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Forces, to Visualise the Invisible

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Abstract

"This is hard to understand as you can't see the forces" exclaimed a student during a science course. Basic concepts in physics like force, energy, power are difficult to observe. Usually we often only make conclusions about their existence out of the resulting effects of their appearances. In addition, the use of similar words in other contexts, sometimes metaphorically, sometimes with other meaning, make the situation even worse. In science courses for pre-service primary school teacher students we have tried to design learning situations where students get personal experiences of the world behind the concepts described in words.

Thus, we designed situations when the students themselves were subjected to different forces or had the opportunity to observe the effects of forces. They wrote reflections on their experiences and we discussed these together in order to get used to how to describe and explain these type of experiences.

The learning outcome was assessed by analyses of written reflections of experiences from different attractions of an amusement park. One of the main outcomes of these reflections were the differences in the observations of the students. Often they had to do several rides to observe the forces they were subjected to. They also found differences in their personal ability to identify the forces. Some students were better in observing some of the forces than the others.

Thus, the participation in one activity with the aim of observing something does not necessarily lead to similar observations of other participants. Previous experiences seem to affect the observations so forces in some directions may be regarded as more powerful or easier to identify by some persons than others. This may be a general characteristic of observations in common situations. In that case this may be one explanation why, e.g., students have different focus in the classroom and learn other things than those intended by the teacher.

1. Introduction

Basic concepts in physics like force, energy, power are difficult to observe. In science courses for pre-service primary school teacher students we have tried to design learning situations where students get personal experiences of the world behind the concepts described in words. Conclusions about the existence of many scientific concepts and their characteristics are based on observations of their resulting effects. They are not directly visible by the observer. Earlier we had, with good results, let the students use their own bodies in experiments in order to directly perceive the existence of, e.g., forces [1]. Later, when we discussed this outcome with the students we found individual differences in the descriptions of their learning outcome, reflections indicating differences in their perceptions of different experiments and other situations [2]. In order to fully understand the relation between arranged learning situations and the outcome of these, studies of the relation between individual perception, observation and reflection are necessary. In addition, as the individual background has influence not only on the vocabulary of the students but also on the perception and on the interpretation of experiments and observations an individual approach is necessary. Further, the use of similar words as those used in physics, in other contexts, sometimes metaphorically, sometimes with other meaning, make the situation even more complicated, especially for the designer of learning situation for groups of students with different background and experiences [3]. Thus, the teacher is challenged to design training situations in the class functional for all individuals.

2. Objectives

The main objective of this study was to design learning activities and to assess the learning outcomes of these. They were made in order to promote activities where observations by students should help them to visualise and understand physical concepts like forces, gravity or energy. Especially, we wanted to study differences in the students' descriptions of their observations as these may be based on differences in their perceptions of the same situation. Further we wanted to investigate if the quality of their reports were related to their examinations later on the theoretical course in physics.

3. Material and methods

We designed learning situations for a group of 25 students in a pre-service program aiming at teaching year 4–6 in compulsory school. The students had chosen to study science and technology for 20 weeks in a non-compulsory course within the program. Here they studied practical physics and biology for about four weeks. About half that time were focused on physics where the students mainly were subjected to different forces or had the opportunity to observe the effects of forces on others. They made experiments and observations in the laboratory but also at home, at playgrounds and when travelling by different vehicles including sailing. During the course they wrote individual reports and reflections of their experiences and made digital presentations together in groups. All these were discussed in the large group in order to get the students used to, how to describe and explain, their experiences. The learning outcome was assessed by analyses of individual written reflections of experiences from different attractions of an amusement park.

The students were formed in groups of three or four and each group had instructions to ride three specific attractions each and investigate and describe the influence of these. They had to deliver a written plan in advance in order to be well prepared. During their observation they made adjustments of their original plans according to the results of their rides.

The qualitative assessment was focused on the students' descriptions of perception, observation, analysis and their resulting conclusions. These did not have to be within the theoretical framework of physics but could also be within the field of cognition.

In the analyses of the reflections we noted references to background data like different activities during the course, to literature, to the curriculum for primary school in Sweden [4]. We also assessed the quality or depth in their descriptions, especially regarding perception, personal development but also more generally by using the 4 R's of Doll, *recursion*, *relations*, *richness* and *rigor* [5]. These factors were analysed in order to find possible influences on the results on the examination in physical theory two months later.

To evaluate the effect of showing personal development and using recursion in the reflection for the results of their examination we made a classification tree. The student are divided into groups that are further subdivided according to the explanatory variable that explains most of the variation in each division.

3.1 Statistical methods

We used the statistical package R 2.15.2 [6] and within the R environment the package effects [7] to make plots of predictions from linear models. The classification tree was made using the R-package rpart [8]. Linear models were constructed for each of the assessment scores using the summed Doll´s R score as explanatory variable.

4. Results

Reflections of 20 students were analysed. Three students could for different reason not participate in the practical examination at the amusement park. The reflections of two students where no analysed as they did not participate in the theoretical examination.

The reflections of the students showed large differences not only in their descriptions of observations but also in the content and type of report. Thirteen delivered fairly shallow reports mainly describing their experiences while seven made deeper analyses of their experiences. In all reflections references to the curriculum were made. Most of them also discussed how a visit to the park could be arranged to suite students from school (Table 1).

Often the students had to do several rides to observe the forces they were subjected to. This was reported in most reflections. During the first ride they usually were too absorbed of all impressions of the attraction. They often found differences in their personal ability to identify the forces. Some students were better in observing some of the forces than others. Already earlier during the course one of the students exclaimed "This is hard to understand as you can't see the forces". Here, in the amusement park they sometimes found differences between their personal experiences also when riding together.

There were fairly few references to activities during the course, in average 1.5/student, while 15 students reported experiences of personal development during the course. Most students showed use of *recursion* or *relations* in their texts, while about one third showed *richness* and only four showed *rigor*.

Comparisons with the characteristics of these reflections with the results of the assessment of the theoretical course showed almost no correlations. The only significant results were between recursion and rigor and high marks on that examination (Figure 1).

It was also possible to find factors which in combination seemed to have influence on the results of the assessment of knowledge of the theories of physics.

Type of reference	Number of students (N=20)
School curriculum	20
Adaptation to young students	16
Deeper analyses	7
Perception, report	7
Perception, in a cognitive context	5
Personal development	15
Observation of group development	2
Recursion	16
Relations	17
Richness	7
Rigor	4

Table 1. Content and quality of the reflections made after experimental exercises in an amusement park.

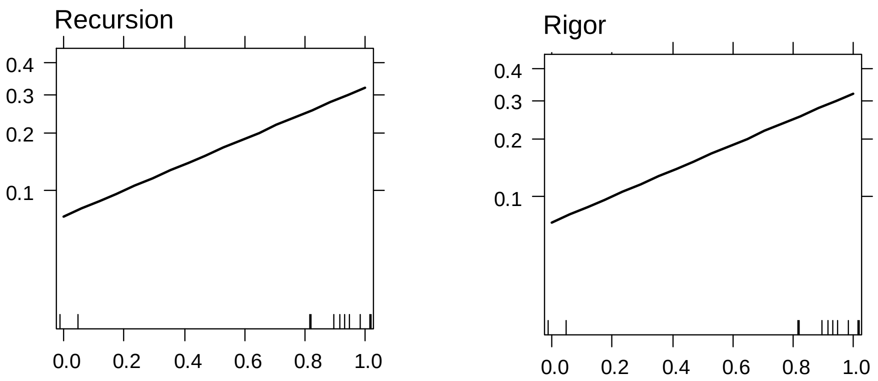

Figure 1. The effect plots of the 4R of Doll, *recursion* (p = 0.007204 **) and *rigor* (p = 0.012004 *).

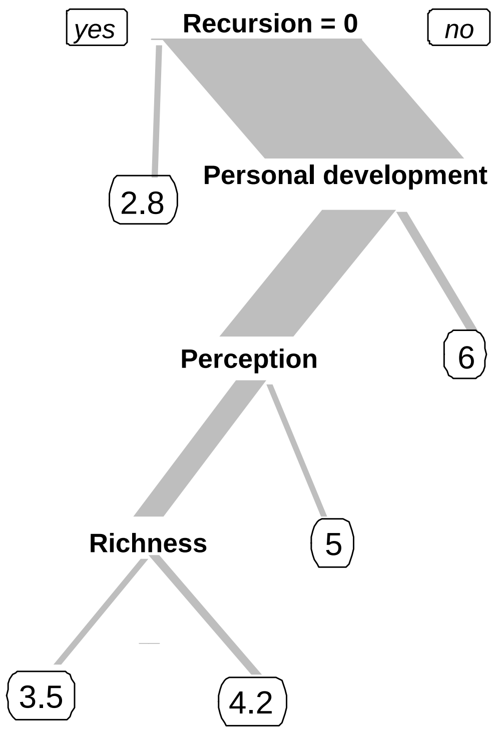

Figure 2. Predictions of results on the assessment of physical theory based on reflections made two months earlier. The left branch shows the result if the explanatory factor is expressed. Here the first division show low results in the assessment (2.8 out of 6) if the student didn't show recursion in the reflection.

5. Discussion

Participation in an activity with the aim to observe something does not necessarily lead to similar observations as those of other participants. Previous experiences of the students and expectations have effect on the observations. For example, forces in some directions seem to be regarded as more powerful or easier to identify by some persons than others. This may be a general characteristic of observations in common situations. In that case this may be one explanation why, e.g., students have different focus in the classroom and learn other things than those intended by the teacher.
The quality or depth in their descriptions was made using the 4 R's of Doll, *recursion*, *relations*, *richness* and *rigor*. The importance of the use of *recursion* (Figures 1 and 2) is not surprising as this skill could be regarded as a type of reflection. If regularly used through reflective interaction with the environment it produces a sense of self with others [9]. The use of *recursion* was not sufficient for reaching good results and to pass the later examination. Further, sixteen students showed *recursion* but only six of these passed the examination. On the other hand, among the students with the best results (6), only two identified personal development in themselves (Figure 2).
Of the other R's it is only *recursion* that is of significant importance although *rigor* is statistically significant but is used only by four students.
Although generalisations may be difficult to do out of this study it supports the importance of visualisations. Especially, as in this case, we have showed that forces are tricky as persons perceive them differently also under similar conditions. Observations and experiences of forces facilitates by group activities, both exercises and discussions.

5.1 Acknowledgements

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