Improving Students' Intrinsic Motivation by Using an Inquiry-based Learning Practical

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Abstract

Inquiry-based learning is an approach for teachers which allows students to experience higher levels of autonomy when compared to traditional approaches. This would, according to self-determination theory, lead to a higher intrinsic motivation of students. In this research, an inquiry-based approach is compared to a traditional approach related to direct instruction, within the setting of a physics practical related to ionizing radiation. The research question is: To what extent does an inquiry-based practical about ionizing radiation result in higher intrinsic motivation of students when compared with a traditional style practical? To determine this, students working on both styles have been compared by the use of a questionnaire regarding intrinsic motivation. The results show that students (N = 55, age 15 – 17) doing the inquiry-based learning practical have significantly more interest/enjoyment and a significantly higher perceived competence. Hence, students doing the inquiry-based practical are shown to have a higher intrinsic motivation regarding the practical.

Keywords: Inquiry-based learning, direct instruction, intrinsic motivation, ionizing radiation

In physics education, it is very common for students to first learn the conceptual theories, after which that knowledge is used to solve given problems. But often the students have no idea these might be real problems that merit solving. This traditional approach, known as direct instruction, is different from an inquiry-based learning (IBL) style, where the order is often turned around. With IBL, certain contextual problems would be posed first, which would invoke the necessity of a new theory to help solve them. Only after the need for a new concept has arisen for the students, teacher and students can together explore new theories to help solve the problems. It has been shown that this inquiry-based approach can have beneficial effects on student learning, when students still have an adequate amount of teacher guidance (Furtak et al., 2012). But another, very important question is what the effect would be on the intrinsic motivation of students. In Western Europe, student attitude towards science is among the lowest in the world (Sjøberg & Schreiner, 2010). This means that students' attitude and motivation is a problem, which makes looking into the effects of IBL on these all the more interesting. IBL has been shown to have positive effects on both the overall attitude of students and the general interest regarding science/mathematics (Savelsbergh et al., 2016), so IBL could be a useful approach to not only improve students' comprehension of physics, but their intrinsic motivation and interest as well. It has been convincingly demonstrated that IBL fosters interest and intrinsic motivation (Potvin & Hasni, 2014).

However, currently there is limited research about the effects of IBL strategies in science education on students' motivation towards doing science. There is some evidence that inquiry-based science education is effective at increasing secondary level students' interest and attainment levels, while also improving motivation of teachers (Rocard, 2007). But a separate question would be if an inquiry-based approach would not only lead to more interest and attainment, but if it would also increase students' perceived competence when performing an activity, or if it would improve how they experience the usefulness of the activity.

According to self-determination theory (Ryan & Deci, 2000), there are three main intrinsic needs supporting intrinsic motivation: autonomy, competence, and relatedness. When using IBL, the need for autonomy would be better satisfied, since students' would have to make their own decisions (albeit with teacher guidance) on how to solve a particular problem and how to assimilate new concepts. In comparison with a more traditional based teaching style based on direct instruction, where students' would be less likely to see the need of the new concepts, this would theoretically lead to a higher intrinsic motivation. Furthermore, because students have to come up with a strategy to solve problems on their own, they could also experience themselves as being more competent, because they are more in control of their learning and the results would be easier to attribute to themselves. But students do still need some guidance, and should not be left completely to their own devices, which might even have a negative effect on their perceived competence. Because of this it is necessary that there are still teachers and instructors present to help ask guiding questions when necessary.

For this research the goal will be to find out if an IBL approach towards learning physics compared to a traditional approach would lead to differences in students' intrinsic motivation when doing physics. The unique setting that is used here, of a physics practical about radiation, also focuses more on the practical nature of science, and less on the more often used theoretical aspect. This goal is pursued by comparing groups of students working with these two different approaches on a practical about ionizing radiation, which have similar physics content, and by looking at how they their intrinsic motivation about the practical changes by doing it.

Theoretical framework

Direct instruction

Direct instruction is a teacher-centred approach, where information is given to students to be internalized, and where they do not learn in a very active manner. The important characteristics of direct instruction are the presentation of new information by demonstration, structured practice with guidance from the teacher, direct feedback, and solitary practice (Ebbens, Ettekoven, & Burgers, 2013). With direct instruction the teacher guides students towards the desired behaviour, often with punishment and rewards, which makes direct instruction a behaviouristic approach.

Inquiry-based learning

With IBL there is a more student-centred, constructivist approach, where the aim is to facilitate a more active way of learning, where students play a bigger role in the learning process. Here students' own ideas and questions are more at the centre, and this method then often results in a more open-ended investigation of problems, instead of structured, step-by-step practice problems like with direct instruction. The teacher also plays a different role here, instead of being the main source of information, the teacher helps students generate their own theories, and guides them in their investigation. IBL can teach students to pose difficult questions, and it also encourages students to investigate and learn more about the world. Students have much more agency during the learning process, and IBL allows students to better see connections between the academic content and their own daily lives (*Inspired Issue Brief: Inquiry-based Teaching*, 2008). IBL can be categorized into four different categories of inquiry, ranging from completely free IBL to a more closed version where students are still very dependent on their teacher and other resources. Banchi and Bell (2008) define these four levels as:

- Confirmation inquiry
- Structured inquiry
- Guided inquiry
- Free inquiry

For this research the category that students will be working with is 'guided inquiry'. Here students still have to come up with their own research questions and plan of work, but the setting that they have to investigate is predetermined, so they are not completely free in their learning approach.

In a pilot done in 2014, where 13/14-year-old students in grade 11 learned about sustainability with a project based on inquiry based learning, motivation of students was collected prior to and after the pilot (Firssova et al., 2014). The students demonstrated appreciation of activities where they themselves needed to take action, and had a more negative attitude in cases where more focus laid on using supportive information. This indicates student's appreciation having more autonomy during a learning process, which IBL could facilitate. Furthermore, in a study where a science curriculum based in IBL was compared with a traditional curriculum (Lynch et al., 2005), it has been found that students using the IBL curriculum were more engaged, and that it encouraged students to learn more for understanding.

Motivation

To better define motivation, Ryan and Deci's self-determination theory (2000) is used, which postulates two main types of motivation, extrinsic and intrinsic motivation. For intrinsic motivation, three essential factors are determined which support this type of motivation: autonomy, competence, and relatedness. Teachers that support the autonomy of students evoke a greater intrinsic motivation towards learning, and a greater desire for new knowledge. The theory argues that feelings of students related to gaining competence also enhance intrinsic motivation for the process. Lastly, intrinsic motivation also flourishes when students can work in secure contexts where they can relate to their peers. Because of a more open-ended approach with IBL, students themselves can make more decisions on how to proceed when working on a problem, granting them more autonomy. This would in theory lead to a better facilitation of intrinsic motivation, and the idea is that IBL would therefore lead to a greater intrinsic motivation of students working with IBL. Besides that, because students play a bigger role in their own learning process, they might also find it easier to attribute their own success to themselves, leading to a higher perceived competence of themselves. And for this context there is no expected difference for the relatedness dimension, seeing as students still work in the same groups and in the same setting.

Extrinsic motivation then refers to performing a certain activity to gain an outcome which is not related to this same activity, for example studying hard for a test because your parents promised a reward for a high grade. This is unlike intrinsic motivation, where the performance of the activity provides its own motivation. This extrinsic motivation can cover a wide range in autonomy, resulting in a so called self-determination continuum, where extrinsic motivation can be either external (e.g. a reward) or internal (e.g. the feeling of accomplishment). On one end of this continuum activities are done because of an outer locus of autonomy, which (often with reward and punishment) forces people to perform an activity they otherwise would not. On the other end the locus of autonomy is internal and regulated, which means that while the performance of the activity itself is not the end goal, the outcomes of said activity do align with the values and desires of the performer.

In the case of the practical, because the setting is the same for both approaches, no difference in external motivation is expected, which means that the comparison between the two would investigate only differences in intrinsic motivation. And as mentioned above, because students have to do more themselves in the open approach they would theoretically have more autonomy, and as a result of this their perceived competence would also be higher.

Ionizing radiation

The setting in which the research will be done is going to be the so called 'Ioniserende Stralen Practicum (ISP)' (Ionizing Radiation Practical). This is a project set up by Utrecht University in which students from high schools can come to the university to work on problems relating to ionizing radiation and radioactivity. There is also a mobile lab to present the practical to schools that are far away from Utrecht. The ISP has existed for over 40 years, since 1972, and until now a step-by-step approach has almost always been used to help the students learn about radiation, which bears great similarities to the direct instruction approach. In recent years, a more open variant of this practical has been developed, which will be used for this research. This open approach is based on IBL, and here students are not presented with problems that should be worked through step-by-step, but they should investigate the problems and possible solutions on their own. The other step-by-step approach has been used for a long time now, but by looking at the IBL approach it can be investigated if this would have a positive effect on the intrinsic motivation of the students towards the practical. To validate the claim that the open version of the experiments can be categorized as guided inquiry, the three managers of the mobile laboratory have been asked to fill out a rubric to assess what type of IBL the open experiments compare to (Capps & Crawford, 2012). The rubrics show the three managers of the program to be in agreement about the open experiments being classified as guided inquiry.

Content wise, the IBL approach does bear great similarities to the closed version of the experiments. The exact same experimental set-up is used, and the same instructions on how to use the apparatus is given. The difference is that where the closed version then has a given set of exercises, where the open version only has a set of clues for the students, and no explicit problems to be solved. When doing the open version, students have to create their own plan of work before they start the experiment, which does take some extra preparatory time. But seeing as the relevant concepts related to the experiments are the same in both approaches, the big difference lies in the way of how students learn these concepts. Hence it is a good setting to compare these two approaches to see how students think differently about them.

Research question

Autonomy is an important factor for fostering intrinsic motivation, and an open-ended inquiry-based approach would give students more agency and autonomy in their own learning process in comparison to direct instruction. Therefore the goal is to see if IBL has a positive effect on intrinsic motivation of students. Competence is also a deciding factor in how intrinsically motivated students are, and the two different approaches may well also lead to a difference between the two approaches. Because of the extra preparation that students doing the open version have, and because students do more of the work on their own, the hypothesis would be that students would have a higher perceived competence, and thus also a higher intrinsic motivation. The posed research question would then be: To what extent does an inquiry-based learning style practical about ionizing radiation result in higher intrinsic motivation of students when compared with a traditional style practical?

Methods

For this research a questionnaire has been used, students filled in both a pretest and a posttest concerning their motivation about the practical. This method will be explained in more detail in the following section.

Quasi experiment

When working on the ISP, schools are now given two options for which type of approach they would like to use: the traditional approach akin to direct instruction, or an open-ended approach based on IBL. School and the attached teachers that participate with the ISP can choose which version they would want to select, it is not entirely possible to just assign random groups to work with either the traditional approach or open-ended approach. This is because they simply might not agree with the chosen method, which could influence results, and it is not up to the ISP to decide what version will be used. Therefore, at first the strategy is to look at schools/teachers that are interested in using the open-ended approach, and approaching them to see if they are interested in having one group that uses the traditional approach and one group using the open-ended approach. Because these groups would then be attending the same school and have the same teacher any bias because of that will be controlled, and the outcomes can be compared with each other better. Students have spent several hours working on the entire practical; usually students have performed two or three experiments in this time. It is important that the accompanying teacher of the students does not influence the process by i.e. guiding the students more than is intended during the open approach. During the session a researcher has also been present, so any noticeable effects by the presence of the teacher (e.g. if he is rushing the students or providing answers for them) have been considered when collecting the data. There is also the difference between if students come to the university to perform the experiments, or if the university actually comes to the school with the experiments. In both cases the used experiments and worksheets are completely identical, so content wise there is no difference. And while the setting in which they perform the experiments is different, because the difference between pre- and posttest will be looked at this difference should not have an influence on the results. The intrinsic motivation of students will be assessed by use of a questionnaire, where a pre- and posttest and the open/closed approach form the independent variable, and the motivation is the independent variable.

Intrinsic motivation inventory

To determine the initial intrinsic motivation of students before starting the project a pretest will be used, based on the Intrinsic Motivation Inventory (IMI) questionnaire, which is in turn based on self-determination theory (Selfdeterminationtheory.org, 2017). This questionnaire measures the following seven subscales:

- Interest/enjoyment
- Perceived competence
- Effort/importance
- Pressure/tension
- Perceived choice
- Value/usefulness
- Relatedness

From these the interest/enjoyment subscale is the most important one, and it is seen as the self-report measure of intrinsic motivation. This of course does not mean that the other subscales are not important, perceived competence and choice are seen as a positive predictor of the self-report of intrinsic motivation, whereas pressure/tension would actually be a negative predictor of this. The effort/importance scale is also seen as relevant towards intrinsic motivation, and the value/usefulness scale is used a scale to assess the internalization of students. The relatedness subscale is also used for studies related to social interactions and such. A selection of subscales was made, based on the time available during the practical and the relevance to the practical. This will be elaborated upon below.

Modified questionnaire

Considering the fact that the research is about high school students who are performing this practical because the school has deemed it mandatory, the perceived choice subscale would be compromised and would not yield meaningful data related to the research question, therefore this subscale is not used. Similarly, the pressure/tension subscale is compromised because students have a time limit when working on the practical, and the results that they have to hand often account for a grade that the students receive. Because of this the pressure/tension that students experience may fluctuate wildly between students that perhaps need a passing grade for the project or students that already have a high grade for physics and can do the practical at their leisure. The subscale about pressure/tension is therefore also not used. Lastly the relatedness subscale is about interpersonal interaction, which is not different between the open and closed setting of the experiment, and is not the goal of the practical itself, so it is also not a relevant subscale and is not used. This leaves us with the four subscales of interest/enjoyment, perceived competence, effort/importance and value/usefulness. From the IMI a translated questionnaire has been constructed, where the questions relate specifically to the practical they are doing. Because of time constraints during the practical four questions will be given per construct, for a total of sixteen questions. These questions will be asked in both the pre- and posttest, with the difference being if the questions are asked in the past tense or not (e.g. 'I think this practical was boring' instead of 'I think this practical will be boring'). Furthermore the order of the questions has been randomized for the posttest, to prevent students from getting the feeling that they are filling in the exact same questionnaire, which in itself could have an influence on their motivation. The pretest is filled in by the students just before they start with their first experiment, and the posttest is filled in immediately after they have finished their first experiment. And while students performing the open experiments have already done more preparatory work this should not pose a problem for the results, seeing as the differences between the pre- and posttest will be examined. All questions are based on a 1-5 Likert scale. A copy of both the used pre- and posttest is given in the appendix.

Reliability

To look at the reliability of the used questionnaire, Cronbach's α has been computed for the questions of each subscale, to determine if they all actually measure the same construct. This has lead to the following results per subscale:

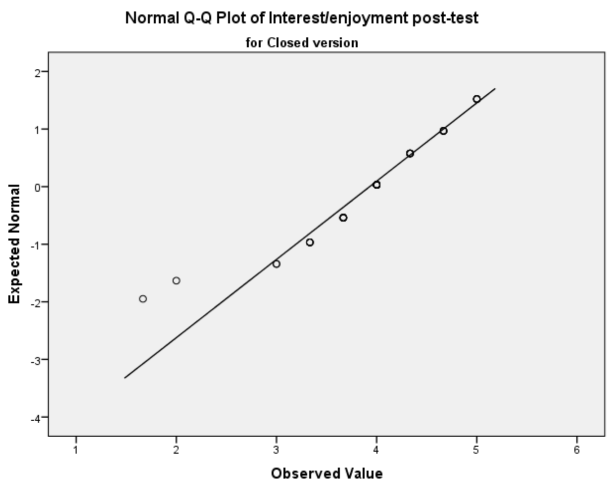
- Interest/enjoyment α = .796
- Perceived competence α = .765
- Effort/importance α = .630
- Value/usefulness α = .866

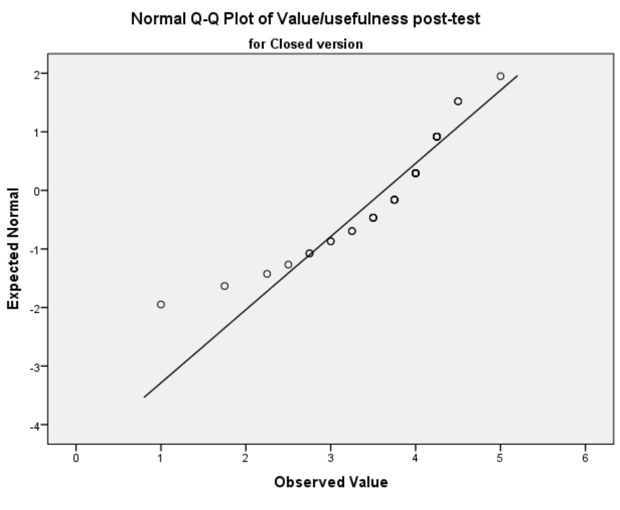
So apart from the effort/importance subscale the questionnaire leads to results that can be considered reliable, with α > .7. The low measure of α for the effort/importance subscale has been examined and no clear question could be identified which led to a lower value, so unfortunately data from this subscale cannot be used in a reliable manner.

When analyzing the results the reliability of the interest/enjoyment scale was initially not as high, and yielded a Cronbach's α with a value lower than .7. After examining the used questions it was found that one question led to this low reliability, and after removing it the reported α of .796 was found. The question was of course not removed haphazardly, but after careful consideration. The (translated) question in case was '*during the practical I will have trouble keeping my attention'*, and while this question is also used in the IMI it was not a completely valid question within the context of this research. This is because the students that did the experiments had to afterwards hand in their work, so that it could be graded. With this knowledge, students would of course not answer that they would not be able to pay attention during the experiments, seeing as it counted for their grade average. This can be seen in the results, where students only answered 'disagree (4)' and 'completely disagree (5)' to the question, and the other options were never answered. So this question does not only seem to distinguish between students that are and are not intrinsically motivated, but it also distinguishes between how much importance students place on the experiments for their grade, which is related to extrinsic motivation. Because of these reasons said question has been removed from the analysis, and the average from the remaining three questions has been used.

To meet the assumptions for application of ANCOVA, the posttest must be approximately normally distributed (covariate does not have to be normally distributed). To determine this a Shapiro-Wilk test was performed for each construct for both the open and closed version, and while four of the six results gave no reason to reject normality, two results (interest/enjoyment closed version and value/usefulness closed version) gave very significant results (.005 and .001, respectively). Because ANCOVA is robust against non-normality, Q-Q plots have been made of these two constructs, to see if there were any really noticeable differences.

Figure 1: Q-Q plots of the two subscales that gave significant results according to Shapiro-Wilk





As can be seen, the data shows no large deviations from a normal distribution which would violate the assumptions for ANCOVA, so ANCOVA will still be used to determine the significance. Another assumption to be met is the homogeneity of regression slopes, and for while for interest/enjoyment and for value/usefulness this assumption has been met, for perceived competence the slopes were not obviously homogeneous, and because of this a Fisher z test was performed on the correlations for the slopes, and this yielded no significant result (.139), which means this assumption has also been met. Apart from these difficulties all other assumptions have also been met, meaning ANCOVA is a valid tool to examine the significance of the results.

Results

In the end, whilst data of many different schools has been collected, there was only one school where students performed both the open and closed versions of the experiment. This was a school where the university came to the school with the experiments, and where three classes have done the practical. From these three classes, two have performed only the closed version of the practical, and in the other class all students did an open experiment as their first one. These three classes did however not all have the same teacher, the class that did the open experiment had a different teacher than the other two. But during the practical one teacher was present for all three of the classes, because the other teacher of the other class could not attend. This does mean that the setting in which the students performed the practical was more or less identical. From the two classes that did the closed experiments data from 38 students has been gathered, and from the class that did the open experiment data from 17 students has been gathered, leading to a total sample size of N = 55.

The results from the three reliable subscales have been analysed, and this has been done by performing an Analysis of Covariance (ANCOVA), where the pretest will be used as the covariate. By using this, a *p value* and a measure of the effect size will be generated to see if there is a significant difference between the group doing the closed and open experiments. But it is also important to know that if there is a difference, in favour of which of the two versions it actually is. In table 1 a table is given with the average results of the subscales for the pre- and posttest, and the gains in between.

Table 1

Averages of Pre- and Posttest Scores per Construct for Closed and Open Version

	Closed			Open		
Averages (SD)	Interest / enjoyment	Perceived competence	Value / usefulness	Interest / enjoyment	Perceived competence	Value / usefulness
Pretest	4.066 (.093)	3.345 (.112)	3.815 (.100)	3.971 (.130)	3.132 (.120)	3.838 (.126)
Posttest	4.039 (.106)	3.592 (.096)	3.631 (.123)	4.397 (.120)	3.867 (.096)	3.911 (.117)
Gains	-0.026	0.247	-0.184	0.426	0.735	0.073

Then in Table 2 the differences between these averages is used to look at the gain, and the differences between the gains of the open and closed version is given to determine which version had a more favourable outcome.

Table 2

Differences in Gains Between Open and Closed Versions

Gains	Interest / enjoyment	Perceived competence	Value / usefulness
Closed	-0.026	0.247	-0.184
Open	0.426	0.735	0.073
Differences	0.452	0.488	0.257

So as shown, for all three of these measured constructs students that did the open version showed a larger gain in intrinsic motivation than in the closed version, but the important question is of course if these differences are significant. Because three different subscales have been examined a Bonferroni correction has been used for the significance level, making it three times as small as the standard .05, namely 0.0166... As was said before, ANCOVA will be used to determine this significance, and the corresponding effect sizes.

For each of the three subscales ANCOVA has been performed with the corresponding pretest serving as the covariate. The results of this are given by Tables 3 through 5:

Table 3

Analysis of Covariance Summary for Interest/Enjoyment

Source	Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Pretest	5.540	1	5.540	20.169	< 0.001	0.279
Version	1.980	1	1.980	7.207	.010	.122
Error	14.283	52	0.275			

So here the *p* value is equal to .010, meaning the result is significant, and partial eta squared, a measure for the effect size is equal to .122. To interpret the effect size, the rules of thumb from Cohen will be used (1977), where a partial eta squared of .01 indicates a small effect, .06 indicates a medium effect, and .14 indicates a large effect. Using this, the effect size of .122 here would indicate a medium effect.

Table 4

Analysis of Covariance Summary for Perceived Competence

Source	Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Pretest	3.567	1	3.567	15.455	< 0.001	0.229
Version	1.496	1	1.496	6.483	.014	.111
Error	12.001	52	.231			

Here the *p* value is equal to 0.014, again a significant result and the effect size is equal to .111, which would also be a medium effect.

Table 5

Analysis of Covariance Summary for Value/Usefulness

Source	Sum of Squares	*df*	Mean Square	*F*	*p*	Partial Eta Squared
Pretest	9.084	1	9.084	25.361	< 0.001	0.328
Version	.821	1	.821	2.293	.136	.042
Error	18.626	52	.358			

So here we can see that the *p value* is equal to .136, which is not a significant result, and the effect size is given by .042, which is a small effect.

Conclusion

By looking at the *p value*s provided by the ANCOVA results, two out of the three measured constructs show significant results between the open and closed versions of the experiment, in favour of the open version, which is striking considering the small sample size. For the interest/enjoyment subscale a significant difference was found, and recall that this subscale is the most important one of the IMI, with it being seen as the self-report measure of intrinsic motivation. The corresponding effect size is equal to .122, which indicated a medium effect. In this research the time to perform an experiment is typically under 45 minutes; if science experiments would regularly be performed with IBL a higher effect size would be expected. It be concluded that there is a significant difference in interest/enjoyment between the open and closed version, meaning that students that perform the open experiments to experience a bigger gain in intrinsic motivation regarding the experiments because of it.

For the perceived competence a similar result is found, with another significant difference and an effect size of .111, indicating a medium effect. Students perceive themselves to be significantly more competent when performing the open version of the experiments, and this links up well with SDT which would suggest that this also leads to a higher intrinsic motivation. For the value/usefulness subscale there is unfortunately no significant result, and an effect size of .042, which is low.

Looking back at the research question, an answer to this can now be formulated. The explicit research question was: *To what extent does an inquiry-based learning style practical about ionizing radiation result in higher intrinsic motivation of students when compared with a traditional style practical?*

And judging by the results the answer would be that the inquiry-based learning practical does result in a significantly higher intrinsic motivation for students when compared to the traditional styled practical. Corresponding effect sizes are of medium value, so the conclusion can be drawn that there are significant positive results for intrinsic motivation when using the open approach, specifically when looking at interest/enjoyment and the perceived competence of students.

Discussion

There were some limitations to both the data and the methods used to collect the data which will be discussed here, as well as some implications for both teaching and for further research on the topic.

Limitations

Because of the removed question in the interest/enjoyment subscale only three questions remained, which is not a lot, especially for the most important subscale of the questionnaire. For further research this scale should therefore be expanded, at least being brought back up to four valid questions regarding interest/enjoyment.

Because of time concerns that students often have, the questionnaire has purposefully been designed to not take up a lot of time. But because this research was performed as the same time that another research about the learning outcomes of students doing the practical was done, one consolidated questionnaire was used where after the motivation questionnaire students also have a questionnaire about their conceptual knowledge. This limits the time which can be used to assess students' motivation, and a longer questionnaire solely based on motivation would be more reliable.

During the practical students often have to finish the experiments within a given timeframe, which can lead to students experiencing some pressure because of this. And whereas the students all start with the pretest and those have all been collected, not all students have managed to fill in the posttest. Sometimes students just forget the fill it in or even if they did fill it in they forget to hand in the posttest. With one of the classes from the research there was also a case that the group was lagging behind with the experiments, and the decision was made that since the experiments are more important for the students than the posttest that they didn't have to fill those in. Because of this data was not representative of the entire group that was tested, and perhaps students that are slower or less organized would show different results for their gains in intrinsic motivation. For any subsequent data that will be collected from questionnaires it is important to inform the teacher beforehand that the pre- and posttests do take up some time, and that is important for the research to gather all of the data, and not be constrained by time concerns.

Furthermore, it was initially intended that there was a second way of data collection, by using a set of optional exercises. The idea of this was that on the worksheets for both the open and closed versions of the practical, an extra exercise would be added, with nothing more than the caption of ‘extra exercise’. The hypothesis for this would be that if students doing the open version of the experiments would have a higher intrinsic motivation and would be more willing to do an extra exercise, when compared to the students doing the closed version. At the beginning of the practical it is also made clear that these extra exercises are not taken into account if their hand-ins are to be graded. Data sampling would be elementary in this case, by just polling the number of students that have commenced working on the optional exercises. It can be done for every experiment that has both a closed an open version of it, so it is also not just doable for the first experiment that students do like the questionnaire. It can also be done without the researcher actually being present, seeing as the only thing necessary would be for the teacher that looks at the hand-ins from the students to report how many groups did something with those optional exercises. For this research, these optional exercises were added to the used material, however due to a simple printing error the data could not be collected for students doing the closed version of the experiments. However, for the open version there is data, but seeing as students work in pairs the data effectively gets halved, and there is only data of 11 groups, which is very little. And seeing as there is no closed version to compare it with, there was no meaningful analysis to be performed on this data. But for further research this does remain a very promising way to collect data, so it is important to keep collecting this data and see if it also yields a significant result.

Lastly, the implications for education are that students do show a higher intrinsic motivation after doing an IBL style experiment, so for teachers trying increase motivation of students when doing science experiments using elements of IBL would work for that. So things like letting students come up with their own research question and make their own plan of work instead of working through a set of given exercises would give them significantly more intrinsic motivation. And the summarize the implications for further research, it is important to expand the used questionnaire, at least on the interest/enjoyment scale, but if time during the experiment permits it it would be good for all subscales. It is also important to keep collecting data on the optional exercises, so it might be used as data triangulation and give a more behaviouristic type of evidence instead of a self-reported one.

References

Banchi, H., & Bell, R. (2008). The Many Levels of Inquiry. *Science and Children*, *46*(2), 26–29. Retrieved from http://static.nsta.org/files/sc0810_26.pdf

Capps, D. and Crawford, B. (2012). Inquiry-Based Instruction and Teaching About Nature of Science: Are They Happening?. *Journal of Science Teacher Education*, 24(3), pp.497-526.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences*. New York: Academic Press.

Ebbens, S., Ettekoven, S., & Burgers, A. (2013). *Effectief leren: Basisboek* (3rd ed.). Groningen [etc.]: Noordhoff.

Firssova, O., Boerner, D., Kalz, M., Ternier, S., Pannekeet, K., Specht, M., … Rusman, E. (2014). *Sustainable inquiry based learning with ICT*. Retrieved from https://www.surf.nl/binaries/content/assets/surf/nl/kennisbank/2014/eindrapportage-project-sustainable-inquiry-based-learning-with-ict.pdf

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and Quasi-Experimental studies of inquiry-based science teaching: A Meta-Analysis. *Review of Educational Research*, *82*(3), 300–329. doi:10.3102/0034654312457206

Inspired Issue Brief: Inquiry-based Teaching. (2008). . Retrieved from http://inspiredteaching.org/wp-content/uploads/impact-research-briefs-inquiry-based-teaching.pdf

Lazowski, R. and Hulleman, C. (2015). Motivation Interventions in Education: A Meta-Analytic Review. Review of Educational Research, 86(2), pp.602-640.

Lynch, S., Kuipers, J., Pyke, C., & Szesze, M. (2005). Examining the effects of a highly rated science curriculum unit on diverse students: Results from a planning grant. *Journal of Research in Science Teaching*, *42*(8), 912–946. doi:10.1002/tea.20080

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: A systematic review of 12 years of educational research. *Studies in Science Education, 50*(1), 85–129. doi:10.1080/03057267.2014.881626

Rocard, M. (2007). *Science Education Now: A Renewed Pedagogy for the Future of Europe*. Retrieved from http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. doi:10.1037//0003-066x.55.1.68

Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review*, *19*, 158–172. doi:10.1016/j.edurev.2016.07.003

Selfdeterminationtheory.org. (2017). *selfdeterminationtheory.org – Intrinsic Motivation Inventory (IMI)*. [online] Available at: http://selfdeterminationtheory.org/intrinsic-motivation-inventory/ [Accessed 16 Jul. 2017].

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project: an overview and key findings*. Retrieved from http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf

Appendix A: the used questionnaires

Pretest:

Klas: 4 havo / 5 havo / 4 vwo / 5 vwo / 6 vwo
Ik heb de volgende experimenten gedaan:

Geef voor de volgende stellingen zo goed mogelijk aan in hoeverre deze waar zijn. Geef slechts één antwoord door het te omcirkelen, foute antwoorden kunnen worden doorgestreept.

Stelling	Helemaal niet mee eens	Een beetje oneens	Neutraal	Een beetje eens	Helemaal mee eens
Ik denk veel moeite te gaan hebben met het ISP-practicum.	1	2	3	4	5
Het ISP-practicum lijkt me leuk om te doen.	1	2	3	4	5
Ik zal mij tijdens het ISP-practicum niet veel inspannen.	1	2	3	4	5
Ik zou het ISP-practicum als interessant willen omschrijven.	1	2	3	4	5
Ik denk dat ik tijdens het ISP-practicum mijn aandacht er niet altijd bij kan houden.	1	2	3	4	5
Ik denk dat het ISP-practicum een belangrijke bijdrage zal leveren aan mijn begrip van radioactiviteit.	1	2	3	4	5
Het ISP-practicum lijkt mij saai.	1	2	3	4	5
Het ISP-practicum lijkt mij nuttig.	1	2	3	4	5
Ik denk dat ik in vergelijking met andere leerlingen het ISP-practicum goed zal doen.	1	2	3	4	5
Ik vind het belangrijk om het ISP-practicum goed te doen.	1	2	3	4	5
Ik denk dat ik erg goed zal zijn in het doen van het ISP-practicum.	1	2	3	4	5
Ik voel mij vaardig genoeg om het ISP-practicum te doen.	1	2	3	4	5
Ik zal niet veel energie in het ISP-practicum stoppen.	1	2	3	4	5
Ik denk dat het ISP-practicum nuttig is voor het onderwerp radioactiviteit.	1	2	3	4	5
Tijdens het ISP-practicum zal ik proberen erg mijn best te doen.	1	2	3	4	5
Ik denk dat het ISP-practicum mij zou kunnen helpen om radioactiviteit te begrijpen.	1	2	3	4	5

Posttest:

Klas: 4 havo / 5 havo / 4 vwo / 5 vwo / 6 vwo
Ik heb de volgende experimenten gedaan:

Geef voor de volgende stellingen zo goed mogelijk aan in hoeverre deze waar zijn. Geef slechts één antwoord door het te omcirkelen, foute antwoorden kunnen worden doorgestreept.

Stelling	**Helemaal niet mee eens**	**Een beetje oneens**	**Neutraal**	**Een beetje eens**	**Helemaal mee eens**
Tijdens het ISP-practicum heb ik geprobeerd mijn best te doen.	1	2	3	4	5
Het ISP-practicum was leuk om te doen.	1	2	3	4	5
Ik heb mij tijdens het ISP-practicum niet veel ingespannen.	1	2	3	4	5
Tijdens het ISP-practicum kon ik de aandacht er niet bijhouden.	1	2	3	4	5
Ik vind dat het ISP-practicum nuttig is voor het onderwerp radioactiviteit.	1	2	3	4	5
Ik voel mij vaardig genoeg om het ISP-practicum te doen.	1	2	3	4	5
Ik denk dat ik erg goed ben in het doen van het ISP-practicum.	1	2	3	4	5
Ik heb niet veel energie in het ISP-practicum gestopt.	1	2	3	4	5
Ik vind dat het ISP-practicum mij helpt om radioactiviteit te begrijpen.	1	2	3	4	5
Kijkend naar andere leerlingen vind ik dat ik het ISP-practicum erg goed gedaan heb.	1	2	3	4	5
Ik vind het ISP-practicum nuttig.	1	2	3	4	5
Ik vind dat het ISP-practicum een belangrijke bijdrage heeft geleverd aan mijn begrip van radioactiviteit.	1	2	3	4	5
Ik had veel moeite om het ISP-practicum te doen.	1	2	3	4	5
Ik vond het belangrijk om het ISP-practicum goed te doen.	1	2	3	4	5
Ik vond het ISP-practicum saai.	1	2	3	4	5
Ik zou het ISP-practicum als interessant willen omschrijven.	1	2	3	4	5