Supporting student teachers in designing IBL-lessons

ABSTRACT.

Inquiry-based learning (IBL) has proven to be a didactical approach that has the potential to increase the, now lacking, motivation of students for science and mathematics. Teachers, however, need tools, and support for changing their daily practice towards more inquiry-based approaches. The attitudes of teachers towards IBL is another missing link in the research domain of IBL. The aim of this study is to determine how student teachers (STs) can be supported in implementing and taking up the benefits of IBL in science and mathematics education. A quasi-experimental study was performed on the supportiveness of guidelines for improving the redesigning of IBL-tasks. Ten STs also participated in pre- and post-interviews on their attitudes towards IBL. In the first meeting STs made a redesign while only using an IBL-framework. In the second meeting STs used an IBL-framework and guidelines to redesign an IBL-task. We evaluated to what extent their designed tasks created opportunities for IBL. Results show that STs felt designing IBL-lessons is hard, but during the second meeting their lesson designs had more degrees of freedom for students, especially in collaboration and communication. STs also mentioned that making IBL-lessons stimulated creativity and cooperation with colleagues. This study shows the added value of guidelines for designing IBL tasks in teacher education. The newly developed coding scheme for evaluating designs is a first step in this process.

KEYWORDS: attitudes, inquiry-based learning, lesson design, science & mathematics education, student teachers

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Supporting student teachers in designing IBL-lessons

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Inquiry-based learning (IBL) has proven to be a didactical approach that has the potential to increase the, now lacking, motivation of students for science and mathematics. Teachers, however, need tools, and support for changing their daily practice towards more inquiry-based approaches. The attitudes of teachers towards IBL is another missing link in the research domain of IBL. The aim of this study is to determine how student teachers (STs) can be supported in implementing and taking up the benefits of IBL in science and mathematics education. A quasi-experimental study was performed on the supportiveness of guidelines for improving the redesigning of IBL-tasks. Ten STs also participated in pre- and post-interviews on their attitudes towards IBL. In the first meeting STs made a redesign while only using an IBL-framework. In the second meeting STs used an IBL-framework and guidelines to redesign an IBL-task. We evaluated to what extent their designed tasks created opportunities for IBL. Results show that STs felt designing IBL-lessons is hard, but during the second meeting their lesson designs had more degrees of freedom for students, especially in collaboration and communication. STs also mentioned that making IBL-lessons stimulated creativity and cooperation with colleagues. This study shows the added value of guidelines for designing IBL tasks in teacher education. The newly developed coding scheme for evaluating designs is a first step in this process.

The Dutch educational system performs excellent on science and mathematics (PISA, 2012; Pisa, 2016; TIMSS, 2012). Though a good educational system is more than excellent performance by students. The development of students' research skills, critical thinking, attitudes, interests, study approaches, and the presence of qualified teachers are also important elements of an education system. PISA (2012) reported that less than half of the Dutch students were exposed to challenging problems by their teachers, furthermore students performed relatively low in problem solving tasks. The Organisation of Economic Co-operation and Development (OECD) found Dutch that students lack study motivation and less inclined to work on complex problems (OECD, 2016).

In general in science and mathematics the motivational problem can be connected to students' lack of autonomy and relatedness to the subjects (Ryan & Deci, 2000; PISA, 2012). In current teaching practices worldwide students hardly get opportunities to realise the relevance of those subjects and how they are connected to real life (Doorman, Jonker & Wijers, 2016; Potvin & Hasni, 2014). While in our everyday life we continuously use products and technology based on science and mathematics knowledge. For example, when we use shampoo in the shower or when we use google maps to find the shortest route towards a friend. Moreover science and mathematics also have an important role in social debate and socio-scientific issues (Levinson et al., 2017). Like in the debate on data security, in the vaccine debate, and when new technologies, such as cryptocurrency, enter our society. These types of daily life situations have the potential to become educational contexts students can relate to (Sanders et al., 2016). By connecting science and mathematics to the real life using contexts and improving the autonomy of students, student motivation will be increased (Osborne et al., 2003).

Providing students a challenging and stimulating learning environment will promote motivation even more (OECD, 2016). They need to see opportunities and advantages for using inquiry-based learning (IBL), and need to be able to tackle plausible disadvantages. Therefore insight in the fattitudes of teachers towards extending their teaching repertoire towards IBL approaches is an important part of our study.

Barron and Darling-Hammond (2008) found teachers are well willing to change their teaching methods. However, they lack information, tools, and support for changing and improving or innovating their daily practice. Especially on differentiation skills, learning reasoning skills and problem solving (OECD, 2016; PISA, 2012). The European Commission funds research on science education: “a call was launched with the aim of making science education and careers attractive for young people” (Horizon 2020, n.d). One of the projects funded by the European Commission is the MaSciL project. The MaSciL project promotes IBL by developing ready-made materials and running professional development courses. During the courses the teachers learn to (re)design traditional textbook tasks into IBL tasks. For supporting teachers in (re)designing these tasks, MaSciL provides guidelines for (re)design that are embedded in theory (Doorman et al., 2014).

In this study we investigate to what extent MaSciL resources for professional development aimed at in-service teachers can also be used in initial teacher education. In order to explore the usefulness of these MaSciL-guidelines for teacher education, student teachers became the group of interest for this study.

The aim is to map students teachers needs in order to adequately support student teachers, so they can implement IBL and thus profit from benefits of IBL education

Theoretical background

The implementation of new didactical approaches require willingness of students and teachers to change their daily practices and their learning and teaching methods (Barron and Darling-Hammond, 2008). Furthermore, resources that are needed for implementing an innovation need to be available and accessible for students and teachers. Therefore we will focus on the attitudes of Dutch student teachers toward IBL and on the required resources for implementing inquiry-based learning. Hereafter we will explain the guidelines for (re)designing IBL tasks.

Attitudes of student teachers

IBL is still a rather new teaching method for (student) teachers. Student teachers and in-service teachers rate new research and reform initiatives in general overwhelmingly positive (Gabel et al, 1987). According to Gabel et al. (1987) this positive view can be explained by the emphasis on new research and reform initiatives in teacher education. Damnjanovic (1999) found secondary in-service teachers were even more positive than secondary student teachers. She suggests this arises from a better understanding of the influences and interpretations of new science teaching methods by in-service teachers compared to student teachers.

Attitudes of teachers toward IBL show some advantages and disadvantages. They feel IBL is time consuming, are afraid to fail reaching deadlines of high stake assessments, and find it difficult to implement IBL in their daily routine (Marlow & Stevens, 1999). On the other hand, teachers like the idea of using relevant and interesting science inquiry in a classroom setting to construct knowledge (Marlow & Stevens, 1999).

Resources for implementing inquiry-based learning

Natural curiosity and the basic research cycle are the fundamental parts of IBL. In the most extreme situation IBL tasks give students the chance to go through all steps of the research cycle; starting by making up a research question and hypothesis, to designing and doing research, evaluate and interpret data, coming up with conclusions, and publish the results (see Figure 1). Quite often the findings of an IBL task lead to new questions.

Minimal criteria for IBL were set up by Minner, Levy & Century (2010). According to them IBL tasks use at least one step of the empirical cycle of research and they require active participation of students. And while taking part in an IBL task, students need to be (partly) responsible for learning, active thinking, and motivation.

IBL tasks need to be motivating for students and workable for teachers. Therefore, the MaSciL project rephrased the criteria for an IBL tasks in four domains; (a) tasks need to be meaningful for students, (b) give the potential to evoke multiple solution strategies, (c) let the students plan their inquiry, (d) let students collaborate and communicate (Doorman, 2011).

Capps & Crawford further developed a framework to analyse educational practice. They identified seven phases of IBL: involve in sci-oriented question (D1); design and conduct investigation (D2); use tools and techniques to gather, analyse and interpret data (D7); observe, describe, record and graph, priority in evidence in respect to problem (D3); use evidence to develop an explanation (D4); connect explanation to scientific knowledge (D5); communicate and justify outcomes (D6) (see Figure 1). These different phases can be initiated by teachers or by students. Therefore, Capps & Crawfords framework has a four-step Likert-scale from totally teacher initiated, mostly teacher initiated and mostly student initiated, to totally student initiated.

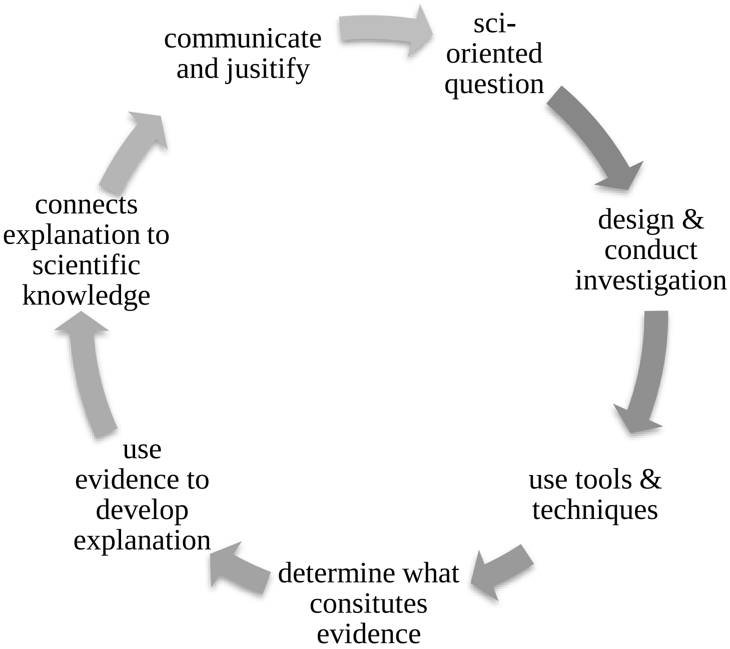

Figure 1.

Framework of Capps & Crawford visualised as IBL circle.

Guidelines for (re)design inquiry-based learning tasks

An original textbook problem can serve as basis when making an IBL task. Most original textbook problems have closed (sub)questions and a highly structured setting. Resulting in students drawing obvious conclusions from simple tasks or simple experiments (Chinn & Malhotra, 2002). The context of a textbook task can be a good starting point in order to make an IBL task, but the activities needs to be changed (Doorman et al., 2014). To support teachers and designers in making better IBL tasks that meet with the needs of students for promoting IBL, MaSciL constructed eleven guidelines (see Table 1 and Annex 4). They are an extra help over and above the IBL cycle and the minimal criteria of Minner, Levy and Century (2010).

The above mentioned theoretical backgrounds on attitudes of student teachers, implementing IBL and guidelines for (re)designing IBL, resulted in two research questions. The research questions of this study are:

- How do the attitudes of student teachers towards IBL change/develop during two sessions addressed to the implementation of IBL in science and mathematics education?
- What is the added value of guidelines to support student teachers in improving tasks for IBL-lessons?

Methods

Three universities of applied sciences were recruited to participate in this study. Two universities of applied sciences were planning subject didactics, a course in which our two sessions about inquiry-based learning could fit. The third university of applied sciences students did not meet the requirements of having subject didactics at the time our study was carried out, student teachers only had internships during our period of research. Thus the participants of this study consisted out of two universities of applied sciences.

Participants

Two groups of student teachers constituted the sample of this investigation, one group of mathematics student teachers from the Hogeschool Utrecht (HU) and one group of chemistry, physics and biology student teachers from the Noordelijke Hogeschool Leeuwarden (NHL). The selection of both groups was made upon the choice of student teachers in science and mathematics who have subject didactics courses in combination with no prior knowledge of IBL. Within this student population there was a wide range in teaching experience (1.5 - 25 years) and a wide range in age (25 - 55 years). During this study Dutch was the main language, therefore all quotations in this paper have been translated from Dutch into English.

Study design

The development of student teachers' attitudes towards IBL was investigated during two sessions of interviews. To investigate how student teachers' attitudes towards IBL develop, student teachers were asked about their initial attitude towards IBL before they learnt about IBL in class. After two meetings on IBL their attitudes were asked again in order to check for a plausible shift in attitudes (see Figure 2).

The pre-interview had an introductory part to align interpretations of IBL and to evaluate their initial attitudes towards IBL. During this introductory part the participants could choose between two tasks, one IBL-focused and one non-IBL-focused (structured) tasks. They were asked which of both tasks they preferred, if they could define the learning goals of both tasks and if the tasks could be used in IBL lessons. The second part of the pre-interview and the whole post-interview conducted the same structured questions. This structured part included questions on advantages and disadvantages of IBL, just as a question on the amount of time teachers used IBL in their classrooms (see Annex 1 and 5).

Per university of applied sciences five students participated in both the pre- and post-interviews, making a total of ten pre-interviews and ten post-interviews.

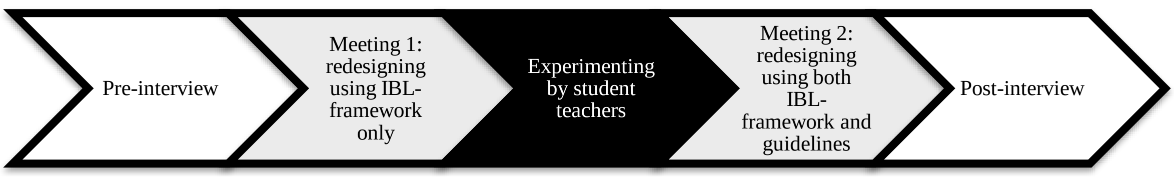

Figure 2.

Flowchart of the study design

In order to test the added value of the MaSciL guidelines a quasi-experimental study was performed on student teachers in two schools of teaching. During the first meeting students made one redesign while using an IBL framework only. They tested this redesign in their high school or vocational (MBO) school. In the second meeting students will use both an IBL framework and the guidelines to redesign a textbook task. An identical PowerPoint presentation was used in both HBO's to prevent an informational difference on the IBL framework between students and to maximise the internal validity (see Annex 2 and 3). The first meeting started with an introductory part on IBL. The introductory part addressed the following themes: "What is inquiry-based learning?", "Why would you use IBL in your lessons?", "Experiencing IBL", "How to use IBL in a classroom setting", "Examples of teaching practice". Then student teachers had time during the meeting to make their first redesign, lastly they evaluated the meeting. During the second meeting a short review of the first meeting was given, then guidelines for (re)designing IBL tasks and guidelines on supporting inquiry by students were introduced and handed out to the student teachers (see Annex 4). All student teachers made a second (re)design (of a textbook task). Finally, also the second meeting was evaluated with the student teachers.

Both the interviews and the (re)designed lessons were collected. The experimenting by student teachers in their high school or MBO school was not collected due to practical reasons as travel distance, time management and the new privacy law.

Data analysis

The attitudes towards science can be very diverse, therefore attitudes were coded with inductive coding inspired by the method of grounded theory (Glaser & Strauss, 1967). First, advantages and disadvantages mentioned during the interviews were listed. Similar phrasings were clustered and for each cluster descriptions were listed (e.g. "Longer preparation time" or "Encourages reflection"). Second, the emerging clusters that were mentioned by at least two students were used as theme and assigned to the interviews (see Table 2 and 3). Finally, we counted the number of times each theme was mentioned.

The (re)designed lessons were coded upon a compressed version the coding scheme of Capps and Crawford (2013) (see Table 1). Out of the seven original D-codes, four combined codes were made: *'meaningful'* (D1), *'plan inquiry'* (D2, D7), *'multiple solution strategies'* (D3, D4 & D5), and *'collaboration and communication'* (D6). These four codes were originated for Doormans' four domains in IBL (2011).

Table 1.

Summary of the compressed version of the coding scheme of Capps and Crawford (for the complete version see Annex 6).

Doing Inquiry	**3pts**	**2pts**	**1pts**	**0pts**
Meaningful (D1): involved in sci-oriented question				
Multiple solution strategies (D3, D4, D5): multiple options for evidence, and for ways to collect/find evidence				
Plan inquiry (D2, D7): design and conduct investigation. Use tools and techniques to gather analyse and interpret data.				
Collaboration and communication (D6): communicates and justifies				
	← Student initiated		***Teaching material initiated →***	

All four codes were rated upon a four-step Likert-scale, from totally teacher initiated, mostly teacher initiated and mostly student initiated, to totally student initiated, as done in the original scheme of Capps And Crawford (2013). Three designs were checked by another researcher at the same time, to gain feedback on applying the four-step scale. Hereafter a rubric for rating the redesigns was formed for external validity. After coding all redesigns, four randomly selected designs were checked with the rubric by a second coder, Cohen’s Kappa was used to check for inter-rater agreement. A good inter-rater reliability was found, Cohen’s kappa .78.

Results

Interviews

During the introductory part of the pre-interview students could select one task that they would give to their students out of two tasks, one IBL-focused and one non-IBL-focused. Two student teachers selected the IBL-focused task. Six students selected both tasks, they wanted to give their students the non-IBL-focused task first and the IBL-focused task later on, when their students knew the theory necessary to complete the task already. Two students selected the non-IBL-focused task.

These findings corresponded directly to how often the student teachers said they used IBL in classroom situations. Student teachers who selected the IBL-focused task used IBL more often in classroom situations than the other student teachers. While the student teachers who only selected the non-IBL-focused task never used IBL in their daily practice.

Though the majority of these teachers never or sometimes used IBL, they did see some advantages and disadvantages for using IBL (see Table 2 and 3).

Before the meetings and the experiments four types of disadvantages were named (see Table 2). One of them, *IBL is more applicable for higher level students*, was not named in the post intervention interview. One quote of this aspect was given by a student teacher:

“I could give this task to a havo/vwo class. But I teach vmbo. I believe my students need way more guidance.”

Table 2.

Disadvantages to IBL mentioned by student teachers.

Description	*Pre-intervention*	*Post-intervention*
Longer preparation time	5	6
Making tasks with correct difficulty level and clear frameworks	4	8
Time consuming in class	4	3
More applicable for higher level students	3	-
More difficult to check learning gain and prevent misconceptions	-	3
Difficult to formulate a question	-	3
Needs a good classroom climate	-	3
Teacher needs to learn different teaching strategies	-	2

In the post-intervention interview four disadvantages came up that were not mentioned during the pre-intervention interviews (see Table 2). For example, three student teacher mentioned they felt it is more difficult to check the learning gain of their students and to prevent misconceptions. One quote of this aspect was given by a student teacher:

"It can cause misconceptions. Especially if students draw their own, wrong, conclusions."

Before the meetings and the experiments seven types of advantages were named (see Table 3).

Table 3.

Advantages for using IBL mentioned by student teachers

Description	*Pre-intervention*	*Post-intervention*
Students become owner of their own learning process	9	6
Encourages reflection	6	8
Encourages student collaboration	7	2
Teachers can give students targeted feedback	7	7
Time saving when regularly used	3	1
Stimulates creativity and cooperation with colleagues	2	8
Good preparation for future study/exam	2	1
Higher learning gain	-	3

One of them, *stimulates creativity and cooperation with colleagues*, was mentioned two times in the pre-intervention interview and eight times in the post-intervention interview. One quote of this aspect was given by a student teacher:

"Two heads know more than one. You know the classes, the students, the school and it is just easier to make IBL-tasks in cooperation with colleagues."

In the post-intervention interview one advantages came up that was not mentioned during the pre-intervention interviews. Three student teacher mention they feel their students' learning gain was higher when using IBL. One quote of this aspect was given by a student teacher:

"If you have found out new strategies yourself, then it retains better. Therefore I always return to their self-made strategies during my explanation."

The last interview question of the post-intervention interview was if the student teachers became more IBL-focused after the intervention. Four student teachers said they were more IBL-focused than before. The other six, including the two students who called themselves already IBL-focused in the first interview, said their attitudes towards IBL did not change.

(Re)designed IBL-lessons

During the first meeting 21 (re)designs were made, six designs by HU-student teachers and fifteen by NHL-student teachers. During the second meeting eight (re)designs were being made, three designs by HU-student teachers and five by NHL-student teachers.

By using an example we want to illustrate the changes made by student teachers and the use of the newly developed compressed scheme of Capps and Crawford for coding the redesigns.

When comparing an original task and the redesign made by a student teacher two main changes can be seen: sub-questions were skipped and this creates the opportunity to use multiple strategies for designing a visual, organized way of communicating the results (see Figure 3).

All domains of this example redesign were scored using the scheme of Capps and Crawford. In this redesign students are engaged in questions provided by the teaching material. This is completely teaching material initiated, therefore zero points are scored on *'meaningful'*. The teaching material suggests to collect certain data, day to day drug level and a formula, though there are multiple options for students to collect this data or find evidence. Therefore two points are scored on *'multiple solution strategies'*. Students need to invent design and conduct the investigation themselves, the teaching material does not provides them any tools and techniques needed. Therefore three points are scored on *'plan inquiry'*. The teaching material gives space to students to create representations and to create logical arguments, therefore three points are scored on *'collaboration and communication'*.

Original task:
A patient is ill. A doctor prescribes a medicine for this patient and advises to take a daily dose of 1500 mg. After taking the dose an average of 25% of the drug leaves the body by secretion during a day. The rest of the drug stays in the blood of the patient.

1. How much mg of the drug is in the blood of the patient after one day?

2. Finish the table.

Day	Mg of drug in blood
0	0
1	1125
2	…
3	…

3. Explain why you can calculate the amount of drug for the next day with the formula:
new_amount = (old_amount + 1500) * 0.75

4. After how many days has the patient more than 4 g medicine in the blood? And after how many days 5 mg?

5. What is the maximum amount of drug that can be reached? Explain your answer.

Redesign:
A patient is ill. A doctor prescribes a medicine for this patient and advises to take a daily dose of 1500 mg. After taking the dose an average of 25% of the drug leaves the body by secretion during a day. The rest of the drug stays in the blood of the patient.

1. Design a product that gives a visual, organized overview of the day to day drug level. The product must at least contain information for two weeks of medicine use.

2. Explain how you can calculate the amount of drug for the next day with a formula.

Figure 3.

Example of an original task handed out during the course and the redesign made by a student teacher of the NHL.

Looking at the results of first and second designs of all student teachers in general, student teachers designed lessons with more degrees of freedom in *'collaboration and communication'* during the second meeting (mean first design = 1.4 points and mean second design = 2.6 points) (see Figure 4). For the other three phases of inquiry that we coded the increase in degrees of freedom was not significant. An example of a part of a task were *'collaboration and communication'* has got more freedom by giving students some examples of plausible ways to communicate is:

"Later on you will present these the results of your investigation and your investigation outcomes. It is fun and informative to, for example, make a drawing of your experimental design, make a movie clip of your experiment or use some self-made photos during your presentation." (Collaboration and Communication, 2 pts)

In the original task the teaching material provided precise steps for how to communicate the explanation (meaningful = 0 points). It was a 'cookbook' practicum with three questions, students had to write down their answers in their notebook.

'Meaningful', *'multiple solution strategies'* and *'plan inquiry'* had almost identical scores in first (respectively a mean score of 0.8, 2.1 and 2.2 points) and second redesigns (respectively a mean score of 1.1, 2.1 and 2.4 points). An example of a part of a task where students provided a research question by the teaching material is:

"In the supermarket you can find natural vinegar or cleaning vinegar. If you check the labels you can find the percentage acetic acid in these vinegars. But is this percentage correct? You will check this during this practicum. Take your own bottle of vinegar with you!" (meaningful, 0 pts)

This redesign was altered by the student teacher by inserting the last sentence, she hoped: "*the context is the same, but because students bring their own vinegar monsters I hope they will feel more ownership."*

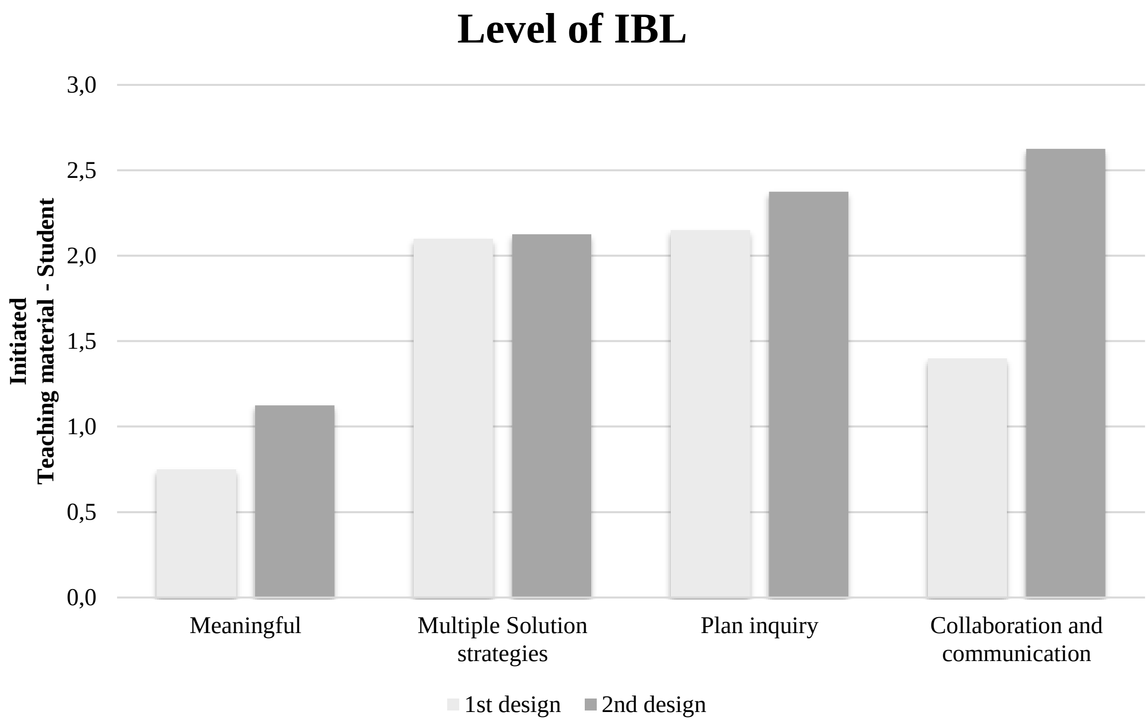

Figure 4.

Level of IBL in 1ˢᵗᵉ and 2ⁿᵈ redesign in the four domains, meaningful, multiple solution strategies, plan inquiry and collaboration and communication.

Discussion

The aim of the study was to better understand how student teachers can be supported in implementing and taking up the benefits of IBL in science and mathematics education.

The research questions of this study were:

- How do the attitudes of student teachers towards IBL change/develop during two sessions addressed to the implementation of IBL in science and mathematics education?
- What is the added value of guidelines to support student teachers in improving tasks for IBL-lessons?

Limitations of the study

In the present study, only a limited group of students of two universities of applied sciences were part of the study population. For generalizing our results this study needs to be scaled up: more students of more universities of applied sciences need to take part in the intervention and be interviewed.

Due to the limited timeframe of this study student teachers were encouraged to experiment in their classroom. It would be of great interest to try-out and observe what actually happened in the classroom settings. Classroom observations give more insight in the actual lessons and whether the redesigns were implemented as intended. Further research on attitudes towards IBL should check whether the verbal responses in interviews correlate with the overt behaviour in classroom settings.

Attitudes of student teachers

By interviewing student teachers we found student teachers became more IBL-focused after the intervention and were able to better motivate and articulate advantages and disadvantages. In the pre-intervention interview student teachers were not overwhelmingly positive about IBL, only two out of ten were IBL-focused. These findings are contrary to findings in studies of Gabel et al. (1987) and Damjanovic (1999).

Longer preparation time is one of the disadvantages mentioned by half of the student teachers in pre-intervention and post-intervention interviews, this are similar to findings of Marlow & Stevens (1999). An interesting development is the increase of diversity of disadvantages in the post-intervention test and the disappearance of the idea that IBL is more applicable for higher level students. Both of these changes can be due to the fact that student teachers were forced to experiment with IBL in their own school environment. Within this limited timeframe, they felt designing and teaching an IBL-lesson was quite difficult. This matches findings of Marlow & Stevens (1999). It asked form new teaching strategies, a different classroom climate and open, but not to open, tasks. We will discuss this findings in combination with our second research question.

The most interesting change in advantages was stimulation of creativity and cooperation with colleagues. The courses given at the HU parallel to our study could be a plausible cause of these findings. The students of the HU followed a course in lesson study and the NHL students already had had a course in lesson study. They probably saw a plausibility to connect IBL and lesson study.

A new advantage, only mentioned in the post-intervention interview, student teachers felt a higher learning gain for students after IBL-lessons. This is an interesting feeling since literature points out that it is very difficult to connect a higher learning gain to the usage of IBL (Bruder & Prescott, 2013). This study shows the relevance of this discussion.

Improving tasks for inquiry-based learning lessons

The redesigns showed student teachers designed lessons with more degrees of freedom, especially in collaboration and communication. The other aspects, meaningful, multiple solution strategies and plan inquiry, had more or less similar mean scores in first and second designs. Together with the newly named disadvantages in the post-intervention interview, i.e. new teaching strategies needed, different classroom climate needed and open but not too open tasks, we can draw some preliminary conclusions. Student teachers want to have a certain amount of control over their classroom situation, because they want to be sure what the learning gain for their students will be. This results in difficulties when making an IBL task, like a clear research question and clear frameworks within the task. A problem that arises from this is the difficulty to check the learning gain of students and to prevent misconceptions. The balance between more degrees of freedom for students to develop their own learning trajectory and the deadlines for upcoming assessment gave a certain kind of friction (Marlow & Stevens, 1999). The added value of guidelines to support student teachers in improving tasks for IBL-lessons was difficult to check. Student teachers did not favour the most open form of IBL, but an intermediate form. The first designs showed already an intermediate form of IBL tasks. The only aspect that significantly changed between the first and second design was collaboration and communication. The added value of the guidelines could have influence, but to check this more research is needed. One way to improve this research method is to do a more in depth interview between the first and second meeting and during the post-interview you let student teachers explain their thinking behind their design choices. And ask them in the intermediate interview what guidelines they would like to have when redesigning and during the post-interview we could use the thinking out loud approach to let student teachers explain the used in their second redesign. This will give a better insight in the added value of the guidelines and in the design skills of student teachers.

Graduate Schools of Teaching at universities or at universities of applied sciences transfer more responsibility to student teachers for engaging and motivating students in their classrooms and therefore they need to be able to design new lessons or redesign textbook tasks. More insight in how to learn how to (re)design lessons and what the effectiveness of (re)designing of student teachers is, is therefore a relevant research area that needs more attention. The development of a coding scheme for evaluating designs is a first step in this process. The results of these new studies can help Graduate Schools making more effective and efficient designing courses for student teachers.

The coding scheme can also be helpful for (student) teachers. With the scheme they can check how much responsibility for what kind of processes of inquiry are elicited by their tasks. If they are willing to let their students take part in inquiry, the guidelines and the scheme support them in redesigning (textbook) tasks into tasks that have the potential to support inquiry based learning. The coding scheme is an evaluation instrument that helps to become aware of possible changes and how textbook tasks can be changed step by step, from teaching material initiated to student material initiated processes of inquiry. The student initiated elements are needed to create opportunities for learning inquiry processes on science and mathematics education. They can choose whether they want to change their whole design or just one or more of the four domains: meaningful, multiple solution strategies, plan inquiry, collaboration and communication. The resulting designs are expected to create challenging and stimulating learning environments that promote the motivation of students for science and mathematics education (OECD, 2016).

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Annexes

Annex 1: interview scheme - interview 1

Outline of Interview (English)

Basic information of participant

Name:	Gender:	School:
Grade:	Years of teaching experience:	Age:

• Have you ever heard about Inquiry-based learning?

• What is your understanding of Inquiry-based learning(IBL)?

• Here are two examples of classroom tasks for students:

For the first one

- ✓ What do you think of the task?
- ✓ What would students learn from this task?
- ✓ Can it be used in an IBL lesson? Why or why not? If so, how will you use it?
- ✓ What kind of support will you offer to the students? When and How?

For the second one

- ✓ What do you think of both versions of the task?
- ✓ Which one would you prefer, Why?
- ✓ Do they have the same learning goal for students to achieve?
- ✓ Do both versions represent IBL? Why or why not? How will you use it (or them) ?
- ✓ What kind of support will you offer to the students?

• How often do you implement IBL in your lessons?
<Every class> <Weekly> <Monthly> <Occasionally>

• Would you consider implementing IBL?

• If so, how would you implement IBL in your lesson? What do you think about the role of teacher in an IBL lesson?

• What do you see as reasons for using IBL? What about main difficulties?

• Personally, are you in favor of using IBL frequently in lessons?

Outline of Interview (Dutch)

Basisinformatie van de deelnem(st)er

Naam: Geslacht: Leeftijd:

School: Leerjaar:

Aantal jaren onderwijservaring: Schoolvak:

• Heb je ooit gehoord van Onderzoekend Leren (of Inquiry Based Learning, IBL)?

• Wat is jouw idee bij Onderzoekend Leren?

• Zou je overwegen om Onderzoekend Leren toe te passen in je lessen?

• Hier zijn twee voorbeelden van opdrachten:

Voor de eerste

- ✓ Wat vind je van de opdracht?
- ✓ Wat zouden leerlingen leren van deze opdracht?
- ✓ Zou deze opdracht gebruikt kunnen worden voor Onderzoekend Leren? Waarom of waarom niet? Als ja: Hoe zou jij deze opdracht gebruiken?
- ✓ Wat voor ondersteuning zou je je leerlingen bieden? W

Voor de tweede

- ✓ Wat vind je van beide opdracht versies?
- ✓ Welke versie heeft jouw voorkeur, waarom?
- ✓ Hebben beide versies dezelfde leerdoelen voor leerlingen?
- ✓ Zou je beide versies kunnen gebruiken voor Onderzoekend Leren? Waarom? Of waarom niet?
- ✓ Hoe zou je deze versie(s) gebruiken in de les?
- ✓ Wat voor ondersteuning zou jij je leerlingen aanbieden?

• Hoe vaak gebruik je Onderzoekend Leren in je lessen?

<Elke les> <Wekelijks> <Maandelijks> <Soms><Nooit>

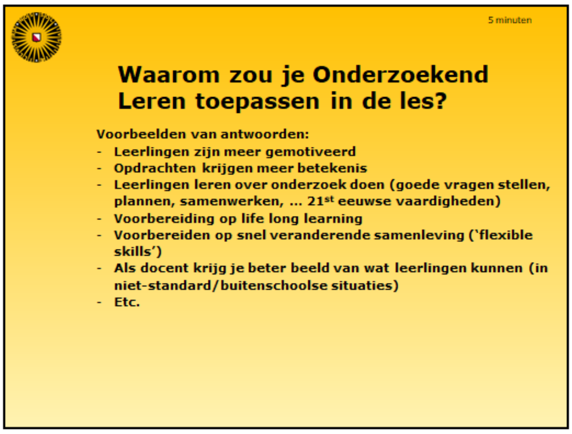
• Zou je overwegen om Onderzoekend Leren toe te passen in je lessen? Als ja: hoe?

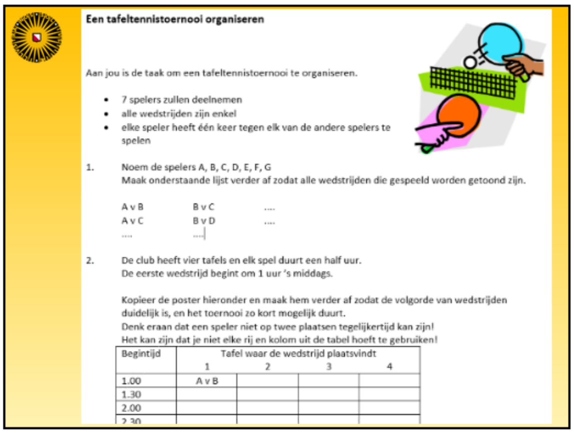
• Welke rol is weggelegd voor de leraar in een les ontworpen rondom Onderzoekend Leren?

• Wat vind je een goede reden om Onderzoekend Leren toe te passen? Wat vind je de grootste bezwaren?

• Hoe sta jij persoonlijk tegenover het veelvuldig gebruik maken van Onderzoekend Leren?

Annex 2: PPP-presentation seminar 1




Een tafeltennistoernooi organiseren
Aan jou is de taak om een tafeltennistoernooi te organiseren.
7 spelers zullen deelnemen
alle wedstrijden zijn enkel
elke speler heeft één keer tegen elk van de andere spelers te spelen
1. Noem de spelers A, B, C, D, E, F, G
Maak onderstaande lijst verder af zodat alle wedstrijden die gespeeld worden getoond zijn.
A v B B v C
A v C B v D
2. De club heeft vier tafels en elk spel duurt een half uur.
De eerste wedstrijd begint om 1 uur 's middags.
Kopieer de poster hieronder en maak hem verder af zodat de volgorde van wedstrijden duidelijk is, en het toernooi zo kort mogelijk duurt.
Denk eraan dat een speler niet op twee plaatsen tegelijkertijd kan zijn!
Het kan zijn dat je niet elke rij en kolom uit de tabel hoeft te gebruiken!
Begintijd
Tafel waar de wedstrijd plaatsvindt
1 2 3 4
1.00 A v B
1.30
2.00


Onderzoekend Leren ervaren
Kan dit ook met leerlingen?


De basiselementen van onderzoekend leren
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- Structuur uit de opdracht -> Ondersteuning door de leerkracht
Vraag: welke basiselementen zie je terugkomen in het filmpje?

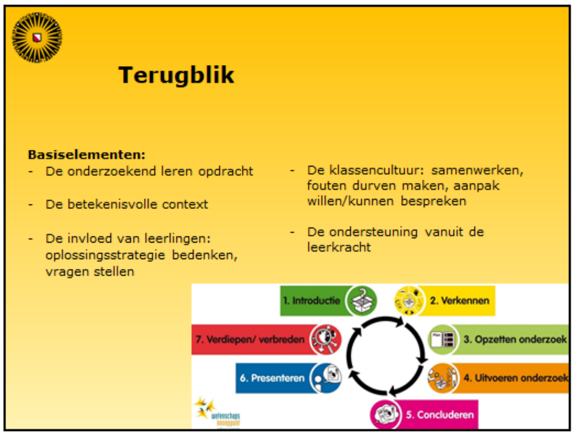

5 minuten
Voorbeelden vanuit de praktijk
Welke elementen zie je terug in de leersituatie waar de door jou meegenomen opdracht onderdeel van uitmaakt?
Basiselementen:
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- De ondersteuning vanuit de leerkracht
1. Introductie
2. Verkennen
3. Opzetten onderzoek
4. Uitvoeren onderzoek
5. Concluderen
6. Presenteren
7. Verdiepen/ verbreden


20 minuten
Zelf aan de slag
Maak een redesign van je opdracht met docentenhandleiding!
Basiselementen:
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- De ondersteuning vanuit de leerkracht
1. Introductie
2. Verkennen
3. Opzetten onderzoek
4. Uitvoeren onderzoek
5. Concluderen
6. Presenteren
7. Verdiepen/ verbreden


Evaluatie
Maak een redesign van je opdracht met docentenhandleiding!
Basiselementen:
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- De ondersteuning vanuit de leerkracht
1. Introductie
2. Verkennen
3. Opzetten onderzoek
4. Uitvoeren onderzoek
5. Concluderen
6. Presenteren
7. Verdiepen/ verbreden


Universiteit Utrecht
Door: Brechtje Anthonissen
& Michiel Doorman
19 april 2017
Onderzoekend leren
UIT ONDERZOEK IS GEBLEKEN DAT ONDERZOEKEN VEEL LEUKER IS DAN ANTWOORDEN VINDEN
Loesje

Annex 3: PPP-presentation seminar 2




Evaluatie
Maak een redesign van je opdracht met docentenhandleiding!
Basiselementen:
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- De ondersteuning vanuit de leerkracht
1. Introductie
2. Verkennen
3. Opzetten onderzoek
4. Uitvoeren onderzoek
5. Concluderen
6. Presenteren
7. Verdiepen/ verbreden


Evaluatie
Ervaringen met onderzoekend leren
en de twee gastcolleges
Basiselementen:
- De onderzoekend leren opdracht
- De betekenisvolle context
- De invloed van leerlingen: oplossingsstrategie bedenken, vragen stellen
- De klassencultuur: samenwerken, fouten durven maken, aanpak willen/kunnen bespreken
- De ondersteuning vanuit de leerkracht
1. Introductie
2. Verkennen
3. Opzetten onderzoek
4. Uitvoeren onderzoek
5. Concluderen
6. Presenteren
7. Verdiepen/ verbreden


Universiteit Utrecht
Door: Brechtje Anthonissen
10 mei 2017
Onderzoekend leren
UIT ONDERZOEK
IS GEBLEKEN
DAT ONDERZOEKEN
VEEL LEUKER IS
DAN ANTWOORDEN
VINDEN
Loesje

Annex 4: guidelines

Guidelines (English)

Guidelines for (re)designing IBL-tasks

Part of (re)design	Tips

From a structured (textbook) task to a task supporting IBL	• *Look for the ‘relevant and meaningful (for the students) problem’ within the context. Take this as the focal point for redesign*
	• *Create opportunities for students to become owner of the problem:*
	  • *Skip sub-questions*
	  • *Have students plan or be involved in planning the inquiry*
	• *Scaffold students’ inquiry process (e.g. with a lesson plan including an introduction of the problem situation and process support)*
	• *Provide guidelines about the final evaluation*

The context	• *Search for different kind of contexts (daily environment context, professional context, scientific context) and choose the one that fits best with the student task.* • *Think of a product design that fits the task.*
Stimulate collaboration and communication	• *Ask for products that can be presented or discussed* • *Make sure the task asks for collaborative work (e.g. sharing of responsibilities)* • *Organize peer feedback*

Guidelines on supporting inquiry by students

Strategy	Suggested questions
Allow students time to understand the problem and engage with it Discourage students from rushing in too quickly or from asking you to help too soon.	• *Take your time, don't rush.* • *What do you know?* • *What are you trying to do?* • *What is fixed? What can be changed? Don't ask for help too quickly – try to think it out between you.*
Offer strategic rather than technical hints Avoid simplifying problems for students by breaking it down into steps.	• *How could you get started on this problem?* • *What have you tried so far?* • *Can you try a specific example?* • *How can you be systematic here?* • *Can you think of a helpful representation?*
Encourage students to consider alternative methods and approaches Encourage students to compare their own methods.	• *Is there another way of doing this?* • *Describe your method to the rest of the group* • *Which of these two methods do you prefer and why?*
Encourage explanation Make students do the reasoning, and encourage them to explain to one another.	• *Can you explain your method?* • *Can you explain that again differently?* • *Can you put what Sarah just said into your own words?* • *Can you write that down?*
Model thinking and powerful methods When students have done all they can, they will learn from being shown a powerful, elegant approach. If this is done at the beginning, however, they will simply imitate the method and not appreciate why it was needed.	• *Now I'm going to try this problem myself, thinking aloud.* • *I might make some mistakes here – try to spot them for me.* • *This is one way of improving the solution.*

Guidelines (Dutch)

Handreiking (her)ontwerpen Onderzoekend Leren

Deel van het herontwerp	Tips/aanwijzingen

Van een gestructureerde taak naar een Onderzoekend Leren taak	• *Kijk naar het achterliggende probleem binnen de context, neem dit als een startpunt voor je (her)ontwerp.*
	• *Creëer mogelijkheden voor leerlingen om eigenaar te worden van het probleem:*
	  ◦ *Door te zorgen dat er meerdere oplossingsstrategieën zijn.*
	  ◦ *Door het aantal sub-vragen te verminderen.*
	• *Bedenk hoe je het onderzoeksproces van leerlingen kan steunen/sturen met een lesplan (de introductie van het probleem, procesondersteuning en het uiteindelijke product hebben meer aandacht nodig dan normaal).*
	• *Maak duidelijk wat je uiteindelijk wilt bereiken.*

De context	• *Onderzoek verschillende contexten (leefwereldcontext, beroepscontext of wetenschappelijke context) en kies degene die het best past bij de leerlingen en bij de taak.* • *Probeer ervoor te zorgen dat het product ook daadwerkelijk betekenis heeft in de gekozen context.*
Stimuleren tot samenwerking en (nog) meer communicatie	• *Vraag om een product dat gepresenteerd kan worden of waar een discussie over gehouden kan worden.* • *Zorg dat samenwerken bij de taak nuttig/noodzakelijk is (gezamenlijk verantwoordelijk maken voor proces en product).* • *Organiseer één of meerdere (peer) feedback momenten.*

Handreiking begeleiding Onderzoekend Leren

Strategie	Vraagsuggesties
Geef leerlingen de tijd om het probleem te begrijpen en de situatie in kaart te brengen. Ontmoedig leerlingen om te snel het probleem te gaan oplossen of om hulp te vragen van docent.	• *Neem de tijd, niet te snel gaan* • *Wat weet je (wel)?* • *Wat probeer je te doen?* • *Wat staat vast? Wat zou er kunnen worden veranderd?* • *Vraag niet te snel om hulp – probeer er samen uit te komen.*
Geef strategische hint in plaats van technische hint. Probeer te vermijden dat je de leerlingen te veel aan de hand neemt door het probleem voor hen in kleine stapjes op te splitsen.	• *Hoe zou je kunnen beginnen met dit probleem?* • *Wat heb je tot nu toe geprobeerd?* • *Kan je een specifiek voorbeeld proberen?* • *Hoe kun je hier gestructureerd / systematisch aan werken?* • *Kun je daar een handige weergave/representatie/voorstelling voor bedenken?*
Moedig studenten aan om alternatieve methodes en benaderingen te overwegen. Moedig studenten aan om hun eigen methoden te vergelijken.	• *Is er nog een andere manier om dit te doen?* • *Beschrijf je aanpak aan de rest van de groep.* • *Welke van deze twee methodes heeft jouw voorkeur? Waarom?*
Stimuleer uitleggen en toelichten door leerlingen. Laat leerlingen zelf de beredeneerstappen zetten en stimuleer ze te overleggen, ideeën toe te lichten en uit te leggen hoe ze ergens bij komen.	• *Kan je jouw methode uitleggen?* • *Kun je dat nog een keer uitleggen, maar dan op een andere manier?* • *Kan je wat Sarah net zei in je eigen woorden zeggen?* • *Kun je dat opschrijven?*
Voorbeeld denken en handige methodes. Als de leerlingen alles hebben gedaan wat ze kunnen, zullen ze veel leren wanneer hen een handige en elegante methode wordt voorgedaan. Echter, wanneer je hier direct mee begint (voordat je ze op andere manieren hebt geprobeerd te helpen), zullen ze de methode simpelweg imiteren en zullen ze niet inzien waarom dit nodig was.	• *Nu ga ik proberen zelf dit probleem op te lossen, terwijl ik hardop nadenk.* • *Ik kan wat fouten maken, probeer ze te vinden!* • *Dit is maar één manier om bij de oplossing te komen.*

Annex 5: interview scheme – interview 2

Outline of Interview 2 (English)

Basic information of participant

Name:	Gender:	School:
Grade:	Years of teaching experience:	Age:

• What is your understanding of Inquiry-based learning(IBL)?

• How often do you implement IBL in your lessons?
<Every class> <Weekly> <Monthly> <Occasionally>

• What do you think about the role of teacher in an IBL lesson?

• What do you see as reasons for using IBL? What about main difficulties? Personally, are you in favor of using IBL frequently in lessons?

• Did you get any support in implementing IBL? What kind of support? Any further demands?

• If your colleagues want to implement IBL, what tips would you give?

• Would you consider implementing IBL more often? If yes: how?

Have you ever heard of MaSciL? If yes: what do you think of their site and teaching materials?

Outline of Interview 2 (Dutch)

Basisinformatie van de deelnem(st)er

Naam: Geslacht: Leeftijd:

School: Leerjaar:

Aantal jaren onderwijservaring: Schoolvak:

• Wat is jouw idee bij Onderzoekend Leren?

• Hoe vaak gebruik je Onderzoekend Leren in je lessen?
<Elke les> <Wekelijks> <Maandelijks> <Soms> <Nooit>

• Welke rol is weggelegd voor de leraar in een les ontworpen rondom Onderzoekend Leren?

• Wat vind je een goede reden om Onderzoekend Leren toe te passen? Wat vind je de grootste bezwaren? Hoe sta jij persoonlijk tegenover het veelvuldig gebruik maken van Onderzoekend Leren?

• Kreeg jij ondersteuning bij het toepassen van Onderzoekend Leren? Wat voor ondersteuning? Had je nog specifieke wensen voor ondersteuning?

• Als een collega Onderzoekend Leren zou willen gaan toepassen, welke tips zou je hem/haar dan geven?

• Zou je na aanleiding van de gastlessen overwegen om Onderzoekend Leren vaker toe te passen in je lessen? Als ja: hoe? Handreiking!!!

• Ben je bekend met MaSciL? Zo ja; hoe vind je de handbaarheid van de site en de materialen?

Annex 6: Coding scheme (re)designs

Doing Inquiry	3pts	2pts	1pts	0pts
Meaningful (D1): Involved in sci-oriented question	The teaching material provides a context that invites/supports students in posing questions that need to be solved through inquiry	The teaching material provides a context that guides students towards the main question (not in the acquisition jet)	The teaching material has a variety of explicitly formulated questions settled around a context, students can select one or more questions	Student engages in question provided by the teaching material
Multiple solution strategies (D3, D4, D5): multiple options for evidence, and for ways to collect/find evidence	Student determines what constitutes evidence and collects it *and/or* Student formulates explanation after summarizing evidence *and/or* Student determines how evidence supports explanation or independently examines other resources or explanations	The teaching material suggests students to collect certain data *and/or* The teaching material guides students in process of formulation of explanations *and/or* The teaching material guides students in determining how evidence supports explanation	The teaching material provides data and asks students to analyse this data *and/or* The teaching material gives possible ways to use evidence to formulate explanation *and/or* The teaching material provides selections for possible evidence supporting explanations, resources or possible alt explanations, students can choose from the selection	The teaching material provides data and students is prescribed how to analyse this data *and/or* The teaching material provides students with evidence/argumentation *and/or* The teaching material tells students how evidence supports explanation or tells about alternative explanations
Plan inquiry (D2, D7): Design and conduct investigation. Use tools and techniques to gather analyse and interpret data.	Students designs and conducts investigation *and/or* Student invents tools and techniques needed to conduct the investigation	The teaching material guides student in designing and conducting an investigation *and/or* The teaching material supports student in determining which tools and techniques can be used	Student selects from possible investigative designs given by the teaching material *and/or* Students select from tools and techniques given by the teaching material	The teaching material provides a given investigative plan to conduct *and/or* The teaching material provides given tools and techniques needed
Collaboration and communication (D6): Communicates and justifies	The teaching material gives space to students to create reasonable and logical arguments/representations and to communicate explanations	The teaching material supports students in development of communication with one or two examples	Student selects from possible ways to communicate explanation given by the teaching material or supported by material through structured examples/templates	The teaching material provides precise steps for how to communicate explanation
	← Student initiated			***Teaching material initiated →***