

How does physical engagement aid students' development of conceptual modelling in Physics?

Gallwch ychwanegu'ch targedau o'ch aseiniad diwethaf gan ddefnyddio'r tabl isod. /
Please add your targets from the previous assignment using the table below.

	Targed/Target	Yr hyn yr wyf wedi'i wneud yn yr aseiniad hwn. What I have done in this assignment.
Targed/Target 1	Correctly use Harvard Referencing when referencing material	Ensured that included references match the guidance provided by the UWTSD library service.
Targed/Target 2		
Targed/Target 3		

Words: 4680

Aim, focus and purpose of research

The topic of research that I chose to study was investigating how physical engagement throughout lessons allows students greater understanding of the underlying physics involved through the creation of conceptual models. This was of particular interest to me as throughout previous lessons, within classes, it became of interest to me to look further into how students are able to learn physics by understanding as opposed to how they may answer questions during exams. This was particularly of significance in seeing the effect that was had on different ability groups and whether there was potential for this to be used as a method of differentiation, allowing all students to access to work at a level relevant to themselves.

Research context

The research detailed within this report was carried out in partnership with another PGCE student who also taught physics, within two 11 to 19 schools in West Wales. The partnership was chosen due to similarities between the schools, both in location and the age groups that were taught, as well as the subject knowledge shared within the partnership, that being a speciality of teaching physics. The research question that we chose to investigate was 'How does physical engagement aid students' development of conceptual modelling in physics?'. For our classes this meant looking at how activities that involve students getting up and moving around develop students' understanding of the concept throughout the lesson.

Literature review

Modelling has always been an integral part of Science and could even be considered one of the key aspects of it – showing understanding of nature through the creation of mathematical models that are able to predict what may happen next. These also have a relevance within science education, particularly that within schools where Gouvea and Passmore (2017) make the distinction between creating a 'model of' something that is able to accurately predict what may happen and creating a 'model for' understanding how something happens. This seemingly arbitrary distinction is perhaps one of the key differences between science and science education as the former allows a pupil to use knowledge whereas the latter allows a pupil to develop

their knowledge through the consideration of the limitations and potential misconceptions (Baumfalk et al, 2019). This view is challenged though, with particular emphasis placed on the applicability of indirect models as pupils progress through school and sixth form (Dounas-Frazer and Lewandowski, 2018) as they have the potential to confuse pupils as they understand the content in greater depth and the models they use no longer reflect the experimental data that they are able to produce.

Brewe et al. (2018) provide a physiological basis into the use of physical engagement to develop conceptual models within physics by studying university students using fMRI to discover how these conceptual models are utilised. Though this study was limited to the teaching of Physics at University, it further relates to the neurological use of models and whether conceptual models should be considered a form of scientific literacy (Mierdel and Bogner, 2019) that once initially created should be regularly revised, adapted and developed in order to allow for efficient use and recall (Damelin et al, 2017).

During a literature review conducted by Arthurs and Kreager (2017) it was noted that whilst there is a growing body of evidence to suggest that having pupils actively participate during the teaching of topics allows for greater development of conceptual models and overall greater retention, there is still a general reluctance by teachers to do so. Furthermore, the increasing use of technology within the classroom can be seen as another reason for which the use of physical representations is not being adopted, it has also been argued that technology can provide a means to virtually develop these models and lead to a greater range of models that possible (or practical) within most classrooms (Lämsä, 2018).

With a focus on elementary school pupils, a study found that 'hands-on' activities not only had a positive benefit for pupils' engagement, involvement and immediate learning but also had an effect on pupils' performance in standardised tests (Gomez-Arizaga, 2016). A similar study carried out in Indonesia found that physical engagement also has a long-term effect on the problem-solving ability of pupils (Yulindar, 2018). This also shows how physical engagement may not be context specific, with potential implications for the results of this research project.

Treagust et al. (2017) discuss the broader role of modelling within science education by looking at how multiple representations are important to allow for understanding, especially for lower ability pupils (Treagust, 2018).

Lesson study design

During this research, the primary research method used was that of Lesson Study; this was a Japanese concept that was introduced to the UK by Pete Dudley. One of the primary ideas behind lesson study is that of providing teachers a common method by which to take part in educational research and for this to be done in a way as to allow teachers to extract findings that will be useful to their classes almost immediately.

Within the design of the lesson study research project, a common aim must be identified by one or more teachers. This aim maybe content specific or pedagogy specific, with this being tailored to suit the environment in which it is being used. Within this study it was decided for ease of practice to consider a pedagogical approach whereby the content that was being taught would have less bearing on the outcome, whilst still developing pupils. Once the aim has been identified a joint planning progress between the teacher researchers takes place where a lesson plan is developed that includes the desired aim in some form. Following this, the first lesson is then taught by the first teacher with the agreed methods of data collection and observation taking place. The results from this are then collaboratively reviewed, considered and discussed to see where improvements may be found. Whilst the second lesson is usually taught with only minor modifications based off the feedback received, during this research this was not possible due to the limited time that was available. Therefore, only one lesson was taught by each researcher.

During this research study three pupils in each class were chosen based upon ability. This provided the researchers with a higher, middle and lower ability pupil within each class. These pupils were then observed throughout the lessons by the opposing research partner who acted as a non-participant observer with minimal prior knowledge of the class. This has the advantage of preventing bias that may be associated with the research acting as the class teacher, however due to our research focussing on the development of conceptual models there is the necessity of discovering pupils' thoughts throughout the lesson. In light of this, the chosen pupils were interviewed in a focus group following the class.

The non-participant observer made notes on the actions of the chosen pupils throughout the lesson based on the Leuven (Laevers, 2003) Scale of Involvement.

Whilst the nature of observation limits the potential accuracy of the results the Leuven Scale was used in order to provide a common framework that could be used by both researchers in both observations as well as allowing for the semi quantitative analysis of the results. In order to further increase the volume of information that could be gained throughout the lesson three short identical question sheets were used in order to assess pupils' understanding at different points, provided an instantaneous method of pupil feedback. These were used once at the start of the lesson to assess the initial understanding of the topic, once following a theoretical explanation of the concepts involved of the topic and once, finally, to assess the understanding gained through their participation in physical engagement.

As aforementioned, following the lesson a focus group took place with the pupils involved in the study, along with the class teacher and research partner acting as the observer. This allowed for the class teacher to ask a range of pre-agreed interview questions to the panel of pupils, thus allowing for pupils' thought processes to be assessed as well as an opportunity for them to express any views or opinions that they may have regarding the lesson. The format whereby the class teacher asked questions to the panel was used to continue the observer's non-participatory presence and provide a level of comfort to the pupils involved so that they were more confidently able to assert any opinions without having to take account of a person that they were unfamiliar with. However, whilst a prior relationship with the researcher asking the questions has some of the previously mentioned advantages, it may also present disadvantages as a level of bias from those taking part in the panel could arise. This could be due to either an overly positive view so that they may please authority figures that they are aware of or an overly negative view if their prior experiences with that teacher led to generally negative feelings. There is the further concern that pupils may wish to say what they believe the class teacher wishes to hear, though attempts were made to mitigate this by insuring pupils that opinions expressed within the interview we are purely for the purposes of research and developing teaching in the future.

Finally, once the lesson and following interview have been completed there is the opportunity for the researchers to collaboratively reflect upon the lesson. This reflection is an essential part of the research methodology as it allows for an immediate consideration of the effect of changes on the lesson, as well as providing the essential learning from the point of view of the non-participant observer in

addition to anything observed by the research acting as a class teacher who has previous knowledge of the class and may have noticed something that could be considered different to normal in relation to the class. In order to provide a structure to these reflections a model of reflection developed by Gibbs (1988) was used as a basis and modified to suit the specific needs of a Lesson Study.

Ethical considerations

Due to the nature of the research being undertaken within an educational context on secondary school pupils it is necessary to consider ethical concerns that may be present. Within this research project the primary ethical concerns arise from the non-participant observation of the pupils in the focus group as well as the interview following the lesson. In order to mitigate these ethical concerns and ensure that all appropriate measures were being taken an ethics form was submitted to the University prior to the commencement of the research. As outlined within this ethics form, all pupils were made aware as to the purpose of the observation as well as pupils within the focus group having parental consent provided, in the form of a signed letter, as well as pupils' assent being confirmed at the beginning of the lesson whilst ensuring to inform them that they are able to withdraw their assent at any time. All data collected during these observations was anonymized and securely stored digitally within the University's firewalled Drive.

Results and analysis

Lesson study one took place within the further west of the two schools. The lesson observed was with a year eight class who had been studying optics for a number of lessons and during this lesson they would continue with this topic with a specific focus on refraction. Whilst completing the first question sheet it became apparent that the higher ability pupils were able to more easily activate prior knowledge, recalling information from previous lessons and apply it to this new context. This is reflected in the pupils' level of involvement where the higher ability pupil was focused on answering the questions provided, the middle ability pupil was somewhat focused on the lesson however failed to provide attention to the question sheet provided with the lower ability people not focusing on the question sheet or lesson, potentially as they were not able to access the work included.

Pupils were then able to begin learning with relation to the content of this lesson through the theoretical explanation provided by my colleague. During this time the higher and middle ability pupils listened but did not engage actively within the class. Examples of this included looking distractedly around and failing to answer questions when they were posed. The behaviour from the lower ability people however provided a greater insight as this pupil was not only exhibiting examples of distracted behaviour but also at times actively disrupting the class. When asked about this during the interview it was discovered that the pupil found the initial part of the explanation too challenging and was then unable to continue following the lesson. The question sheet results following this showed a limited improvement across the range of pupils with higher ability pupils exhibiting a greater increase in attainment as they were now able to answer all of the questions to at least some degree.

The physical engagement within this lesson was that of pupils holding onto a large stick in order to simulate a wave-front crossing the boundary between two materials. Due to the limited space available within the classroom, the class was taken outside to a nearby area where the activity could be performed. Both the observation and subsequent interview revealed that the level of involvement that pupils showed whilst outside varied significantly dependent upon whether the pupil was currently engaged with the activity or merely observing classmates participating. Whilst the pupil was engaged with the physical activity involvement levels could be seen to be significantly higher than when in the classroom discussing theory, particularly for the lower ability pupil. However, the opposite was true when a pupil was merely observing. The results from the final question sheet showed a marked improvement for the lower ability pupils which was also highlighted during the interview where they responded by discussing how they found the question sheet easier the final time. Furthermore, during the interview it was highlighted by the higher ability pupil that they found the theoretical teaching and board work sufficient to understand the concept and regarded the physical engagement as an inefficient use of time due to the behaviour of other pupils.

Following the reflection of the lesson it was considered that a possible improvement to the lesson could be to use a smaller scale example of the concept that could be performed within the classroom. This would allow for numerous quick examples to be given throughout the course of teaching the lesson therefore providing less time for those not involved to become distracted. Targeting specific pupils could also

allow for those with the greatest potential to benefit to participate most whilst those who may gain less are able to focus on a method that allows them to better construct their conceptual model of the topic.

The second lesson study took place within the larger of the two schools, however individual class sizes remain comparable. The class involved with the observation was a year 9 class who were beginning to revise their Physics work that had been completed ~4 months earlier. Whilst the lesson covered a range of topics involved in Electricity and Magnetism, the essential topic relating to the research being conducted was the transmission of current around a circuit and how the placement of bulbs may affect their brightness. Due to the pupils' prior knowledge of the topic, the question sheet was essential in order to establish what they were able to recall from previous lessons and allow for the distinction to be made with what they learnt throughout the stages of the lesson. As seen within lesson study one, the higher ability pupil was generally able to recall a greater amount in comparison to the middle lower ability pupils, however observation notes show that the higher ability pupil was initially more distracted and took a short amount of time to settle on the task.

During the theoretical explanation of the movement of current around the circuit all pupils remained engaged, though the lower ability pupils required repeated explanations of some concepts and instructions in order to complete the task that had been set. This was similarly reflected upon analysis of the question sheet that followed showing that the mid and higher ability pupils gained a significant amount of damage whereas the lower ability pupil was able to immediately recall less of the knowledge that had been discussed.

As the central topic of focus within the lesson was the transmission of current around electrical circuit a number of possible physical models could have been used to demonstrate this effect. In order to actively involve a number of members of the class the Rope method was chosen as this provided a way for a number of pupils to be involved whilst allowing for the class teacher to control both the pace of the demonstration as well as the explanation associated with it. From the learning gained in lesson study one the physical engagement was carried out within the classroom, in order to minimise disruption to the lesson, whilst still allowing for a number of pupils to become involved and participate around the classroom. Whilst

the lower ability pupil continued to require repeated explanations regarding the processes involved, the level of involvement observed was far greater than during the theoretical exclamation. During the interview the middle ability pupil reported how the ability to link together abstract concepts such as electricity to a physical model that they partook in allowed them to not only understand what was happening at that time but also allowed them to develop a 'mental' (conceptual) model that they could later reflect on. Throughout these demonstrations however the higher ability pupil was not able to remain consistently engaged and was seen explaining concepts to surrounding pupils. This could show that they were secure in their understanding and wished to share it, or it could show that they did not see sufficient benefit in the use of the physical engagement. Attempts were made to explore this during the interview, but sufficient clarity was not provided for the researchers to make a definitive judgement.

During the reflection it was noted that generally pupils remained engaged throughout the lesson, though a notable exception was some of those that were not involved in the demonstrations whilst they were taking place. Additionally, it was also noted that in the future further written work could be provided to higher ability pupils to allow them to further develop their own knowledge should they already understand the concept whilst demonstrations take place. In addition, the lesson could be improved in the future by further reducing the length of the physical engagement and spacing a greater number throughout the lesson.

From this experience, the researchers believe that in order to gain a greater understanding in future lesson studies additional clarity surrounding the use of the semiquantitative research methods could be developed in order to reduce possible observer bias. Additionally, with such a method the presence of two non-participant observers could be used to create an average of the results, though the additional disruption that this may cause to the class would also need to be considered.

Discussion

From the results, it can be seen that whilst physical engagement has an overall benefit the potential benefits for some pupils are greater than others. It can be seen that for lower ability pupils the use of practical activities provides a way for them to engage with the topic that may not be present when the theory alone is discussed.

This could be compared to the work of Treagust (2018) who also found that there is the potential for lower ability pupils to make greater progress, however the results found during this research project appear to show greater improvements when compared with Treagust's. This could be due to a number of factors including the topics taught, the pupils they were taught to as well as a difference in culture between Wales and the United States of America.

Furthermore, whilst my results do not show any negative effects for higher ability pupils they also failed to show significant progress between the stages where the theory is introduced and where the physical engagement occurs. The reasons for this would need to be investigated further however a potential explanation can be found in the research of Kozhevnikov et al. (2007) wherein the ability to develop conceptual models is linked to that as spatial visualisation. This has the implication that if a pupil is highly adept at spatially visualising concepts then they may also be able to use this skill within the comparative creation of conceptual models.

These findings ensure that physical engagement is used where appropriate with greater consideration given to which students participate as well as which students are likely to gain the most from it.

Conclusion

In conclusion, the validity of the lesson study design must also be considered when considering the implications of these findings. The primary research method used was that of non-participant observation, this is beneficial in that it allows for a researcher with limited prior knowledge of the class to observe the chosen individuals without interacting with the class, however it must also be considered that the presence of an unknown individual may influence the behaviour of the class. Furthermore, as there was only one non-participant observer present during each lesson study the results recorded can also be considered a reflection upon the individual's personal biases. Attempts were made to mitigate against these biases through the use of the Leuven (Laevers, 2003) Scale of Involvement which assigns a numerical value to described levels of involvement. Whilst this assists in removing possible biases, there is still scope for differences in interpretation of the Scale. As previously mentioned, attempts were made to put the focus group pupils at ease by having the researcher acting his class teacher asking questions with the non-

participant observer noting down responses. Whilst this will remove some reluctance on behalf of pupils it must also be considered that they may not wish to reveal some of their true opinions with regards to the lesson for fear of repercussions or perhaps to merely avoid any confrontation with the teacher by providing what they believe are the desired answers. Additionally, due to the timetables of the schools, a limited amount of time was available in which pupils could be interviewed and subsequently for the researchers to review the lesson.

Unfortunately, in the period leading up to the research lesson the physical engagement methods described were unable to be trialled ahead of time due to the limited number of age-appropriate classes taught by the researchers. It is therefore possible that the activities used within these lessons were not presented as well as possible which may have led to negative impressions by pupils that could be attributed to the impact of the researchers as opposed to the activities and methods used.

Given the limitations identified above along with research taking part into similar schools in West Wales the ability to generalise these results for wider application in education can be considered limited. However, whilst these results may not be considered widely applicable it is the belief of the researchers that they can certainly be applied with the classes used within the lesson study as well as a likely application within the general schools involved, and with possible applications within schools judged to be within similar contexts.

Within my next school placement, I shall continue trialling how physical engagement can be embedded throughout lessons as well as in a variety of topic contexts. In particular, if the opportunity arose, I should relish the opportunity to use one of the activities described in this research again in order to further assess how they may work with additional classes.

If the research would be conducted again it would be interesting to use two similar classes from within the same school of similar abilities within the lesson studies in order to provide results that could be more closely compared. This would remove some of the uncontrolled variables that were in place ahead of the research occurring such as prior knowledge and differences in prior teaching styles.

Recommendations

Upon detailed consideration of the findings of this research I would recommend that where appropriate conceptual models are developed through the use of physical engagement. This should be done consistently through a number of quick activities that provide a measurable benefit to pupils so that its presence does not distract from the overall lesson. It has been noted throughout this research that physical engagement may be of particular benefit to those of lower ability, though as this was observed within mixed ability key stage three classes the possible benefits to those set within lower ability classes is unknown at this stage.

In light of this there are a number of possible aspects that could be investigated within future research projects including the potential benefits of physical engagement in schools of different contexts, across different age ranges as well as for classes that are set according to ability.

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