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Advancing Informal MINT Learning: Preparation and Novelty at a Mobile Laboratory

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Abstract

Over the past 20 years, mobile laboratories and science centers have become part of many science education programs around the world. Designed to pique the interest of youth in science and technology (S&T) topics and careers, these programs are popular among teachers, parents and pupils. However, mounting evidence suggests that pupils experience little or no change in their attitude towards S&T through an experience with these out-of-school learning places (OLSePs), indicating that investigations need to dig deeper into impact factors for program success.

The mobiLLab high-technology learning laboratory was developed at the University of Teacher Education in St. Gallen. Through a background investigation, mobiLLab researchers and faculty identified priority factors for investigation. The focus of the study was to explore how classroom preparation, teacher attitude and pupil novelty affect S&T outcomes, which were defined as S&T interest, attitude and self-concept. A mixed-methods pilot investigation was designed to explore the question, How do differences in pre-visit activities and pupil novelty space explain variations in pupils' S&T outcomes at a mobile laboratory? and the sub-question, To what degree do teachers' attitudes moderate these variations? Investigators adapted a research framework from Orion and Hofstein's [1, 2] novelty space theory. The modified mobiLLab novelty space triangle framework captures several factors thought to most influence pupils' mobiLLab experience: whether they explore or seek direction to work with technology (capability dimension), previous experiences with informal learning programs (setting dimension), and previous related S&T knowledge (cognitive dimension).

The spring 2014 pilot study involved 9 teachers and 208 pupils, who completed pre- and post-visit surveys. Investigators also observed mobiLLab school visits and conducted teacher interviews. Like other existing studies about OSLePs, t-test results indicate that pupils experienced little, if any, change in their S&T outcomes between pre- to post-visit surveys. MANCOVA test results suggest that gender, previous experience with OSLePs, and pupils' exploratory behavior are strong predictors of pupils' overall S&T outcomes. Changes in pupils' S&T outcomes from pre- to post-visit surveys could be explained by pupils' exploratory behavior and differences in classroom preparation time. Similarly, teacher interviews indicate that pupils' comfort and familiarity with mobiLLab experimental equipment affects their ability to profit from a mobiLLab visit. Perceived teacher attitude about S&T was not found to have a significant effect on pupils' S&T outcomes. A detailed presentation of pilot results will be followed by discussion of the main study design, which focuses on dispositional 'trait' and at-visit 'state' novelty factors.

1. Introduction

Too few young people in western countries who show talent in science and math are completing university degrees in these disciplines and choosing related careers, causing a shortage of high technology and industry workers and raising concerns about their science literacy [3-5]. The ROSE report [3] explains: "These negative attitudes may be long-lasting and in effect rather harmful to how people later in life relate to S&T as citizens." Resource-poor Switzerland is especially vulnerable to this trend, as it is lacks not only raw materials but also qualified, motivated workers who can maintain healthy economic development through their talent and innovation.

Existing studies show that while visits with science centers and mobile laboratories sometimes result in positive changes in pupils' science and technology (S&T) interest and knowledge immediately after a visit, changes fade after one or two months [6-12]. Investigation of the effectiveness of these programs should dig deeper into possible impact factors uncovered by these studies, such as classroom preparation.

2. Identifying priority factors for investigation

The mobiLLab high-technology mobile learning laboratory was developed at the University of Teacher Education in St. Gallen (Pädagogische Hochschule St. Gallen (PHSG)). Created to support the PHSG strategy to promote interest in MINT (Math, Informatics, Natural science, Technology) careers among Switzerland's youth, the mobiLLab program brings experiments to secondary schools in the German speaking part of Switzerland. During a typical visit, 13- to 16-year-olds spend a morning or afternoon at 4 of 12 experimental posts, at which they work in pairs with no frontal instruction. To identify factors for investigation, PHSG researchers conducted a qualitative background investigation [13], which involved a literature review and interviews with mobiLLab faculty, staff, teachers, pupils, and leaders of similar programs worldwide. Results showed that the main desired mobiLLab program outcome is to promote youth's S&T interest, or an "attitude of awareness, affinity and curiosity about science and technology." A short list of impact factors was also identified. Drawing from these results, researchers selected impact factors of classroom preparation, pupil familiarity/novelty, and teacher attitude, and defined pupil S&T outcomes as interest, attitude and self-concept. A mixed-methods investigation was designed to explore the questions, 'How do differences in pre-visit activities and pupil novelty space explain variations in pupils' S&T outcomes at a mobile laboratory?' and 'What moderating role do teachers' attitudes play?'

3. Developing a framework for studying novelty at high-technology OSLePs

Existing studies of out-of-school learning places (OSLePs) suggest that unfamiliarity, or novelty, can be a barrier to learning and interest development [2, 14-16]. A framework for investigating novelty was developed by Orion and Hofstein [1, 2], who identified three factors that define the "novelty space" of pupils on a field trip. The main hypothesis of their three factors model was that the more familiar pupils are with the knowledge required (*cognitive* aspect), the field trip area (*geographical* aspect) and the kind of event (*psychological* aspect), the more productive the field trip experience will be. They describe the importance of preparation and other related factors for reducing novelty space.
However, these existing studies about novelty and OSLePs investigate outdoor field trip experiences and do not address the particular case of a high-technology learning laboratory. Therefore, a modified novelty space model was developed based on three factors thought to be most influential on pupils' mobiLLab experience: whether they explore or seek direction when working with technology (capability dimension), previous experiences with OSLePs (setting dimension), and previous S&T knowledge (cognitive dimension).

4. Methods

Pilot data collection in spring 2014 involved 9 teachers and 15 of their class groups who experienced a mobiLLab visit. All nine teachers and 208 pupils completed pre- and post-visit surveys and investigators conducted mobiLLab school visit observations and interviews with all 9 teachers. Pupils responded to survey items about S&T in general and the mobiLLab program using a scale of "1"=completely untrue ("*stimmt gar nicht")*, "2" = somewhat true *("stimmt wenig*"), "3" = very/quite true ("*stimmt sehr"*), "4" completely true *("stimmt völlig"*). Paired t-tests revealed whether pupils' interest, attitude and self-concept regarding both science and technology changed significantly between pre- and post-surveys (when $p<0.05$). For significant changes, Cohen's d was calculated to indicate the magnitude of the change (Cohen's d can be interpreted from Cohen's (1988) effect sizes for t-tests: small d=0.2; medium d=0.5; large d=0.8.).

Through interviews and surveys, teachers described their classroom preparation and their experiences with the mobiLLab program. Because teachers' accounts of their preparation varied so little for most factors, time was the only aspect from which a preparation typology could be created. Four preparation types were defined (Figure 1) based on duration, or days before the school visit that preparation started, and on classroom lesson-hours (45 minutes each) devoted to preparation.

	Lesson time high (> 8 lesson-hours)	**Lesson time low (< 8 lesson hours)**
Duration long (started >15 days before mobiLLab)	2 teachers	3 teachers
Duration low (started <15 days before mobiLLab)	2 teachers	2 teachers

Figure 1: Preparation typology based on duration (days before visit) and lesson-hours.

The effects that preparation and novelty factors (independent variables (IVs)) had on pupil S&T outcomes (dependent variables (DVs)) were explored through multivariate analysis of variance (MANOVA) statistical tests. When any interactions between IVs occurred, each IV was tested separately. Teacher attitude variables were included in the tests as covariates (CVs). The magnitude to which each factor explains the variation between two groups, such as between boys and girls, can be roughly interpreted using Cohen's [17] benchmarks for partial eta squared: small (η_p^2=.01), medium (η_p^2=.06) and large (η_p^2=.14).

5. Results and Discussion

Figure 2 shows averages and standard deviations of responses from pupils who completed both pre- and post- surveys (108 male; 97 female; 3 no response). Pupils indicated on average a relatively strong (*M=3.02*) tendency to explore technology and a positive perception of teachers' interest in S&T (*M=3.43*). Regarding technology-related themes, pupils' interest in technology was moderate and decreased slightly from pre- to post-survey (*M=2.55->2.43; Cohen's d=0.18*), their attitude was positive and showed no significant change (*M=3.04->3.07; p=0.284*), and their positive self-concept decreased slightly (*M=2.86->2.80; Cohen's d=0.10*). Responses about natural science themes were similar: pupils indicated a moderate interest in natural science that decreased slightly (*M=2.52->2.44; Cohen's d=0.13*), a somewhat positive attitude that showed no significant change (M=2.94->2.97; p=0.348), and a positive self-concept that decreased slightly *(M=2.87->2.82; Cohen's d=0.09).*

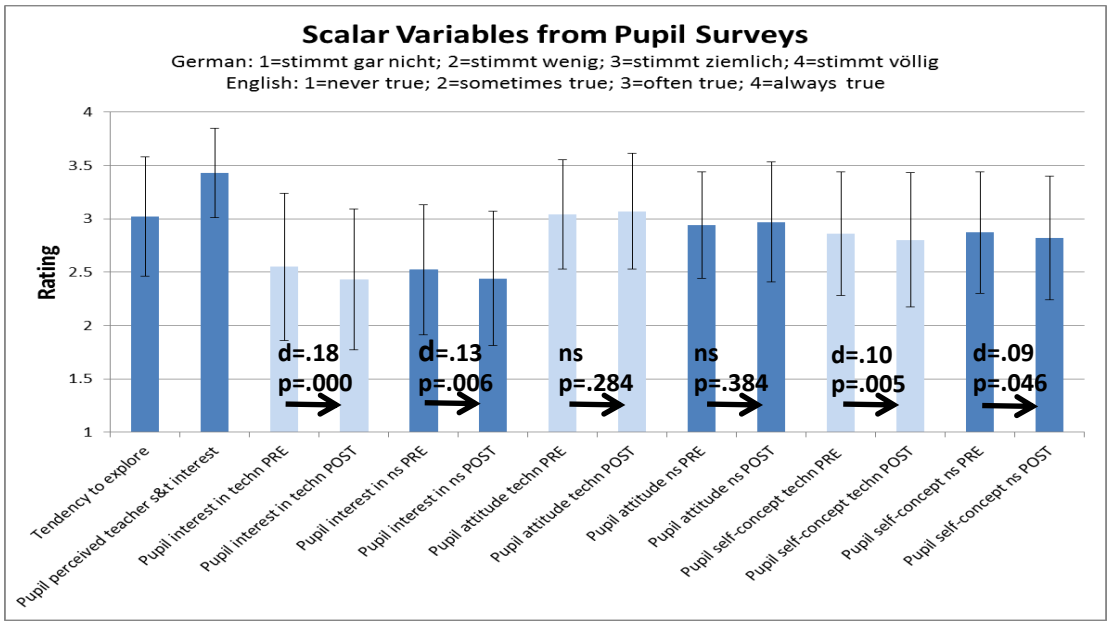

Figure 2: Pupils' tendency to explore technology, perceived teacher interest and S&T outcomes.

Factors identified through MANCOVA analysis that significantly relate to pupils' S&T outcomes are shown in Table 1 below. Factors that most strongly (large effect) explained variations in pupils' overall technology outcomes were "explores versus seeks direction" (η_p^2 =.34), "experience at technology OSLePs" (η_p^2 =.28), and "gender" (η_p^2 =.29). Factors that most strongly explained variations in pupils' overall natural science outcomes are "explores versus seeks direction" (η_p^2 =.17)" and "experience at natural science OSLePs" (η_p^2 =.15). The remaining factors showed a medium or small effect. Changes in pupils' technology outcomes from pre- to post- visit survey could be explained by "explores versus seeks direction" (medium effect: η_p^2 =.05); changes in pupils' natural science outcomes could be explained by "preparation type" (small-medium effect: η_p^2 =.03).

Factors with insignificant effects were how oriented pupils felt for the visit, how engaged pupils were at the visit, perceived learning goal, type of post-visit task pupils completed, the experimental posts pupils worked, teacher attitude about situated and constructivist learning, perceived teacher interest in S&T and perceived peer interest in S&T.

These results suggest that pupils with more overall positive S&T outcomes were boys, who tended to explore (rather than seek direction) when working with technology, had more experiences with informal learning settings, had higher grades and experienced a longer preparation (between-group comparison). Regarding changes in pupils' S&T outcomes from the pre- to post-visit surveys (within-

subject changes), only pupils' tendency to explore technology and classroom preparation seem to be important.

Factor (Independent Variable)	Pupils' technology outcomes				Pupils' natural science outcomes			
	df	df error	F	η_p^2	df	df error	F	η_p^2
Between-group comparisons: multivariate effects (p<0.05)								
Explores vs seeks direction	3	197	32.3	.34	3	195	13.0	.17
Experience: techn OSLePs	3	195	25.1	.28	3	193	11.4	.11
Experience: nat.sci. OSLePs	not significant				3	193	8.3	.15
Math grades	3	195	4.0	.06	3	193	5.2	.07
Science grades	3	194	4.2	.06	3	192	11.0	.15
Preparation type	9	566	4.2	.06	9	467	2.2	.03
Gender	3	191	25.4	.29	3	189	5.7	.08
Perceived peer interest	3	191	4.4	.06	not significant			
Within-subject changes from pre-to post-survey: multivariate effects (p<0.05)								
Explores vs seeks direction	3	197	3.4	.05	not significant			
Preparation type (time)	not significant				9	462	2.4	.03

Table 1: Factors that significantly affect pupil S&T outcomes: interest, attitude, self-concept.

A closer look at preparation through post-hoc tests suggest that pupils who experienced a preparation that started closer to the mobiLLab visit and involved more classroom time ('duration short, lesson time high), showed significantly greater interest in both science ($p<0.049$) and technology ($p<0.012$) and a more positive attitude (science, $p<0.011$; technology, $p<0.010$). These results could suggest that when preparation starts too early, pupils have more difficulty bringing together the information they need for the visit, frustrating them even before they experience the mobiLLab visit. Also, more classroom time spent on preparation seems to promote pupils' positive S&T interest and attitude.
An effective preparation, according to teacher interviews, 1) encourages pupils to bring materials they are interested in testing at the experimental posts, 2) relates classroom activities and assignments to mobiLLab, 3) helps pupils 'lose their fear of equipment,' and 4) orients pupils to the plan for the day. The last point is not supported by quantitative results, which suggested pupils' orientation is not a significant impact factor. However, the group of survey items about orientation showed a low reliability and this scale of items has been optimized for the main study survey.

6. Conclusions and Implications

Most striking is the strong link (large MANCOVA effect) identified between pupils' tendency to explore technology and their S&T outcomes. Somewhat similarly, Luckay and Collier-Reed [18] found that, when compared with Art students, "Engineering students are statistically more likely to … interact with technological artefacts with less fear and more self-initiation (*Tinkering*)." Qualitative data suggest that, in addition to the importance of this dispositional "trait" of exploring/ tinkering, pupils' situational "state" of exploratory behavior is also relevant to pupils' mobiLLab experience. That is, pilot study teacher interviews, as well as perspectives from PHSG faculty [13], suggest that improving pupils' familiarity with the mobiLLab equipment would help them to engage in the mobiLLab experience.
Based on these results, a main study is being carried out in Spring 2015, to better understand both dispositional and situational novelty factors, and the relationship between them. That is, data are being collected about pupils' 'traits,' such as their tendency to explore technology, and also about their at-visit novelty 'state,' such as their feeling of familiarity with the equipment. Studies of high-technology OSLePs need to examine impact factors relevant to their programs' success, such as orientation and technological capability factors. By influencing such factors, OSLeP programs can 'catch' pupils' momentary interest and open up the potential for development of lasting shifts in dispositional interest in science and technology [6, 19-21].

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