UNIVERSITY OF GOTHENBURG

Ann-Marie Pendrill & Åke Ingerman

Enhancing formal learning in informal learning settings – Considerations for teachers and guides,

Michelsen, C. (Ed.) (2008) Proceedings of the Fourth Nordic Network of Researchers in Science Communication Symposium (NNORSC-4): The Necessity of Increased Cooperation Between the Researchers and Science Centres, Centre for Science and Mathematics Education, University of Southern Denmark, pp. 53-62

Enhancing formal learning in informal learning settings Considerations for teachers and guides

Ann-Marie Pendrill[1] and Åke Ingerman[2]
1) Department of Physics, Göteborg University, Sweden, Ann-Marie.Pendrill@physics.gu.se
2) Department of Education, Göteborg university, Sweden, Ake.Ingerman@ped.gu.se

ABSTRACT

An encounter with a phenomenon in a science center exhibit can provoke many questions and discussions among the visitors. Interaction with a guide can enhance the experience and help the visitors develop a deeper understanding and see more connections to other phenomena. The outcome of the discussions depend on the visitors, but also on the guide's strategy. This paper builds on empirical material in more formal learning situations, but with relevance for interactions e.g. in a science center. We first consider formal learning outcomes based on informal learning experiences in an amusement park. We then consider tutor preparation and tutor choices, with respect to entering in the dialogue, engaging with the students and finally, ending the teaching interaction. We find that an alliance between formal and informal learning situations can be mutually beneficial.

1. Introduction

What strategies can a guide adopt in order to optimize visitor outcome of the interaction and involvement with an exhibit? An encounter with a phenomenon in a science center exhibit can provoke many questions and discussions among the visitors. Interaction with a guide can enhance the experience and help the visitors develop a deeper understanding and see more connections to other phenomena. In an amusement park, interaction with a guide can also help visitors discover physics or technology behind different amusement rides. The outcome of the discussions depend on the visitors, but also on the guide's strategy. The previous experience of the guide is an important factor. Still, the feedback to the guide on the effectiveness of different types of interaction is often limited, since there is, in general, no way to find out what happens in the group when they are left on their own after the interaction.

In this work, we are particularly interested in quasi-informal learning situations where e.g. a science center exhibit is visited and interacted with as a part of a formal course. How can a teacher prepare such visits? Understanding common ways of thinking about concepts related to the exhibit is essential for the design of the exhibit itself, but also for the approach of the guides and for possible assignments by a teacher. In informal learning situations, the interaction is often limited in time and the goals are open. The guide would like to understand the aim of the visit and also to know the visitor's thoughts and previous knowledge, to be able to build on that knowledge. Strategies for eliciting visitor preconceptions are thus important. Thoughts on the strategy for the interaction can be part of the design, and, ideally, also developed in collaboration with the designer and the guides during the testing of the exhibit.

In order to develop a model for analysing the interactions, we draw on material from more formal learning situations. In section 2 we consider a question with possible learning goals in connection with a playground or amusement park visit. The physics content concerns acceleration as a swing passes the lowest point and the question arose from a group dialogue among first year engineering students at Chalmers during their second week of term. The group dialogue was paraphrased as a problem on a written test given to a large group of students, as a way to find the different ways students would describe this situation. The results demonstrate that many students hold incompatible views without noting the conflict between the everyday and physics use of the term acceleration. The results of this analysis can be used to create tasks for group discussions in preparation for future amusement park visits for physics learning. This type of conflict can often lead to interesting group discussions, where teacher interaction may be essential to bring out more clearly the challenge inherent in the contradiction.

In section 3 we consider the situation where a teacher supervises small- group discussions as part of a larger class. As in the case for science center dialogues, the interaction time with the group is often a small part of the total time the group may be involved with the exhibit, challenge or problem at hand. In both cases the teacher or guide would like to know the thoughts, questions and difficulties of the group concerning the topic in order to optimize the interaction. The limited time available for the total interaction emphasizes the need for a strategy to elicit the thoughts of the group. Our consideration is based on video-recordings of group tutorials with limited teacher interaction. The students are studying physics during the first year of their engineering programmes at Chalmers. The video recording provides a window to analyse what happens to the discussion in the group before, during and after the teacher intervention. The results presented aim to be of direct relevance both to physics teachers and science center guides, through the focus on restricted interaction with groups around a given physical situation.

Figure 1: A spiral rabbit and a "slinky" mounted in a swing to demonstrate forces on the rider during various parts of the ride

2. Considering formal learning outcomes based on informal learning experiences

A teacher may include extramural activities as part of a more formal school subject. The framing of the visit makes possible a more controlled preparation of the visit and also a more direct evaluation of the learning outcomes. In this section we focus on one aspect of the possible physics learning content from an amusement park or playground visit - the understanding of acceleration and the relation between acceleration and forces in a pendulum motion.

Light, heavy, light, heavy. During the pendulum motion in a swing, the body feels a periodic change in the forces acting on the body. In everyday life we experience the force required for acceleration in all its vector character. However, the experience of the body is rarely utilized in the teaching of mechanics. The study of the laws of motion often starts in non-motion or in uniform rectilinear motion, where the absense of net forces is counterintuitive.

What is the acceleration at the lowest point of a swing? Newton's second law relates acceleration to force, as **a=F**/m, so the acceleration is experienced throughout the accelerated body. A visual measure of the forces on the body can be obtained e.g. using a spiral toy as in Figure 1 (Pendrill and Williams, 2005). At the lowest point the swing has maximum speed. The everyday conception of acceleration as increase of speed, contrasts with the mathematical definition of acceleration as the time derivative of the velocity vector. Although the acceleration along the line of motion is zero, the maximum speed leads to a maximum in the centripetal acceleration due to the motion along the circle. However, since this acceleration is orthogonal to the motion, it involves changes only the direction of the velocity, but not the magnitude.

In a small-group discussion, one student (A) argues that, since the potential energy is lowest at the lowest point, the velocity has a maximum, and the derivative must then be zero. Another student (B) thinks that there must be something wrong with this argument, since you feel heavier than usual at the bottom. When the teacher asks if they could try to discuss the situation to resolve the contradiction, they asked if they should repeat their arguments. This dialogue was later used for an end of term quiz for first-year students, who were asked how they would help the students sort out the physics. From the replies we can identify different ways of thinking about force and acceleration in circular motion. The main categories found an analysis of the student replies are

I. The acceleration is zero
II. Referring to the centripetal force
III. Referring to the change of direction as the swing passes the lowest point
IV. Focusing on the change of angle between centripetal acceleration and the acceleration of gravity.
V. A clear distincion between the different components of the acceleration

Acceleration is zero

Some of the students' replies in the first category are undisturbed by the experience of forces at the bottom, and just express support for student A, or rephrases his claims. Other replies seem to treat force and acceleration as unrelated concepts, e.g.

- Student A is right. But the force you feel is due to the centripetal acceleration, which arises when you move in a circle.
- In the lowest position, a=0, since the swing "wants" to be there. The normal force is largest at the bottom when F_c get most "resistance" from mg.
- Student A is right. Student B is referring to the normal force.
- The acceleration is zero, but still, there is a force

The reference in the second reply to what the swing "wants" can possibly be traced to considerable amusement caused among some of the students by a similar phrase in one of the items in the Force Concept Inventory (Hestenes *et al*. 1992, Halloun *et al*. 1995) during the first day of term. The second student seems to refer to the centripetal acceleration as a non-acceleration.

Centripetal force
In the second category, most students' replies give expressions for the centripetal force and its dependence on velocity, but do no address student A's concerns, as e.g.:

- You feel heaviest at the bottom where the velocity is largest, giving the largest centripetal force, leading to a large normal force.

This is the most common type of answer.

Change of direction
In category III, students' replies more explicity discuss the change of direction of motion.

- There is absolutely an acceleration at the bottom. How else could the swing start moving upwards? It is because of the centripetal acceleration.

This respondent may recall a discussion in class about the acceleration in the highest point for a ball thrown up into the air.

Change of angle
The change in angle between the direction of the centripetal acceleration and the acceleration of gravity certainly accounts for the change in normal force from the swing acting on the rider, as referred to in replies in category IV, and would not happen in the absence of a circular motion. In the case of uniform circular motion in a vertical plane, which had been discussed in detail in class, this is the only contributing effect, whereas in a swing, the angular velocity is changing periodically and is largest at the bottom, leading to a maximum also of the centripetal acceleration, itself.

- You move along a circular track and always experience an inward force. But it feels heaviest at the lowest point because the because the centripetal force coincides with the normal force.

In this particular quote, we can also note the common confusion about directions of centripetal and/or normal forces.

Orthogonal components
Finally, some students clearly express in their replies (category V) that

- The acceleration in the lowest point is orthogonal to the velocity.

or use other ways of expressing an awareness that the different components of the motion can be treated separately.

Acceleration and force

From the replies presented above, it seems that students often fail to make the connection between force and acceleration, expressed in Newton's second law. Still most students are perfectly able to write down the law, when requested to do so. The relation between formulæ and physics deserves special attention! A stronger emphasis on the connection between force and acceleration is important to make use of the learning potential of an amusement park visit. In earlier work (Bagge and Pendrill 2003, Pendrill 2008), we have shown how 10- year olds could connect the experience of the body both to the motion of an amusement ride and to visual measurement with a slinky (as in Figure 1). Establishing this connection could thus start much earlier.

Group discussions can be one way to invite students to challenge contradicting, but coexisting points of view. However, teacher intervention can often be essential to expose or resolve the contradiction. Additional excerpts from supervised small-group discussions about acceleration can be found in Pendrill (2008). The replies from the student tests presented here give input to revise the task for student group discussions on acceleration, and also emphasized common incomplete understanding worth addressing. The next section focuses more directly on the interaction between the teacher and a group.

3. Considering tutor preparation and tutor choices

What happens when a teacher visits a small group discussing a puzzling exhibit or working on a physics problem? This section investigates sample dialogues, attempting to relate to what was discussed in the group before and after the teacher's visit. We present a simple model lending structure to the analysis and focusing on unearthing some major choices made, and not made, by the teacher in the particular situations. The analysis enables us to draw some conclusions on how to prepare for tutoring situations and how to handle them in practice in such a way as to support the learning outcome.

A common feature of physics courses is that students work on various problems, often in small groups tutored by teachers. At our physics department the forms of the group work are relatively free. Students are free to form and reform groups, work in the presence of other groups or separately. The content is set by a list of problems, and no particular form for the group interaction is imposed on the students, and the students receive no particular training in how to work in groups. From a small informal survey among some of the teachers at the department it is clear that typical preparation mainly consists of different kinds of consideration of the conceptual and mathematical difficulties of the problems set for the students – sometimes restricted to 'solving' the problems. From our personal experience of teaching at various physics departments, this situation is not uncommon.

Ideas for interaction are mainly drawn from personal experience, partially from discussions from colleagues and sometimes from literature such as Jacques (2000). However, it is scarce to find less generic literature which gives opportunities for reflection in relation to the teachers' practice and which is suitable to draw on with respect to how to facilitate students' learning of the physics content and to spot and address conceptual difficulties in the groups you encounter – in short literature supportive in developing good practice. Most literature is concerned with investigating cooperative learning, more stable groups, favourable mixing, size and physical arrangements, and looking for achievement differences (see e.g. Springer et al, 1999, and Bennet et al, 2004, for overviews). In connection with informal learning, the dialogues within family groups have been investigated e.g. by Ash (2003). These issues are discussed also in connection with the presentation of Context- Rich problems in physics. (for example, see Heller and Hollabaugh, 1992, Heller et al 1992, and Waltner et al 2007)

The empirical data consists of video and audio recordings of groups of three or four, while they were working with two mechanics problems. During the hour they had at their disposal, a teacher visited them two times each, on average for five minutes. The students were first year university students in a MSc program on biotechnology at Chalmers University of Technology, taking a service course in mechanics (almost identical to the course given to students majoring in physics). The students were volunteers from the full class of 35 students, and for the duration of the hour they were in separate rooms, while the students not participating in the study worked in groups in their normal classroom with the same problems, also tutored on the same level. At the time, lecturing on non-accelerated mechanics had just come to a close, and these problems were the last of this kind ‘officially’ considered in class with tutoring. The first of these problems presented the students with the situation of an ox dragging a box. They were asked what forces acted in the situation. Then, they were asked how the forces would be affected if the mass of the box doubled and if the mass of the ox was doubled. The second problem concerned the best choice of angle for a string used to drag a board over rough ground.

Having transcripts of the students’ conversation readily available, we closely followed the supervisory episodes, as well as a few minutes running up to and following the episode where the teacher was present. Initial discussions resulted in a simple model of the episodes, which was used to systematically structure observations in the whole of the material.

Tutor interaction analysis

Having transcripts of the students' conversation readily available, we closely followed the supervisory episodes, as well as a few minutes running up to and following the episode where the teacher was present. Initial discussions resulted in a simple model of the episodes, which was used to systematically structure observations in the whole of the material.

The model we use to structure our analysis of the tutoring episodes can be described by four questions:

1. What happens when the teacher enters? What is the effect on the students' discussion and how does the teacher inform herself on the students' conceptual context?
2. What does the teacher chose to thematise, and on what level, in the main part of the interaction?
3. What characterises the interaction?
4. How is the episode brought to a closure, and what potential does it offer to the students?

By answering these questions for each of our episodes we enable a discussion on alternative paths available to the teacher, which can be considered in practice. By answering these questions for each of our episodes we enable a discussion on alternative paths available to the teacher, which can be considered in practice.

Here we will limit ourselves to consider one episode in part to show some basics of our analysis. In the extract below the students H, I, J, K have been working with the first problem about five minutes, and the teacher (T) enters. The minute before the students have been discussing whether friction (unclear what friction) is the 'driving' force that makes the whole thing move. They are certain there must be a force directed forward, which is larger than the friction on the box when moving at constant velocity.

1. All including T hello [nervous laughter from students]
2. K well, I don't know

3. I this is when one realises how little you know about these things
4. T It looks innocently simple, doesn't it?
5. All yeah, [murmuring]
6. K yeah, we know that there must be a force that it [the ox] affects the box with, ok?
7. H the forces in the rope should be equal
8. I equal
9. H equal in both directions
10. I equal in both directions, yes, but the driving force, wouldn't that be that the ox has larger friction than the box? [3 second pause, T looks troubled]
11. H,I no [Laughter from all including T]
12. T Perhaps you are getting close, somewhere there
13. I We don't want to be close, we want to
14. K ok, we have a...
15. T if we start with the rope, why are the forces equal in the different directions. You do not always discuss, but just claim, have you thought about it?

Looking at this extract, in lines 1-5, the students' discussion is interrupted when the teacher enters, giving small opportunities to listen in on how they have approached the problem. In line 6- 10, the students are asking two main questions to the teacher for affirmation: Are the forces in the rope equal in both directions, are the driving force the friction on the ox?

We can observe several conceptual problems such as where force balance is requested (in the rope, on the ox etc), whether the forces should be equal for constant velocity or there should be a driving force, and what system is considered (the ox and box together, separately, or something else). When the teacher does not confirm the student question (end of line 10), the hint is taken (line 11). The teacher then makes a decision on how to proceed, and on line 15 starts thematising the force balance in the rope on a quite detailed level, similar to a short interactive lecture. She unconsciously chooses to ignore the other possibilities of addressing conceptual problems that was displayed in the student conversation. Further down the line, when the teacher no longer is present, the students initially fail to see the connection between force balance in the rope and force balance in the whole system of ox, box and rope. Only after considerable discussion (approximately 10 minutes), the group starts to recognise what force balance requires in the present problem (that the sum of all forces external to the system should equal zero for constant velocity).

4. Conclusion

Group discussions are influenced by participants previous perception of the problem, which are not always discussed explicitly. In general, the teacher or guide, has one (or more) optimal outcomes of the discussion, which may be more or less conscious. Many different obstacles or impediments may obstruct the intented learning outcome of an exhibit or a problem. A conceptual problem discovered in an informal learning situation can give input to formal teaching. At the same time the formal learning situation offers possibilities of more detailed studies in controlled situations. Analysis of recorded discussions can be helpful, e.g. for the development of strategies to elicit ways of thinking about the exhibit or problem at hand. We point to our questions as guiding points for the reflection of teachers and guides: How can you enter the interaction?, how can you engage the students or visitors? and finally, how do you end the interaction? An essential question is how to be well prepared to meet these situations. This paper aim to give some tools for the prepration to handle choices in relations to these situations. From the analyses in this work we conclude that

- Access to empirical material of the kind presented here is valuable in seeing opportunities for the actions of teachers and guides.
- Essential for facilitating student learning is to discern student conceptual difficulties and it is an advantage to consciously consider alternative actions.
- It is important as a teacher to be informed on common conceptual difficulties on the particular topic taught, e.g. from colleagues, systematic reflection, and literature.

An alliance between formal and informal learning situations can be mutually beneficial.

Acknowledgements

This work has benefited from interesting discussions with our colleague Tom Adawi concerning the Ox and box problem. We also express our appreciation to the students who participated and to Maria Berge and Ann-Sofie Axelsson who played an essential role in recording and preparing the video material that we analysed. Partial financial support for this project has been provided by the Committee for Educational Science of the Swedish Research Council (VR-UVK), and also by the Chalmers Strategic Effort in Learning and Teaching (CSELT).

References

Ash D. (2003)
Dialogic Inquiry in Life Science Conversatsion of Family Group in a Museum, J Res. Science Teaching, **40** 138-162

Bagge S. and Pendrill, A.-M. (2003),
Extramuralt Lärande på Liseberg, Contribution to "Det 7. nordiske forskersymposiet om undervisning i naturfag i skolen", Kristiansand, 15-18 juni 2002

Bennett, J., Lubben, F., Hogarth, S., Campbell, B. (2004)
A systematic review of the use of small-group discussions in science teaching with students aged 11-18, and their effects on students' understanding in science or attitude to science: Review summary. University of York, UK.

Halloun, I., Hake, R., Mosca, E. and Hestenes, D. (1995).
Force Concept Inventory, The test is available, password protected, at modeling.la.asu.edu/R&E/Research.html

Heller, P. and Hollabaugh, M. (1992)
Teaching problem solving through coorperative grouping. Part 2: Designing problems and structuring groups," Am. J. Phys. 60, 637–644, see also http://groups.physics.umn.edu/physed/Research/CGPS/CGPSintro.htm

Heller P., Keith, R. and S. Anderson (1992)
Teaching problem solving through coorperative grouping. Part 1: Groups versus individual problem solving," Am. J. Phys. 60, 627–636

Hestenes, D., Wells, M. and Swackhamer, G. (1992).
Force Concept Inventory, Physics Teacher 30(3), 141-158.

Jacques, D. (2000)
Learning in groups: a handbook for improving group work, Kogan Page, London

Pendrill, A.-M. and Williams, G. (2005)
Swings and Slides, Physics Education, 40, 527-533

Pendrill, A-M. (2008)
Acceleration in school, in everyday life and in amusement parks, accepted for publication in Science Education in the 21st Century (Nova Science Publishers, NY, Ed. Ingrid V. Eriksson)
Springer, L., Stanne, M.E., and Donovan, S. (1999)
Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta analysis, Review of Educational Research, 69(1), 21-51
Waltner, C., Weisner, H., and Rachel, A. (2007).
Physics in context - a means to encourage student interest in physics. Physics Education, 42, 502-507.