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Abstract

The study examines the nature, conditions and outcomes of student learning from an organised guided tour in the German Museum in Munich. The instructional methods that best support student cognitive and affective learning were investigated as well as how students' motivational and emotional states influence their achievement. A sample of 96 secondary school students took part in two different versions of a guided tour on an energy topic. The tours varied in the degree of support of student's active involvement, group work and the variety of general activities offered during the tour. The data collected indicate that both tour versions led to an increase in student understanding of the visit topic to nearly the same extent. However, the version stimulating students' active participation, group work and including a larger variety of activities aroused more positive attitudes. Students of the modified school program showed higher interest and intrinsic motivation, felt more competent and were less bored after the guided tour. In addition, the results suggest that students' visit-related emotional states predict the degree of their post-visit topic understanding, even when demographics and prior knowledge are taken into consideration.

Keywords: museum, learning, attitudes, secondary school, guided tour

Introduction

It is widely recognised that students learn from a variety of sources outside of school classrooms – museums, science centres, biological gardens, zoos and other institutions of informal learning. The nature of learning in informal settings is typically found to differ from classroom-based learning. A pertinent description of the features of informal learning is provided by Wellington (1990) who emphasizes the voluntary, open-ended, learner-led, non-assessed, less structured and more social character of informal learning. School learning, on the other hand, can be characterised as more teacher-controlled, well structured, and compulsory with expected and measurable outcomes.

These distinctions bring with them further informal learning properties frequently mentioned in the museum learning literature: the motivating and engaging character of exhibits (Falk & Dierking, 2000; Gardner, 1991; Griffin, 2004; Griffin & Symington, 1997; Paris, 1997; Russell, 1990), the support of sense of aesthetic appreciation and critical standards (Schauble, Leinhardt, & Martin, 1997), and the promotion of discovery learning (Falk & Dierking, 2000; Griffin, 2004; Griffin & Symington, 1997). Finally, teachers can look at their students from a different angle, in which a classroom 'bad' child may become a museum 'good' child (Falk & Dierking, 1992).

The characteristics of the informal learning location, such as exposure to authentic exhibits, gives informal learning environments a chance to engage students in a way schools never can. However, this is only if the museum educators and developers of the guided tour do not restrict themselves to classroom-like instruction. Therefore, the development of organised school tours has become a challenge for teachers and museum educators as well as the focus of the present study.

We made several methodological changes to a program for secondary school students offered by the German Museum in Munich. Our goal was to find out which kinds of instruction would foster better conceptual understanding of a scientific topic as well as support more positive attitudes towards science and technology – affective learning. The implementation of a quasi-experimental repeated measures design allowed us to investigate how specific motivational and emotional states influence student achievement in an informal learning setting.

Conceptual framework

Despite the previously described differences, museum and classroom-based learning have in common that students are expected to make gains in their understanding of the topic in both environments. The majority of studies indicate that visits to museums or other informal educational institutions lead to knowledge gained by schoolchildren (Bamberger & Tal, 2006; Gilbert & Priest, 1997; Lucas, 2000; Mortensen & Smart, 2007; Tuckey, 1992) as well as adults (Falk & Storksdieck, 2005; Falk & Adelman, 2003; Stevenson, 1991). Informal learning is also known to have 'a staggering degree of effectiveness' in arousing positive attitudes toward science and technology or in other words, affective learning (Russell, 1990, p. 260). The motivational aspect of field trips can be referred to as a 'unique type of self-motivating learning' (Rennie & McClafferty, 1995, p. 179). Wollins, Jensen, and Ulzheimer (1992) found out that children's most extensive memories were related to the emotional rather than the cognitive component of their visit. Another study of primary school children visiting the UK National Space Centre determined an immediate although transient increase in children's interest in and respect for space and science as well as a long-term drop in schoolwork-related anxiety (Jarvis & Pell, 2005).

Having acknowledged that museum visits contribute to learning, the further challenge is to discover which factors enhance or inhibit knowledge acquisition. Previous research has shown that they include student individual characteristics, environmental settings (lighting, temperature, crowdedness etc.), and exhibit design (Falk & Dierking, 2000). The most frequently mentioned are visitor's motivation, prior knowledge, degree of choice and control over the visit, and the amount and quality of student communication during the visit. These influential factors, grouped within personal, social and physical contexts, have been organised into a theoretical framework – the Contextual Model of Learning – by Falk and Dierking (2000). Several factors in the personal context that are relevant for the present study are reviewed in the following.

Visitor's prior knowledge. The influence of prior knowledge on museum learning has been widely examined (Beiers & McRobbie, 1992; Falk & Adelman, 2003; Falk & Storksdieck, 2005; Lucas, McManus, & Thomas, 1986; Tully & Lucas, 1991). Most researchers agree that prior knowledge seems to support learning in museums. Tuckey (1992) in her interview-based study of primary school pupils in an interactive science centre concluded that while museum exhibits can increase understanding, they appear to not be able to teach unfamiliar concepts. Thus, a certain level of prior knowledge is desirable for learning to occur. Beiers & McRobbie (1992) also found prior knowledge to be important in their study of seventh graders visiting a sound section of an interactive science centre. Similar findings were reported in terms of the role of prior experience in learning from informal sources: In a study by Tully and Lucas (1991), interactive science centre visitors were asked to assemble and reassemble a lock. The procedure was videotaped and the participants were randomly interviewed afterwards. The results indicate that the group of visitors, who watched others trying to assemble the lock before they attempted, had a significant advantage over those who didn't have the prior experience of watching.

Visitor's motivation and expectations. People have different reasons for attending museum or science centre exhibitions as well as expectations for those visits. The impact of a visitor's motivation and expectations on learning is dependent on individual factors such as prior knowledge or interest. Falk and Storksdieck (2005) studied learning of different motivation groups, which either had the intent to entertain family or friends, to learn about the world, or to have a good time. Learning of motivation groups was examined with respect to varying degree of prior knowledge and interest. The results indicate that motivation to entertain with friends or family was positively correlated with learning in the case of low prior knowledge and high interest. The motivation to learn about the world was associated with learning in case of high prior knowledge and high interest. The motivation of having a good time did not show any positive connection to learning. Surprisingly, in contrast to school learning, little research has been conducted on the impact of intrinsic versus extrinsic motivation on achievement in informal learning settings. Nevertheless, as intrinsic motivation is considered to be a reliable predictor of school success (Parkenson, Lomax, Schiller, & Walberg, 1984; Schiefele & Schreyer, 1994; Uguroglu & Walberg, 1979), we assume that it should be related to museum learning as well.

Visitor's emotions. In terms of emotions, the majority of studies about museum learning only examine enjoyment and interest (e.g., Falk & Adelman, 2003; Henderlong & Paris, 1996; Rennie, 1994). Only a little research on other emotions experienced during a museum visit has been conducted and was focused on either emotional components of knowledge such as awareness, personal attitudes, or concerns about the topic (Adelman, Falk, & James, 2000) or exhibit arrangements as determinants of visitor emotions from a marketing and consumer satisfaction perspective (Caldwell, 2002; Legrenzi & Troilo, 2005). A large amount of other learning emotions, especially negative ones like boredom or anger, and their relation to learning in the context of a museum visit is left unnoticed. Empirical studies suggest that learning-related emotions such as anxiety, fear, boredom, anger, and others are indirectly – through learning strategies and attention – and directly related to school success (Derryberry & Tucker, 1994; Isen, Daubman, & Nowicki, 1987; Pekrun & Hofmann, 1999; Trope & Pomerantz, 1998). Even though docent-led museum visits can be to a certain extent compared to school learning, not all achievement emotions listed above would influence learning success during museum visits. We suggest that among negative achievement emotions, boredom and anger would be more influential in free-choice settings than anxiety or fear that are rather associated with school-related assessment situations.

Obviously, the most important factor influencing learning from organised school group visits is the educational program designed for the schools (Falk & Dierking, 1992). As groups visiting museums or other informal learning settings have been the subjects of numerous studies (e.g., Griffin, 2004; Kisiel, 2006; Rennie, 1994), various recommendations for the optimization of school visits can currently be found in the museum learning literature. The most frequently mentioned ones are summarised below:

- Use a variety of activities targeting the different sensory modes (reading, listening, using maps etc.) (Falk & Dierking, 1992; Price & Hein, 1991).

- Offer well-designed group worksheets: worksheets should represent a basis for post-visit activities, include meaningful questions directed toward exhibits themselves, include different types of questions, present questions in an easy to handle format, provide orientation clues about where the information can be found, and support social peer interactions (Kisiel, 2003; Krombaß & Harms, 2008; Mortensen & Smart, 2007; Price & Hein, 1991; Wilde & Urhahne, 2008).

- Provide an appropriate level of structure: experimental research indicates that most learning occurs when there are no extremes in choices and control over the visit; successful school programs should include some structure and scaffolds in the student activities but also schedule some time for free exploration (Wilde, Urhahne, & Klautke, 2003).

- Encourage group work: topic-relevant social interactions, especially in dyads, support children learning on school field trips (Borun, Chambers, & Cleghorn, 1996; Matsusov & Rogoff, 1995; Tuckey, 1992).

- Promote interactions with docents: the guides are recommended to provide cues by asking questions to help students to concentrate on significant aspects of the material (Martin, Brown, & Russell, 1991).

- Use advance organizers and pre-orientation activities extensively: providing students with information about the museum building, the exhibition nature, floor plan, purposes of the excursion as well as telling students how the content is related to their school curriculum (Anderson & Lucas, 1997; Burnett, 1996; Falk & Balling, 1982).

- Reinforce classroom-based follow-ups: arranging subsequent reinforcing events after the visit (correction of the worksheet or trip-based tasks in the classroom) and making connections to the school curriculum is crucial for ensuring long-term impact of museum visits (Anderson, Lucas, Ginns, & Dierking, 2000).

Several of these recommendations focusing on encouraging active student participation, group work, increasing the variety of activities and sensory modes were applied to the school program 'Energy forms and their use' within the present study. Besides this, the impact of specific motivational and emotional variables on student achievement was analysed. The study hypotheses are formulated as follows:

1) While contents of the school program remain unchanged, both programs should contribute to cognitive learning approximately to the same amount.

2) The modified school program leads to higher intrinsic motivation, improves situational interest, enhances perceived competence, and reduces negative emotions more than the original guided tour.

3) What is the meaning of motivational and affective states in museum learning? We assume that student motivation and emotions can explain student learning outcomes over and above student demographics and prior knowledge.

Method

Participants

The study was conducted with four 8th and 9th grade secondary school classes, consisting of a total of 96 students from Munich and the surrounding areas. Two randomly selected classes (42 students) constituted the control group and the other two (54 students) the experimental group. The students' age ranged between 13 and 16 with the mean of 14.14 (*SD* = .83) years and was nearly the same across the classes. Fifty-four percent of the sample were males. Groups were fairly homogeneous in terms of prior knowledge as shown by t-test for independent samples, $t(94) = -1.17$, n.s.

Setting

The study took place at the German Museum in Munich, which is one of the biggest world science museums. The German Museum promotes public understanding of science by offering a large collection of operational technology, science-related exhibits as well as interactive elements like push buttons or participatory experiments.

The museum has an excellent educational department that focuses on guided tours for schools, which is also the focus of the present study. The school programs were developed within the educational department of the German Museum. The programs are offered to all types of schools ranging from primary school to gymnasium, the German equivalent to English grammar school. The duration of a typical school program is about two hours and includes a practical section.

The present study focuses on the program 'Energy forms and their use' for 7^{th} to 9^{th} grade secondary school students. The program's content covers different power machines as well as the development of the use of energy sources. The program was designed to fit the school curriculum: the topics energy, power, capacity etc. are discussed in the eighth grade. The program begins with the oldest machines that used human and animal muscle power, then continues with windmills and waterwheels used in the Middle Age as well as steam engines from the eighteenth century. Finally, the classes are guided to the new energy sources department, where students learn about how energy is produced nowadays, which technologies are used, and which are more efficient and environmentally friendly. Students participating in the program usually spend about two hours in the German Museum with about half of the time allocated for the power engines section and another half for the new energy sources section. The power engines gallery houses mostly large size exhibits, including wind- and waterwheels as well as steam engines, whereas the new energy sources gallery contains more information tables, diagrams and computer information systems.

Instruments

Knowledge. Following the recommendations of other studies about learning in out-of-school settings (Falk & Storksdieck, 2005; Rennie, Feher, Dierking, & Falk, 2003; Rennie & McClafferty, 1996; Rennie & Williams, 2002), multiple instruments were employed to assess changes in student understanding of the program's topic. The assessment procedure was based on two different assessment tools: Personal Meaning Mapping and a multiple-choice test.

Personal meaning mapping (PMM) is a relatively new approach to assessing knowledge gains about a topic over time (Falk & Storksdieck, 2005). It asks the participants to brainstorm a concept or a topic and put everything down that comes to their mind in relation to this topic. Then, the individuals are encouraged to explain why they wrote what they did to an interviewer with the goal to open up individual's conceptual framework about the cuing word. The PMM allows measuring individual's conceptual change along four dimensions – extent (changes in the number of appropriate words), breadth (changes in the number of conceptual categories used), depth (changes in degree of understanding within each breadth category) and mastery (overall assessment of changes in individual's understanding). We adapted the original method of PMM to our study's time and setting constraints: the procedure was restricted to recording words or phrases associated with the cuing word and thus measuring the extent of changes in the number of appropriate words. The children were given about one minute to complete the PMM on the topic 'energy'. Then, the appropriate words recorded by the children were counted. These words fall within the category "energy as scientific concept" and do not include individuals' subjective associations like physics teacher name or similar. As the "extent" dimension of the PMM method reflects "the most basic aspect of an individual's understanding of a concept or topic" (Falk & Storksdieck, 2005, p.752) student answers were given a smaller weight (0,5 points for every word) in the total knowledge score. Giving students one point for every correct word would have inflated some students' PMM scores.

A multiple-choice instrument consisting of 11 questions was especially developed for this study. The multiple-choice measure was chosen due to time constraints; after the tour, the students are usually tired and motivated to fill in only a short multiple-choice test. The questions were related to the exhibits, the content of the tables and diagrams, and what the guide said. The questions were directed at either factual knowledge or conceptual knowledge. Factual knowledge questions asked for specific details or elements of the exhibition, while conceptual knowledge questions targeted at scientific principles or generalizations (Anderson & Krathwohl, 2001). A sample item for factual knowledge is: 'When was the first steam engine constructed?' a. Beginning of 18th century (correct), b. Beginning of 19th century, c. Beginning of 17th century, d. Beginning of 20th century. This item requires retrieving from memory a fact about the history of steam engines. Conceptual knowledge was measured with items like: 'What can the functioning of a steam engine be compared with?' a. cooking pot, b. air pump (correct), c. bicycle, d. steam iron. This item requires understanding of a steam engine's functioning and is targeted at scientific principles understanding.

The validity of the knowledge test was established through consultation with the museum educational and university staff. The museum educational staff helped in controlling the content of the test. They checked for scientific correctness of items and avoidance of ambiguity in wording. Furthermore, a pilot test was done on a group of university students, who also checked for the clarity of the questions and the approximate completion time. The item difficulty indexes in the pre-test were between 20% and 80% for all items. Each correct answer on the test was scored with 1 point, except for one item where multiple answers were possible and 0.5 point was given for each.

Finally, to obtain an overall knowledge score, the points obtained in both the PMM and the multiple-choice test were summed together. To establish the change in knowledge from pre- to post-test, the knowledge measurement procedure was not changed and was applied after the visit in the same order.

Motivation. Many activities in museums can be described as intrinsically motivating because visitors take part in these activities for their own sake. A visitor's perception of competence, which is nurtured by the belief of being able to exert control over the environment and fulfil task requirements, influences their engagement in activities. For measuring intrinsic motivation and perceived competence short scales from the Intrinsic Motivation Inventory (IMI) by Deci and Ryan (2008) were applied. The variables were measured by three items each on a 5-point Likert scale ranging from 1 - 'not at all true' to 5 - 'totally true'. Reliabilities and sample items of these scales are given in Table 1.

Please insert Table 1 about here

Positive emotions. The momentary state of being interested in a museum task or activity can be labelled as situational interest (Krapp, Hidi, & Renninger, 1992). The frequent stimulation of situational interest should in the long term lead to a stable interest disposition. The measure used for evaluating situational interest was taken from the Perceived Interest Questionnaire (PIQ) developed by Schraw, Bruning, and Svoboda (1995). This questionnaire was originally designed for assessing student interest in literary texts and provided a general measure of situational interest in the content and events described by the text. The wording of initial item set of PIQ was slightly modified to suite the setting and purpose of the present study. In order to see if the school program satisfied students' desires and demands, a second positive emotion was considered. The satisfaction scale provided a measure of general visit satisfaction and was especially developed for this study by the authors. The satisfaction scale items and statistical parameters are presented in Table 2.

Please insert Table 2 about here

Negative emotions. Modified extracts of the Achievement Emotions Questionnaire – Mathematics (AEQ-M) developed by Pekrun, Goetz, and Frenzel (2005) were applied to measure negative emotions associated with the visit. AEQ-M is a multidimensional self-report instrument designed to assess student emotions (enjoyment, pride, anger, anxiety, shame, hopelessness and boredom) in different learning-related contexts (attending the class, studying and doing homework, and taking tests and exams). Since among the three learning contexts, the classroom is the most similar to museum learning, three anger and three boredom items from the respective section of the AEQ-M were selected to assess negative emotions related to learning in a museum. For all emotions, 5-point Likert scales were used as a means to indicate emotional impressions. Reliabilities and item examples of the measured emotions can be found in Table 1.

Treatment

The program 'Energy forms and their use' is a two-hour guided tour through the power machines and modern forms of energy use sections. The program begins with greetings and introductory words from the guide. Then, self-selected student groups (2-3 students in each) are given 15-20 minutes to explore and complete a three-page worksheet. Each page of the worksheet refers to a subsection or sub-theme of the power machine section: waterwheels, windmills and steam engines. Altogether, the worksheet contains 15 open-ended questions that the students are supposed to answer using information from the labels and their own observations. After this exploratory phase, the program continues with the guided tour, during which the exhibits included in the worksheets are discussed first. The class is then taken to the new energy sources department. This second part does not include any group work; rather the program is continued in a docent-led manner.

Please insert Table 3 about here

Taking into account the recommendations for developing school programs, the original program's design was modified in the following ways. After the greeting and introductory words, students were divided into groups that were kept constant through the whole program. The groups were not self-selected, rather nominated by a simple procedure: the students each took a piece of candy from a bag and those with the same colour formed a group. This nomination procedure was chosen in order to increase group diversity, give students the possibility to work with students they usually do not work with and avoid the concentration of 'troublesome' students in the same group. After this, as in the original program, students were given 15 to 20 minutes time to complete the worksheets in their nominated groups. The worksheets, however, were modified: taking into account the recommendations concerning the question format (Wilde & Urhahne, 2008), open questions were replaced by multiple-choice ones. The correct answers to the worksheet questions led, as in a puzzle, to a 'solution' word. The new worksheets included ten questions and covered the waterwheels and windmills sections. In addition, students were told that their group would be given a point for every right solution word. The points for all group activities were accumulated and a winning group was determined. After the completion of the worksheets, the guide, as in the original program, presented the exhibits to the students in more detail. After the docent-led phase, the students as a group had put together a paper-puzzle representing the most important parts of the first steam engine developed by Newcomen, as well as to name these parts correctly. This activity was scheduled in the middle of the program to give the students a break from passive listening and compensate for not including steam engine-related questions on the worksheet. Afterwards the class was taken to the new energy sources department, where the docent-led tour was combined with a quiz. The guide asked different multiple-choice questions that were also presented on a flip chart and after a short reflection time, the groups were told to provide their answers. Each question was then accompanied by the guide's short analysis of the students' answers and clarifications. At the end of the program, the groups' points were accumulated and the winning group was congratulated. However, no prize was awarded so that the joy of receiving the prize would not interfere with the enjoyment of the program due to the methodological changes. All changes to the program were methodological, the program's content or duration was not changed. An overview comparing the two programs is provided in Table 3, whereas Table 4 summarizes the new elements of the program and relates them to the recommendations for designing a successful program mentioned in museum learning research.

Please insert Table 4 about here

Procedure

The impact of the methodological changes in the school program 'Energy forms and their use' was assessed on the basis of quantitative tests by using a repeated measures design with an experimental and a control group. The pre-test addressed only topic-related knowledge, whereas the post-test encompassed both knowledge and attitudes. The following affective variables were included in the post-test: intrinsic motivation, situational interest, and perceived competence for the visit, satisfaction with the visit, visit-related boredom and anger. In order to control for the effect of possible intervening variables, demographic data such as age or gender were also collected.

All the measurements took place on the day of the visit. After arriving in the museum the classes were led to the museum's coat check hall (equipped with enough chairs), where the students filled in the knowledge pre-test questionnaire. The knowledge post-test and affective variables questionnaires were filled in directly after the visit. The complete assessment procedure was about 30 to 40 minutes in length.

Results

Participation in both programs resulted in student knowledge gains. Table 5 indicates that in the case of the experimental group all knowledge measures applied yielded significant gains from pre- to post-test. Whereas the control group showed significant knowledge gains only as measured by the multiple-choice test alone and in combination with the PMM.

Please insert Table 5 about here

As predicted by our first hypothesis, both programs contributed to student learning about the energy topic to nearly the same extent. As can be seen in Table 6, the comparison of the overall knowledge level change from pre- to post-test yielded no significant difference between the treatment groups. This, however, did not apply to the sub-test level: the experimental group showed significantly better learning results on the PMM part of the test, whereas the control group – on the multiple-choice test (see Table 6).

Please insert Table 6 about here

In the second hypothesis, it was assumed that the modification of the school program would have a positive impact on students' attitudes towards museum learning. The comparison of the treatment groups in terms of affective learning in Table 7 indicates that the students in the experimental group were significantly more intrinsically motivated, found the visit more interesting, felt themselves more competent in relation to program tasks and were less bored than the control group. As can be seen from the results in Table 7, the experimental group was also more satisfied with the visit and experienced less anger than the control group – both findings were however not significant.

Please insert Table 7 about here

In order to test the third hypothesis, the correlations between cognitive and affective variables for both treatment groups together were analyzed. First, the Pearson correlations in Table 8 reveal that knowledge post-test results correlated most strongly with knowledge pre-test scores, which suggests a positive impact of prior knowledge on learning outcomes. Somewhat weaker, but still significant correlations were detected between knowledge post-test scores and anger, age and satisfaction. This means that students tended to score higher on the knowledge post-test if they already had some knowledge on the visit topic, experienced minimal anger during the visit, and were older and more satisfied with the program.

Please insert Table 8 about here

It was assumed in hypothesis 3 that student motivation and emotions contribute to learning outcomes when prior knowledge and demographic information are taken into consideration. By means of a hierarchical multiple regression analysis the effects of prior knowledge, demographic and affective variables on the knowledge post-test score were determined. The multicollinearity diagnostics revealed that the variance inflator factor (VIF) for all predictor variables was below 1.0, which according to Kleinbaum, Kupper, and Mueller (1988) indicates that there was no multicollinearity between the predictor variables. To minimize the possibility of suppression effects, only the variables that were found to correlate with the criterion variable were considered in the regression analysis. This led, e.g., to the exclusion of boredom (see Table 8). The independent variables were introduced into the model in three steps. In order to control for a possible effect of demographic variables, age was entered first. In the second step, prior knowledge as measured by the pre-test knowledge scores was entered into the regression equation. In the third step, the affective variables satisfaction and anger were introduced into the model. The overview of the introduced variables and the results of multiple regression analysis are presented in Table 9. The proposed model yields three significant predictors explaining 25 percent of the variance of the knowledge post-test scores ($F(4, 85) = 6.91$, $p < .001$). The two strongest predictors are student age ($\beta = .31$, $p < .01$) and prior knowledge ($\beta = .31$, $p < .01$), followed by anger ($\beta = -.24$, $p < .05$). The direction of the relationship suggests that being older, having more prior knowledge and having experienced less anger during the visit significantly contribute to learning.

Please insert Table 9 about here

In addition, including affective variables into the model in the third step improved the overall model fit (the amount of explained variance raised by 7%). Thus, as expected by our third hypothesis, emotional variables, and namely, anger, explains some variance in student post-test knowledge score over and above student demographics and prior knowledge.

Discussion

The present study contributed to museum learning research in several ways. First, it provided further evidence of student cognitive learning from organised museum

visits. Second, it established that the frequently mentioned recommendations in the museum research literature, such as providing more opportunities for group work or supporting active student participation, can significantly improve student motivational and emotional states during the visit and are successful in promoting student understanding. Third, the results provide further insights into factors influencing student museum learning: thus, specific emotional states, and namely, anger experienced during the visit, were found to explain student learning outcomes when other previously established predictors are considered.

The comparison of the effects of two quite different instructional strategies on student affective learning indicates that providing more room for socialization, introducing activities involving various sensory modes as well as supporting student active participation were more beneficial in terms of student attitudes: the modified guided tour increased student intrinsic motivation and perceived competence, and was seen to be more interesting and less boring than the traditional docent-led tour. We believe that the modifications to the program fulfilled their purpose in making the visit more enjoyable and enhancing students' positive attitudes towards science and technology, which is the primary goal of informal learning institutions (Russell, 1990). Increasing students' positive attitudes toward science and technology museums is especially important during the adolescent age, as teenagers are generally not very excited about museum field trips – a regrettable fact, since museums are increasingly recognised to possess a very wide range of relevant resources. Therefore, the program modifications that increase students' positive attitudes and motivation to take part in further museum visits would contribute to enhancing students' learning of science in the long run.

As the content of the program was not changed, the modified program had the same impact on learning as the original school program. However, there were some noteworthy differences between the treatment groups at the sub-test level. The control group improved their knowledge significantly more as measured by the multiple-choice test, whereas the experimental group showed higher gains in Personal Meaning Mapping. An explanation to this could be that the control group received most of the information from the guide. The experimental group, in contrast, acquired their knowledge mainly from group work, free exploration and active participation during most phases of the museum visit. This might have enabled them to construct meaning on the basis of their prior knowledge, recall the newly acquired information more easily and consequently, reproduce more energy-related concepts in the Personal Meaning Mapping. The increase of topic-related vocabulary in the PMM extent dimension can be regarded as a sign of improved understanding (Falk & Storksdieck, 2005). However, as only a short PMM version was used to capture students' meaning construction, the results have to be interpreted with care and need further validation.

The findings on individual factors determining student learning from organised museum tours generally support those of past studies (Beiers & McRobbie, 1992; Tuckey, 1992) in that student prior knowledge contributes to better understanding of the visit topic. This finding can be explained from the constructivist perspective on knowledge acquisition, which says that the new knowledge is generated on the basis of existing knowledge through assimilation and accommodation (Driver, 1989). Besides prior knowledge emotional factors like anger, can explain some variance in student learning. In the past, negative affect was rarely examined in museum learning research. It is not considered within the Contextual Model of Learning and has hardly been examined among the factors influencing museum learning. This may be traced back to the original free-choice nature of informal learning: museum visitors engage on their own free will and in most cases can leave whenever they want. The situation with class visits is quite different: Children do not always willingly attend museums and offering them worksheets to fill in does not usually cheer them up. Even on unstructured free exploration fieldtrips, children do not have as much free choice as adults usually have and, thus, are more likely to become subjects to anger and other negative emotions. For example, in the original program the strongest emotion experienced by the students was boredom. Consequently, negative affect should be taken into account while considering factors influencing learning during class visits and a high priority for teachers and museum educators should be finding ways to reduce it.

The study's limitations consist of a relatively large number of methodological changes applied to the school visit, which may preclude us from telling what exactly accounts for the students' enhanced motivation and enjoyment: new worksheets, a fun quiz or doing a steam engine puzzle? Multiple changes, however, were necessary to make a large impact on student experiences in the open learning environment of a science and technology museum. If only one detail of the guided tour had been changed, it is likely that random noise would impede us from detecting its effect on student learning. However, all the changes made were aligned in a general overarching theme: enhancing variety in proposed activities and supporting student active participation. Therefore, it is possible to conclude that instructions sharing these qualities would contribute to heightened attitudes.

Further research should concentrate on the analysis of the long-term impact of organized museum visits on student learning, motivation and emotions, as Rennie et al. (2003) suggest. It would be of interest to find out if the established positive impact on student attitudes is of long-standing nature and can be measured even weeks later. Museums are recognised to have potential of eliciting lasting impressions and long-term memories that stand the test of time. These impressions and memories can be used as a basis for integrating museum experiences in the school curriculum. For example, a museum visit can be used to introduce a new scientific topic to a class.

Other challenges pertain to developing new analytical methods that would enable the investigation of the process of learning per se. Interviews, think-aloud protocols, or video studies have the potential to explore learning from a learner's perspective and thus, give an even better understanding of instructional modifications in guided museum tours. Obviously, investigating informal learning is connected to a number of challenges that we encourage future research to examine. The potential benefit of museums offering better guided tours that enhance the students' attitudes and understanding, is worth the effort.

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Table 1.

Scales used in the study to measure motivation and emotions

Scale	Items	Sample item	Cronbach's α
Intrinsic motivation	3	The guided tour in the museum was fun to me.	.86
Perceived competence	3	I think I was fairly good at the tasks in the museum.	.85
Situational interest	6	This guided tour is one of the best that I have ever taken part in.	.87
Satisfaction	4	I am very satisfied with the guided tour.	.84
Anger	3	I was angry that I had to attend the guided tour.	.77
Boredom	3	To tell the truth I found the guided tour boring.	.92

Table 2.

Satisfaction scale

Item	*M*	*SD*	r_{it}
All in all, the guided tour ran well.	3.00	1.11	.67
I felt well during the guided tour.	2.60	1.31	.65
The atmosphere in the exhibition was pleasant.	3.08	1.30	.67
I am very satisfied with the guided tour.	2.57	1.24	.70

Note. r_{it}: item-total-correlation

Table 3.

Comparison of original and modified school program

Original program	Modified program
Self-selected groups	Nominated groups
Open-ended worksheets	Multiple-choice worksheets with solution word
Guided tour in the power machines section	Guided tour in the power machines section
No puzzle	Steam engine puzzle
Guided tour in the new energy sources section	Quiz questions with guide clarification in the new energy sources section

Table 4.

Research recommendations implemented in the modified school program

Research recommendation for designing school programs	Corresponding elements of the modified school program
Support group work and socializing activities - Borun et al., 1996 - McManus, 1988 - Cox-Peterson, Marsh, Kisiel, & Melber, 2003 - Price & Hein, 1991	Group activities are provided through the complete program, not only at the beginning
An appropriate level of structure: instructional-constructivist-oriented learning environment - Bamberger & Tal, 2006 - Wilde et al., 2003	Combination of guided tour with group work Worksheets including a free-choice element (not every question has to be answered to get the solution word)
Variation in activities during the visit and in sensory modes used - reading, listening, practical work etc. - Falk & Dierking, 1992 - Price & Hein, 1991	Listening to guide's explanations Reading labels and worksheets during group work Talking for answering guide's questions and during group work Practical fine-motor skills during the steam engine construction puzzle
Encouraging interactions with docents in guided tours by means of questions - Martin et al., 1991 - Price & Hein, 1991 - Russell, 1990	The guide stimulated students' participation using the quiz questions

Table 5.

Comparison of knowledge pre- and post-test results of experimental and control group by t-tests for paired samples

	Pre-test		Post-test				
	M	*SD*	*M*	*SD*	*t*	*df*	*p* <
Control group							
PMM	2.73	.92	2.84	1.32	.49	41	*ns*
Multiple Choice	4.99	1.83	6.90	1.88	7.52	41	.001
Overall	7.71	1.85	9.74	2.55	5.89	41	.001
Experimental group							
PMM	2.54	.96	3.17	.95	4.28	53	.001
Multiple Choice	5.66	1.47	6.65	1.73	3.62	53	.001
Overall	8.19	2.09	9.81	2.01	4.71	53	.001

Note. PMM: Personal Meaning Mapping.

Table 6.

Comparison of knowledge gains of experimental and control group by t-tests for independent samples

	Experimental group		Control group				
Knowledge test	*M*	*SD*	*M*	*SD*	*t*	*df*	*p* <
PMM	.63	1.08	.11	1.45	2.01	94	.05
Multiple Choice	.99	2.01	1.92	1.65	2.41	94	.05
Overall	1.62	2.23	2.03	2.53	.82	94	*ns*

Note. PMM: Personal Meaning Mapping.

Table 7.

Comparison of attitudes of experimental and control group by t-tests for independent samples

	Experimental group		Control group				
Scale	*M*	*SD*	*M*	*SD*	*t*	*df*	*p* <
Intrinsic Motivation	2.65	1.18	2.19	.80	2.22	92	.05
Perceived Competence	3.92	.91	3.15	.91	4.11	92	.001
Situational Interest	2.55	1.10	2.15	.75	2.10	92	.05
Satisfaction	2.91	1.11	2.69	.93	1.01	90	*ns*
Anger	2.48	1.23	2.67	1.10	.79	93	*ns*
Boredom	3.28	1.38	3.89	1.19	2.26	92	.05

Table 8.

Zero-order correlations of cognitive, affective and demographic variables

Variable	Knowledge pre-test	Knowledge post-test	Intrinsic motivation	Perceived competence	Situational interest	Satisfaction	Anger	Boredom	Age	Gender
Knowledge pre-test	—	.37***	.12	-.00	.19	.19	-.23*	-.15	-.05	-.22*
Knowledge post-test		—	.16	-.05	.02	.21*	-.26*	-.08	.25*	.04
Intrinsic motivation			—	.39***	.74***	.68***	-.59***	-.69***	-.13	-.13
Perceived competence				—	.32**	.35**	-.10	-.22*	-.13	-.18
Situational interest					—	.73***	-.49***	-.59***	-.15	-.24*
Satisfaction						—	-.50***	-.57***	-.08	-.09
Anger							—	.70***	.21*	.03
Boredom								—	.21*	.21*
Age									—	.04
Gender										—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$; Gender-coded: 0 - female, 1 - male.

Table 9.

Hierarchical multiple regression analysis on knowledge post-test scores

	Knowledge overall post-test scores			
	B	*SE B*	β	ΔR^2
Step 1: Control variables				.046*
Age	.58	.28	.21*	
Step 2: Cognitive variables				.134***
Age	.71	.27	.26*	
Prior knowledge	.42	.11	.37***	
Step 3: Affective variables				.066*
Age	.83	.26	.31**	
Prior knowledge	.35	.11	.31**	
Satisfaction	.03	.06	.05	
Anger	-.15	.07	-.24*	
Total R^2				.245***

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.