased into an intention to change and served as a basis for a first lesson design (Plan phase). At the end of the PD program, participants attended a group meeting in which they evaluated the PD program and member-checked their individual developmental path.

Table 2. Survey of the PDCA cycle.

PDCA cycle	Participants actions	Procedures of the PD program	Research data
PLAN	Set learning goals Design lesson Design SQ 1 Set expectations for learning	Instruct teachers how to design SQ 1	Lesson designs
DO	Teach lesson Gather student data using SQ 1 and SQ 2	Researchers design SQ 2 (for example, see Figure 1)	
CHECK	Summarize the student data Reflect on the lesson using the students' data	Offer frames Reflection questions in the online reflection format	Answers from reflection questions in the structured reflection format ('Do you think that your specific lesson design has had an influence on the outcomes of SQ 1, and if so, how?')
ACT	Propose intention to change	Offer frames Reflection questions in the online reflection format	Intentions from structured reflection format ('Which change in your practice would positively influence students' outcomes?')

Note. SQ 1 = student questionnaire 1, which aims to collect data on student learning. SQ 2 = student questionnaire 2, which aims to collect data about students' perception of the regulation of the learning processes.

Frames used in this study

All frames in this study are based on the overarching concept of lesson segments. Content and attributes of lesson segments were designed so that teachers could represent their existing approaches to instruction, context based instruction and approximations of context-based instruction. For lesson segments that represent the most common approach to instruction within a single lesson, we followed Gage (2009), who identified the following lesson structure to be most common: a lesson that starts with the presentation of specific information by the teacher, followed by a phase where the teacher assigns exercises to apply or recall that information. After this, students have to answer the assigned exercises, which is sometimes concluded by testing of reflection (Explanation → Questions to Recall and/or Apply → Answering questions). Lesson segments that constitute context-based education are twofold, both can be preceded by an orientation phase and/or followed by a reflection and/or test phase: Context with central question(s) → Answering question(s) → Explanation and Context with central question(s) → Explanation → Answering question(s). For a survey of the lesson segments used in this study with definitions, see Table 3.

1. Your teacher started this lesson by writing down the planning on the whiteboard
    a. He determined what was going to happen this lesson
    b. He consulted with us about what was going to happen this lesson
    c. I had great influence on what was going to happen this lesson

2. Your teacher then showed you a short movie starring *Lionel Messi* and asked you to start a company that makes identical copies of this football player
    a. He chose the movie and made up the questions about it
    b. We jointly chose the movie and/or made up the questions about it
    c. As a class, we chose the movie and topic of today and/or made up the questions

3. Your teacher then offered you the opportunity to answer the questions on cloning *Lionel Messi*
    a. He showed me how to answer the questions
    b. He helped me quite a lot in answering the questions
    c. I answered the questions on my own, without any help from my teacher

Figure 2. An example of a student questionnaire (SQ 2) (taken from George's lesson).

Table 3. Survey of lesson segments.

Lesson segment	Definition
Orientation	Introducing the subject, formulating goals, activating prior knowledge, and planning time and activities.
Test	Assessing to what extent the learning outcomes and/or processes match the pre-set goals.
Reflect	Looking back on results or processes, finding explanations for success or failure, finding improvements
Explanation	Explaining or presenting the content
Context with central questions	Introducing the context and attendant central questions or problems
Questions to Recall and/or Apply	Reproduction: assigning questions or tasks for which knowledge or skills learned earlier have to be literally repeated. Application: assigning questions or tasks in which knowledge acquired earlier has to be applied in new settings.
Answering questions	Answering the questions

In this study, three specific frames were designed to assist teachers. The first frame was defined as *Lessons can be seen as specific sequences of lesson segments*. When using this frame, participants can interpret certain student data by pointing at a specific chosen order of lesson segments in the lesson given. For example when participants are used to starting a lesson by presenting knowledge, changing the sequence into starting with an application question could affect student learning. The second frame was *Regulation of learning processes can be done by either the teacher, or the students, or shared*. This frame centres around the amount of regulation that is given to students in each lesson segment. Student self-regulation has become more and more important in constructivist views of teaching, such as the reform in this study (context-based education). The third frame was defined as *There are different types of contexts and they can have different functions*. This frame focuses on understanding the content and purpose of a context as this was the reform setting in which this research took place. Following Gilbert's notion, contexts can vary from the application of concepts to being authentic and having students participate in a community of practice (Gilbert 2006). As all types of contexts have the potential to positively affect learning (Bennett *et al.* 2007), participants in our research were free to use any type of context they wanted.

Data collection and analysis

We collected research data in this study to determine (a) if and how teachers used frames to interpret and use student data, and b. the development of teaching practices when using student data (see Table 1, right column). To determine the use of frames in the *interpretation* of student data, we collected all explanations and phrases of causal effects participants wrote down in the online reflection format during the Check phase of the PDCA cycles. Next, we investigated whether they used frames to do so, and how they did this. To determine if and how participants utilized frames to *use* their student data, we collected all the participants' intentions formulated in the Act phase of the PDCA cycles. Next, we investigated whether they used a frame to do so and how they did this. Analysis on the use of frames was done by two researchers (i.e. the first and second author). For both the interpretation and the use of data to propose change, we investigated if and how participants used the ideas or terminology of the frames that were offered in the PD program. For examples of how this analysis was done, see Table 4.

To determine how student data influenced the *participants' professional development* in terms of teaching practices, we analysed participants' developments throughout the PD program. For this end, we first made a chronological overview for each participant on paper. In the final PD session, we presented each participant with this survey of personal data, lessons designed and given, choices made and answers given to the questions pertaining to each of the PDCA steps in the online structured reflection format. After this, we had the participants check these summaries for internal validity (Miles and Huberman 1994). All participants confirmed that the overview represented accurately how they developed throughout the program. We analysed these written out developments of participants by categorizing a. lesson designs being in the same or other direction as the previous lesson and (b) experienced problems and successes in terms of SQ1 or SQ2 showing lower or higher scores than expected or other problems noted in observations by the participants. Next, we related the development directions with problems and successes. Did the participants choose to repeat the change, propose a change in the same direction or choose a complete different direction for change? In the final PD session, we also asked participants about the strengths and weaknesses of the entire PD program in an open format questionnaire.

Results

In this section, we will first present a case study to describe the way in which one teachers' teaching practice was influenced by her student data. We chose to present Paula for this case study, because her development pattern and use of data can be used to clearly represent the specific research approach taken in this study. In the second part of the section, we describe how often and in what ways all participants used the frames that we provided to interpret and make use of student data and their professional development in changing teaching practices.

Table 4. Illustration of how the analysis on the use of frames was done.

Frames[a]	Interpretation	Use
Frame 1	'The learning outcomes were high because I changed the sequence of my lesson; I started with a context'	'I want to start with a context' *or* 'I want to present the concept before the answering phase'
Frame 2	'Students had a role in the reflection phase; they had to present their answers to the rest of the class'	'I want students to find information themselves, without my help'
Frame 3	'Starting with a good, challenging context made students very active in answering the questions and resulted in high learning outcomes'	'I want a good, authentic context that motivates students to find information'

Note. [a]Frame 1 = Lessons can be seen as specific sequences of lesson segments. Frame 2 = Regulation of the learning process can be done by either the teacher, or the students, or shared. Frame 3 = There are different types of contexts and these can have different functions.

Case study Paula

Paula is a 52-year-old biology teacher who teaches mainly in the lower general secondary education grade level (grades 7–9). Before becoming a teacher, she worked as a teaching assistant for several years. She is an enthusiastic person who wanted to participate in this research in order to expand her teaching repertoire and get to know the context-based reform. At the start of her PD program, she outlined the structure of her typical lessons as follows: (a) checking homework for approximately 10 min; (b) explanation of new topics or students making a summary of the new topics using the textbook, 30 min; (c) students working on exercises from their textbooks (mostly exercises to recall) for the final 10 min. When she compared her typical teaching practice to the proposed reform, she intended to start by using a context with a central question and have students work out the answer themselves. Her first lesson design (Plan) started with a biological context in which a granny wants to get rid of the aphids in her oak tree. Can she combat aphids using chemicals without negative consequences for other organisms in the food web? She denoted the sequence of lesson segments in this lesson design as follows: Context with central question (teacher) → Answering questions (students independently) → Test (Shared). She expected 80% of the students to answer the learning effect questions in SQ1 correctly and, indeed, 80% of the students did (see Table A1). When reviewing the outcomes of SQ2, she was surprised that many students felt as if she helped them a lot in answering the questions, whereas she designed this to be fully student regulated. She answered positively to the question in the Check phase ('Do you think that your specific lesson design has had influence on the outcomes of SQ1, and if so, how?'). She answered (quotes): 'Starting the lesson with a context and let students find answers has had a positive influence on the learning outcomes' and 'Designing a lesson in which students answered the questions relatively independent had a positive influence on the learning outcomes'. In her first explanation, she attributed the good learning outcomes to the changed lesson sequence and the introduction of a context at the start. She used the frame 'Lessons can be seen as specific sequences of lesson segments' to explain the positive learning outcomes. In the second explanation, she also attributed the high learning outcomes to the students' relatively independent search for answers, although she did encounter a problem because students scored SQ2 as different from her design. With this latter explanation, she used the frame 'Regulation of the learning process can be done by either the teacher, or the students, or shared'. The next step in the PDCA cycle was to propose change by answering the following question in the structured reflection format: 'Which change in your practice would positively influence student outcomes?' (Act). She answered as follows (quote): 'I want to let students answer the questions from the context completely by themselves, without my help'. In this intention, she again used the frame 'Regulation of the learning process can be done by either the teacher, or the students, or shared'. Paula learned that her first lesson design did not support students in working independently at the level she intended it to be, but that starting the lesson with a context and letting students find information themselves indeed result in high student learning. On the basis of that, she decided to design a new lesson (Plan) that started with a context, where students had to answer the questions without her assistance. She then moved on in the PDCA cycle by teaching that lesson, collecting student data and so on (see Table A1).

The use of frames

Table A2 shows how other participants used frames in the Check and Act phases of their PDCA cycles. We chose to show the Check and Act phases because in these phases, participants could use frames to either interpret their student data (Check) or formulate intentions to change (Act). It is clear from Table A2 that all participants used one or more frames to interpret student data. This is illustrated, for example, by Kimberley when she reflected on her successful first lesson by saying: 'By using a context, I noticed that their thinking skills were addressed more than before. They started asking questions more deeply.'

Table 5. Survey of the numbers of frames used in this study to interpret (Check phase) or use (Act phase) student data.

Lessons	PDCA phase	No frame	Frame 1*	Frame 2	Frame 3
	ACT**		5	4	
1	CHECK		4	3	
	ACT		1	5	1
2	CHECK		2	3	1
	ACT	2		4	
3	CHECK	2	1	1	
	ACT	1	1	1	3
4	CHECK**	2	1	1	1

Note. *Frame 1 = Lessons can be seen as specific sequences of lesson segments. Frame 2 = Regulation of the learning process can be done by either the teacher, or the students, or shared. Frame 3 = There are different types of contexts and they can have different functions. **The PD program started by eliciting an intention (Act phase) and, therefore, the first Check phase is not included in this table. The PD program ended with the interpretation of students' data from the fourth lesson (Check) and, therefore, the final formulation of an intention (Act phase) was not included in this table.

In this way, Kimberley interpreted the expected positive learning outcomes by pointing to the important role of starting with a context and thus used the frame 'Lessons can be seen as specific sequences of lesson segments'. The participants also used frames to formulate an intention to change in their subsequent lesson. To illustrate how teachers did this, we will illustrate George´s interpretation and intention after teaching his first lesson. The lesson started with a context, after which he explained the main concepts. In his interpretation of the student data (Check), he stated that using a context helped students to understand the concept and had a positive influence on students' participation in the subsequent activities. When asked for a next change to optimize student learning, he formulated two intentions, for which he used two frames.

Table 5 shows how often participants used frames in the Check and Act phases of their PDCA cycles. In the beginning of their professional development, participants mainly used frame 1: i.e. that a lesson can be seen as a series of lesson segments and frame 2: that is that regulation of the learning process can be done by either the teacher, or the students, or shared. They used the third frame less and not until later in their development (i.e. not until the second PDCA cycle).

Teacher professional development

The second part of the RQ pertained to how using student data influences participants' teaching practices. First, participants show to keep the changes they made to their teaching practice when making new changes (see Table 6). For example when Kimberley reflects on the first lesson in which she introduced a context, she moves on to change the regulation, but keeps the context in place in subsequent lesson (see Table A2). Second, participants did not stop developing, but persisted in their development and were mostly successful in their attempts to make changes and build further upon evident successes. Even as participants experienced that their student data were not as expected or when they encountered difficulty in class (problem), they still tried out new directions to make their lessons successful. This can be illustrated by Bob's choices after his third lesson in data interpretation, when he stated that (quote): 'There was not much of a working atmosphere due to the absence of many students who were on a study week'. However, he did use frame 3 to design a relevant context to motivate students in the subsequent lesson design (see Table A2). This persistence in professional development contrasts with findings in other research, were motivation to proceed in development was low once problems were encountered.

Conclusion and implications

The use of student data can be roughly classified according to their intent. On the one hand, student data can be used for accountability purposes. On the other hand, student data can be used

Table 6. Summary of the development directions after experiencing success or problems in the lessons.

Lesson	Success (S) or problem (P)	Keeps the changes, intentional change in new direction	Keeps the changes, intentional change in same direction	Keeps the changes, intentional change to repeat the success	Does not keep the changes, intentional change in new direction	Stops developing
Bob						
1	S	X				
2	S		X			
3	P	X				
4*	S					
Kimberley						
1	S		X			
2	S		X			
3	S		X			
4	S					
Paula						
1	P		X			
2	S		X			
3	S	X				
4	S					
George						
1	P		X			
2	S			X		
3	n/a	X				
4	S					
Vincent						
1	S	X	X			
2	P		X			
3	S	X				
4	S					

Note. *The PD program ended after the interpretation (Check phase) of the fourth lesson. The formulation of intentions after the fourth lesson (Act) is therefore not included in this study.

to support teacher learning. This study has gained insight into how this second aim can be addressed more effectively. The known problems for teachers wanting to improve their teaching via collecting, interpreting and using student data are that they encounter difficulties in the two crucial steps of data interpretation and a productive use of data. In this study, we therefore provided participants with three frames that they could use when reflecting on their student data, and studied if and in what way these helped them to interpret their student data and propose productive change. The frames we offered were all based on the concept of lesson segments (see Methods). The research question of this study was aimed to determine if and how frames contributed to teachers' interpretation and productive use of student data and the influences of using student data on teachers' professional development in terms of how they changed their teaching practices.

Starting off their development, all participants chose to formulate an intention for which they used the first frame. This is illustrated by Bob who wants to start the lesson by creating a context through elaborating on the application questions he would normally assign at the end of the lesson. Next, results on the ways in which participants *interpreted* their student data show that they indeed used the frames provided with in doing so. Specifically, they mostly used the first frame to explain the outcomes as a product of a specific combination of lesson segments. Some also used the second frame by attributing specific results to choices made about the regulation of specific lesson segments done by either the teacher, shared or students. Only one participant used the third frame for interpretation purposes (Bob in his fourth lesson), indicating that this frame might not be very instrumental for teachers starting up their professional development and might serve as input for more secondary developments. When participants tried to *use* their student data

and propose change, they especially used frame 2 in making changes to the second and third lesson design. Also, frame 3 was used slightly more than in the interpretation phase (see Table 5).

Results on the *professional development* in terms of how data use influenced teaching practices in line with the proposed reform show that, in moving through the PDCA cycles, participants designed lessons in which they mostly kept their prior adjustments to lesson designs. For example, when they first used frame 1 to shift a context to the start of the lesson and this was found to be successful, they kept this change in successive lessons. Next, participants tended to maintain their successful changes in their next lesson design and proposed new changes in the same direction (using the same frame) or in another direction (possibly using another frame). Interestingly, participants also persisted in their development when confronted with problems. After the second lesson, participants started to formulate intentions outside the provided frames, such as the intention to ensure a tight connection between the context with attending questions on one hand and the learning goals on the other. Such intentions that were formulated without using the provided frames indicate that the frames in this study might serve as catalyst that initiates professional development in a direction of choice (in this study being context-based education), without having to be used extensively in the subsequent process of development.

What becomes clear from this study is that participants in general used frames that we offered to both interpret their student data and propose change. This contrasts with earlier research, in which precisely these two steps were found to be problematic (Ingram *et al.* 2004, Mandinach 2012). Findings in this study also show that this approach can help to overcome teachers' reticent attitude of bypassing or reducing the use of tools and materials that they are offered in a PD setting and keep on using their own experience and routines (Borko *et al.* 2010). We think reasons for the effective use of frames in the present study can be found in the design of the frames, as we provided the participants with frames that comply with the three criteria for practicality (Doyle and Ponder 1977). First, frames in this study indeed offered instrumental content to participants; concrete procedures on classroom level in the form of lesson segments. Knowledge too concrete would not be readily transferable, and knowledge too abstract not directly useable (Zeitz 1997). Frames in this study were designed at an intermediate level of abstraction, so that they were directly useable for teachers, but not so concrete that teachers could use them only in specific situations. The instrumental content (lesson segments) in this research also allows teachers to attribute certain outcomes to a specific part of a lesson design. And whereas teachers in other known cases attributed, for example specific learning outcomes, to external and uncontrollable factors (Janssen *et al.* 2009), participants in this study attributed outcomes to controllable and internal factors (e.g. ability, effort). Such attribution is known to promote the formulation of productive change proposals (Weiner 2010). Second, participants also showed to use frames rather adaptively in connecting the proposed reform (context-based education) to their existing teaching practices, which relates to the congruency criterion. Third, frames were also found to cost little time and effort, as they were tailored to the needs of teachers who have to teach many lessons every day and desire comprehensible, useable and effective tools.

In this research, we present data from a small number of cases and portrait Paula as a single case study to explore the role of practical frames in the interpretation and usage of student data in-depth and in authentic teacher settings. Limitations of case studies in general are the limited possibilities of scientific generalization to population as well as the risk of researchers letting equivocal evidence and biased views influence the direction of the findings (Yin 2014). This latter issue was covered for in this research by having multiple researchers analyse the data and providing member checks with participants. As to generalization issues, studies with an exploratory motive in smaller groups such as the present study focus on generalizability to theoretical propositions (e.g. mechanisms, rationale) and not so much populations. However, now that we found practical frames to be valuable for a small group of teachers, it will be interesting to set up a quasi-experimental research design with a larger group of teachers to study generalizability to populations.

The use of student data in this study sharply contrasts with the more conventional approach in which student data are collected for accountability purposes. In accountability settings, student data are collected by standardized modes of student assessment on a large scale and used to map teacher quality by comparison to others. The risks of such a use are what Ball (2003, 2015) proposed to be datafication, performativity and the tyranny of numbers leading to a decreased sense of professional expertise and authenticity of teachers. In the approach taken in this study, we explicitly took another stance and aimed to promote teachers' professional expertise. The approach takes the teachers' existing situation and intentions for each sequential development step as starting points within the context of educational reform. Also, teachers collected data themselves tailored to the goals they set beforehand and were assisted with practical frames to interpret and use these data. In the process, teachers made incremental steps that both connect to their volition and capability. Furthermore, the entire PD program took place in the authentic teaching settings of participants, thus taking all kinds of situational characteristics such as the school context, the classroom, the teacher's schedule, and the teacher's resources into account. In this way, using student data does not limit professional expertise, but rather enhances it. In conclusion, this research can provide directions for further conceptualization of data use in improvement procedures within PD settings in terms of what data should be collected, how these should be collected, and, especially, how teachers should be supported in their interpretation and use of student data.

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Appendices

Table A1. Paula's development.

	PLAN			CHECK		ACT	
Lessons in the PD program	Lesson design	Results SQ 1 compared with expectations	Results SQ 2 compared with the lesson design	Interpretation	Frame use	Intention	Frame use
Regular	*Explain (teacher) → Questions to Recall and/or Apply (teacher) → Answering questions (shared)*	n/a	n/a	n/a	n/a	I want pupils to be actively searching for information to answer the central question I want to start the lessons by using a context	Regulation Lesson segments
1st lesson	*Context (teacher) → Answering questions (students) → Test (Shared)*	80% of the students answered correctly, just as I expected	This was scored as I intended the lesson, but half the class felt as though I helped them a lot in answering the questions	'Starting with a context had a positive influence on the learning outcomes' 'Designing a lesson in which students answer the questions rather independently had a positive influence on the learning outcomes'	Lesson segments Regulation	I want to let students answer the questions from the context completely by themselves, without my help	Regulation
2nd lesson	*Context (teacher) → Answering questions (students) → Test (Shared)*	50% completely correct, 50% for 2/3 correct. This was above my expectations	This was scored as I intended the lesson	"Starting with a relevant context and let them answer the questions independently involved them in the learning process and increased learning outcomes.	Lesson segments and Regulation	I want the students to design a context with attendant questions	Regulation
3rd lesson	*Orientation (Teacher) → Context (students) → Answering questions (students)*	Above my expectations	Most students answered that they were indeed responsible for the context and answering of the questions	By allowing them to come up with a context, the relevance of the topic increased. This had a positive influence on the learning outcomes.	Regulation	For the next topic, I would like a context with a real profession and I would like to introduce a little bit about the profession myself.	Context type
4th lesson	*Context (teacher) →explain (teacher) →answering questions (students)→ test (shared)*	As I expected	Mostly as designed, but students answered that they regulated the Test phase, where I intended it to be a shared regulation	By first presenting the doctor-context they have been paying attention to the explanation of the contraceptives. This had positive learning effect.	Regulation and Context type	n/a	n/a

Table A2. Survey of the frames used in the interpretation and use of students' data in the Check and Act phases of the PDCA cycles.

	CHECK		ACT	
Lessons	Interpretation	Frames	Intentions	Frames
Bob				
	n/a	n/a	I want to start the lessons by using a context. I will create a context by elaborating on the application questions I normally assign at the end of the lesson	Lesson segments
Lesson 1	I think that starting with a context made students more active and serious this lesson. They also seemed to be more focused and involved.	Lesson segments	I want the students to work in groups when answering the questions, so that they can help each other.	Regulation
Lesson 2	I think that the learning outcomes were high because they worked together in answering the questions.	Regulation	I would like the students to answer the questions in groups and give them a role in the reflection phase.	Regulation
Lesson 3	There was not much of a working atmosphere due to the absence of many students who were on a study week. But because they had to exchange their answers and reflect as a class, they did their job.	n/a	I want to start with a relevant context, followed by relevant attendant questions so that students are challenged to study and learn.	Context type
Lesson 4	I think that the students were engaged in the topic of the lesson because of the relevant movie I showed and the funny attendant questions.	Context type	n/a	n/a
Vincent				
	n/a	n/a	I want to start with a context and I would like students to think of one.	Lesson segments and Regulation
Lesson 1	I think that due to the context, the students were immediately focused on the topic. For some students, it seems hard that I'm not presenting everything before they start answering the questions.	Lesson segments and Regulation	I want students to answer the questions independently, without my help I want to limit the reflection to the problematic questions	Regulation n/a
Lesson 2	I think that the students have high learning outcomes because they had to find information themselves. In this way, the students started to think more deeply about the topic.	Regulation	I want students to reflect on their answers themselves.	Regulation
Lesson 3	The students seemed to get trapped in the context. I think that because of this, mainly the students' discussion skills have been enlarged. Still, the results were good enough.	None	I want a tight connection between the context with attendant questions and the learning goals.	None
Lesson 4	The students clearly learned new concepts due to the tight questions I gave them in class. In addition, I was surprised that they discussed in class on the relationship between evolution and classification.	None	n/a	n/a
Kimberley				
	n/a	n/a	I want to start with a context and first demonstrate how to proceed in such a context. I want students to present the answers to each other.	Lesson segments Regulation

(*Continued*)

Table A2. (Continued).

	CHECK		ACT	
Lessons	Interpretation	Frames	Intentions	Frames
Lesson 1	Through using a context, I noticed that their thinking skills were addressed more than before. They started asking questions more deeply. I also noticed that the students made connections with other biological topics. All of this had a positive effect on the learning outcomes.	Lesson segments	I want to start again with a context and formulate attendant questions myself, but this time I won't demonstrate first.	Regulation
Lesson 2	The use of a context and giving students more independence in answering the questions had a positive effect on the learning outcomes, even though it was hard for students to concentrate at that late hour of the day	Lesson segments	I want to start by using a context again. After that, students will have to think of their pre-existing knowledge, followed by a students' task to find information in the textbook. I want to formulate good attendant questions with the context, so that students really have to find the details of the learning goals and learn enough.	Regulation n/a
Lesson 3	As a result of using a context and formulating good attendant questions, they learned what I wanted them to learn	Lesson segments	I want a relevant, interesting and detailed context and have students formulate the learning goals.	Context type and Regulation
Lesson 4	n/a	n/a	n/a	n/a
George				
	n/a	n/a	I want to start by using a context that I normally present after my explanation. This will be followed by my explanation and then the students can find information in their textbooks.	Lesson segments and Regulation
Lesson 1	Starting the lesson with a context and my presentation really helped students to understand the complicated concept. I also think that students were more active in the lesson.	Regulation	I want to present the context by using an animation or short movie to get students interested and motivated. I want students to find information directly after the presentation of the context, without my explanation.	Context type Lesson segments and Regulation
Lesson 2	Starting with a relevant context helped the students to learn the concept	Context type	I want to try out the same lesson set-up for a less appealing topic to see if I can make that more interesting.	None
Lesson 3	n/a	n/a	I want to discover a process together with the students by using multiple contexts in a row.	Lesson segments
Lesson 4	I think that I have to try harder to motivate the pupils to work. I found the topic boring. It wasn't 'my day' today.	n/a	n/a	n/a

Note. Frames: 'Lesson segments' = Lessons can be seen as specific sequences of lesson segments (Frame 1), 'Regulation' = Regulation of the learning process can be done by either the teacher, or the students, or shared (Frame 2) and "Context type = There are different types of contexts and these can have different functions (Frame 3). The interpretations and intentions are literal quotes from the participants.