SECONDARY SCHOOL STUDENTS' PERSPECTIVES ON AND ATTITUDES TOWARDS LABORATORY WORK IN BIOLOGY

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Abstract

Interest in Biology among secondary school students in Slovenia is dropping from year to year. 1,046 secondary school students were surveyed about their preferred number of group mates in the laboratory, their attitudes towards and positive and negative views of laboratory work in Biology. From the students' perspective, the preferred way of teaching biology would be a mixture of interesting lectures and laboratory activities where they would have the opportunity to find solutions to the problems on their own through work in small groups. This is in direct opposition to prevailing teaching practice, where lectures are the dominant way of teaching. To overcome the loss of interest in Biology among students, action is needed immediately. Bridging the gap between students' perspectives on and opinions about good teaching practice and actual teaching practice should follow three tracks: the first one involves changes to the syllabus in such a way that less is more; the second one requires rewriting of manuals and textbooks, and the third is a change in the teaching practice of individual teachers. If for the first two teachers can find the excuse that this is outside their sphere of competence, there can be no excuse for avoiding immediate changes in teaching techniques.
Key words: *attitudes, biology, laboratory work; secondary schools, students.*

Introduction

Decline of interest in Science and Science careers is a world phenomenon recognized by many (Osborne et al., 2003; Osborne, 2007), and Slovenia is not an exception from this observation. Science is unpopular among students as early as in upper primary school, and attitudes concerning Science subjects are even more negative than in the other parts of the world (Gabršček et. al., 2005). Because Science subjects (Physics, Chemistry, and Biology) are optional for passing matura examinations (the final stage of general secondary schooling in Slovenia), we can use the number of students who choose these subjects as a possible measure of their popularity.

As an example we would like to present the frequencies of some representative subjects chosen by 10,742 students in the year 2006. To pass the matura exam, each student has to choose three compulsory subjects (mother language, foreign language, mathematics) and two optional subjects. Among natural science optional subjects, 1,477 (13.7%) students chose Biology, 1,671 (15.6%) Physics and 1,208 (11.2%) Chemistry. A combination of two natural science subjects was chosen by only 540 (5 %) students. On the side of the social sciences and humanities studies, the most popular subjects were Geography 4,741 (44.1%), History 4,227 (39.3%), Psychology 2,118 (19.7%), and Sociology 1,983 (18.5%). The most popular combination was Geography and History, chosen by 1,459 (13.9 %) students. To make matter worse, the number of students choosing Natural Science subjects has declined from year to year (Annual report – general matura, 2006).

The possible reason for the unpopularity of Biology lies in the findings from studies about biology teaching in Slovenia. The topics covered in the syllabus are highly academic; lectures are the dominant methods of school instruction, and barely connected with students' everyday experiences or interests (Verčkovnik 2000; Bajd and Artač, 2002; Šorgo and Hajdinjak, 2006; Strgar, 2007; Šorgo and Špernjak, 2007), and greatly influenced by the demands of the matura examinations (Ivanuš Grmek and Javornik Krečič, 2004).

Recognizing this problem many educators worldwide are trying to find a way to make Natural Sciences more attractive, while not losing quality, but even raising it. Based on results of many studies (Gallagher and Stepien, 1995; Duggan and Gott, 2002; Hodson, 2003; Jenkins, 2003, Tranter, 2004; Michael, 2006; Šorgo, 2007), it was possible to summarize that one possible approach to raising the quality of teaching and learning (and as a side effect increasing student interest in Science) is a switch from teacher-centred to student-centred methods of school work. Discovery and inquiry methods of work allow process-oriented instruction (Weiss and Regan, 1991; Massialas, 1991) with fully engaged students, so these methods should more often replace traditional, lecture-based teaching. From this perspective, laboratory and experimental work should be considered as one of the cornerstones in teaching Science, because through such work it is simultaneously possible to achieve the highest cognitive levels of knowledge, to acquire many skills (e. g., manipulative skills) unlikely to be achieved with other methods, and students generally have positive attitudes toward laboratory work (Hofstein and Lunetta, 2004; Šorgo et. al., 2008).

In Slovenian 9-year compulsory primary school, biological topics are integrated into various subjects until the 7th year of schooling. In the last two years of primary schooling Biology, Physics, and Chemistry are taught as separate subjects. In secondary schools the destiny of Biology largely depends on the type of school. In the general gymnasium programme (a 4–year academic programme), Biology is compulsory in the first three years for all students. In 210 academic hours students should learn about cell biology, plant and animal kingdoms, human anatomy and physiology, evolution, human genetics and ecology. If a student chooses Biology as one of the matura subjects, then an additional 140-hour course on comparative anatomy and physiology of the animal kingdom and molecular genetics is taught, and students have to perform and prepare reports on a number of laboratory experiments. In technical (4-year programme) and vocational schools (3-year programme), the diversity (both in topics and number of academic hours) in Biology teaching is greater. In some schools the topics are again integrated into various Science and Technology subjects, but in other more biotechnical oriented schools, Biology remains a separate subject. In such schools, depending on the goals of the programme, additional subjects like Microbiology or Human Anatomy can be taught. More detailed information about the school system of Slovenia is available online (Education in Slovenia).

As educators of future Biology teachers in the subject Didactics of Biology, we were professionally challenged by the question of how to prepare them to accept the idea that increasing the number of students interested in Biology wouldn't result solely from success on examinations, but more likely from a good working atmosphere and attractive and pleasant learning experiences during their schooling. We started with the idea that the first step on the part of the teacher towards achieving a good working atmosphere in the classroom (without losing – perhaps even raising – the quality of achieved knowledge) should be recognition of teaching practices that correlate with students' positive attitudes about and opinions of such work. In the other words, teachers need to know what their students think about the work in the classroom. The other reason was our aim to teach future biology teachers basic research strategies in action research as a tool for improving their upcoming teaching practice.

Because we had no studies about secondary students' attitudes or preferred teaching practices concerning Biology in Slovenia, we focused on laboratory work as a plausible candidate for improvement of students' teaching experiences. Our research question was the following: 'What are secondary school students' perspectives on and attitudes towards laboratory work in Biology?'

As a possible framework for teaching our future teachers how to assess student attitudes towards laboratory work in the classroom, we prepared a questionnaire. The questionnaire was assembled in such a way that different types of statistical techniques were needed to obtain results from a classroom. The task for the future teachers was the following: "You must find a class of students, post questionnaire to them and prepare a report based on your findings during a two-week practical course at secondary schools." In this way 46 pre-service Biology teachers in their final year of study collected 1,046 questionnaires from students in 46 classes at 28 (20 %) of 140 secondary schools in Slovenia and produced their reports. We recognised an opportunity to explore their raw data on a larger scale and to perform additional comparisons (between different classes of students or types of schools) not available to them.

Methodology of Research

Structure of the questionnaire

To find out what are secondary school students' perspectives on and attitudes towards laboratory work in Biology, a questionnaire was assembled. The questionnaire was divided into four parts and was completed anonymously.

In the first part we asked secondary school students for personal data concerning their schooling (year of schooling, type of school, and gender). Schools were classified into three categories: general secondary school (gymnasium), technical school, and vocational school.

The second part was a single statement: When teachers give us a work, I would prefer to work: a) alone, b) in pairs, c) in groups of three or four, d) in larger groups.

The third part was a closed questionnaire using a five-point Likert scale (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). In the original questionnaire written in Slovene, we used a mixed approach, so in some cases disagreement with a statement represents in reality a positive attitude. For the purposes of statistical analysis we have coded such statements in the opposite direction, as suggested by Selwyn (1999).

The fourth part concerning laboratory work allowed for open ended answers:

a) Write down three positive statements about laboratory work.
b) Write down three negative statements about laboratory work.

Structure of the sample

Our sample can be recognised as a simple random sample from the hypothetical statistical mass. We collected 1,046 questionnaires from the secondary school students from 46 classes at 28 secondary schools in Slovenia. Our sample represents about 1% of the student population (103,203 in the school year 2003/04) from about 20% of Slovene secondary schools (Education in Slovenia).

Analysis of the results

Analysis of the results followed three tracks and was performed using the statistical package SPSS® 12.0.

The Chi-square was used as a test when we tried to identify students' preferences in the matter of group size.

In answers obtained with the Likert type questionnaire, mean and standard deviation are reported. To compare means between two groups the Mann-Whitney test was used, and the Kruskall-Wallis test when three or more groups were compared.

Open ended answers were coded according to the principles of grounded theory (Basit, 2003; Torkar and Bajd, 2006). With this method some detailed in-depth information about individual cases is lost, but it was possible to identify the quantitative form of the answers. Groups

were formed arbitrarily and were wider or narrower, sometimes even overlapping, so that they can be recognized only as a rough quantitative estimate of student opinion. Even so, it was possible to isolate major views.

Results of Research

Results are reported as tables and commented in discussion.

Group work

Table 1. Results for preferred number of students in a work-group (N = 1023)

Preferred number of students in a group	Boys [N]	Boys [%]	Girls [N]	Girls [%]	Total [N]	Total [%]
Single	24	6.4	33	5.1	57	5.6
In pairs	105	28	229	35.3	334	32.7
In a group of 3 or 4 students	191	50.9	339	52.3	530	51.8
In a larger group	55	14.6	47	7.2	102	10.0

Attitudes towards laboratory work

To measure attitudes, a closed questionnaire on a five-point Likert scale was used. The questionnaire has a reliability of 0.761 measured as Cronbach's alpha

Table 2. Statistics from the questionnaire about students' attitudes towards laboratory work in Biology (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). Variables marked with an asterisk were coded in the opposite direction (1 Strongly agree, 2 Agree, 3 Neutral, 4 Disagree, 5 Strongly disagree).

Statements	Mean	SD
Biology is boring*	2.62	1.15
The knowledge of biology gained in school is valuable in everyday life	3.64	0.98
Natural science subjects are more interesting than Social Science subjects	3.22	1.24
I do not like practical work because of fear of doing things incorrectly*	1.97	1.00
In Biology we normally do not talk about interesting issues*	2.63	1.10
I like experimentation	3.96	1.08
During a course we should do more by ourselves	2.63	1.15
I am interested in animals and plants	3.45	1.15
If I had a choice, I would abandon biology at the first possible opportunity*	2.70	1.21
In biology teaching there should be more practical work	3.51	1.1

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Teaching of science subjects is modern	3.26	0.92
I am afraid of injuries during laboratory work*	1.79	0.97
The knowledge achieved in laboratory work is important in everyday life	3.36	1.04
It is best if the teacher demonstrates experiments to us, and we just have to observe*	2.50	1.24
Knowledge achieved in biological laboratory work can be used in laboratory activities in other subjects	2.91	0.98

Table 3. Differences between genders in attitudes towards laboratory work (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). Variables marked with an asterisk were coded in the opposite direction (1 Strongly agree, 2 Agree, 3 Neutral, 4 Disagree, 5 Strongly disagree).

Statement*	Gender	N	Mean	SD	Z	p
Biology is boring*	Boys	384	3.22	1.18	-3,235	0.001
	Girls	655	3.48	1.11		
Natural science subjects are more interesting than Social Science subjects	Boys	380	3.33	1.23	-2,249	0.025
	Girls	649	3.16	1.25		
I do not like practical work because of fear of doing things incorrectly*	Boys	382	4.14	0.99	-3,007	0.003
	Girls	652	3.97	1.00		
In Biology we normally do not talk about interesting issues*	Boys	380	3.23	1.13	-3,065	0.002
	Girls	651	3.45	1.08		
I like experimentation	Boys	378	4.08	1.06	-3,129	0.002
	Girls	654	3.89	1.09		
During a course we should do more by ourselves	Boys	381	2.75	1.21	-2,352	0.019
	Girls	651	2.56	1.10		
I am interested in animals and plants	Boys	383	3.33	1.16	-2,525	0.012
	Girls	652	3.52	1.15		
If I had a choice, I would abandon biology at the first possible opportunity*	Boys	382	3.14	1.22	-3,020	0.003
	Girls	652	3.39	1.20		
In biology teaching there should be more practical work	Boys	383	3.61	1.12	-2,679	0.007
	Girls	655	3.45	1,08		
Teaching of science subjects is modern	Boys	379	3.18	0.99	-2,018	0.044
	Girls	654	3.30	0.88		
I am afraid of injuries during laboratory work*	Boys	382	4.32	0.97	-3,581	0.000
	Girls	654	4.15	0.96		

Table 4. Differences in attitudes towards laboratory work between stages (students' year of schooling). (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). Variables marked with an asterisk were coded in the opposite direction (1 Strongly agree, 2 Agree, 3 Neutral, 4 Disagree, 5 Strongly disagree). All values of Chi square are reported at 2 degrees of freedom.

Statement*	Year#	N	Mean	SD	χ^2	p
Biology is boring*	1th	291	3.23	1.10	25.93	0.000
	2th	361	3.26	1.16		
	3th	300	3.63	1.14		
The knowledge of biology gained in a school is valuable in everyday life	1th	288	3.51	0.96	6.85	0.033
	2th	361	3.69	1.01		
	3th	298	3.61	1.02		
In Biology we normally do not talk about interesting issues*	1th	287	3.27	1.08	11.75	0.003
	2th	360	3.30	1.12		
	3th	300	3.54	1.11		
During a course we should do more by ourselves	1th	287	2.46	1.21	9.94	0.007
	2th	361	2.68	1.19		
	3th	298	2.70	1.01		
If I had a choice, I would abandon biology at the first possible opportunity*	1th	288	3.23	1.12	5.92	0.052
	2th	360	3.21	1.23		
	3th	300	3.40	1.29		
In biology teaching there should be more practical work	1th	290	3.63	1.09	12.58	0.002
	2th	361	3.63	1.11		
	3th	299	3.38	1.04		
Teaching of science subjects is modern	1th	286	3.20	0.91	7.08	0.029
	2th	360	3.22	0.94		
	3th	300	3.37	0.90		
Knowledge achieved in biological laboratory work can be used in laboratory activities in other subjects	1th	291	3.03	0.95	15.18	0.001
	2th	362	2.93	0.99		
	3th	301	2.72	0.94		

year of schooling at secondary school

Table 5. Differences in attitudes towards laboratory work between students from different types of schools (5 Strongly agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly disagree). All values of Chi square statistics are reported at 2 degrees of freedom. School: 1 – general secondary school (gymnasium); 2 – technical 4-year school; 3: vocational – 3-year school.

Statements	School	N	Mean	SD	χ^2	p
The knowledge of biology gained in school is valuable in everyday life	1*	572	3.54	1.01	11.811	0.003
	2**	359	3.74	0.96		
	3***	100	3.81	0.89		
Natural science subjects are more interesting than Social Science subjects	1	573	3.09	1.28	16.398	0.000
	2	354	3.36	1.17		
	3	98	3.53	1.14		

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During a course we should do more by ourselves	1	574	2.53	1.07		
	2	356	2.73	1.19	8.356	0.015
	3	98	2.84	1.31		
I am interested in animals and plants	1	574	3.33	1.15		
	2	358	3.54	1.15	16.401	0.000
	3	99	3.77	1.11		
In biology teaching there should be more practical work	1	575	3.44	1.06		
	2	358	3.57	1.12	7.951	0.019
	3	101	3.68	1.19		
I am afraid of injuries during laboratory work	1	574	4.36	0.85		
	2	359	4.02	1.07	24.409	0.000
	3	99	4.05	1.06		
The knowledge achieved in laboratory work is important in everyday life	1	571	3.28	1.00		
	2	359	3.45	1.08	7.314	0.026
	3	101	3.48	1.11		
Knowledge achieved in biological laboratory work can be used in laboratory activities in other subjects	1	577	2.81	0.94		
	2	360	3.02	0.97	13.407	0.001
	3	101	3.05	1.13		

1* – General high schools (gymnasium); 2** – Technical schools; 3*** – Vocational schools

Positive opinions about laboratory work

The students had to write down three positive statements about laboratory work in Biology. The answers were grouped according to the grounded theory.

Table 6. Students' positive opinions about laboratory work.

Group	Frequency	Percent
Interesting	557	22.7
Better knowledge	394	16.1
Useful	317	12.9
Clarity	224	9.1
Methods of work	215	8.8
Entertaining	203	8.3
Group work	165	6.7
Achieving new knowledge by own efforts	122	5.0
Connecting theory with practice	51	2.1
No grading in the time of work	43	1.8
Real work	37	1.5
Organised activities	33	1.3
Active work	24	1.0
Different	22	0.9
Easier	8	0.3
Miscellaneous	39	1.6
Total	**2454**	**100**

Negative opinions about laboratory work

The students had to write down three negative statements about laboratory work in Biology. The answers were grouped according to the grounded theory.

Table 7. Students' negative opinions about laboratory work.

Group	Frequency	Percent
Fear of injuries	403	25.6
Boring	218	13.8
Not enough laboratory work and field work; nothing negative	155	9.8
Too much work in too little time	112	7.1
Preparing reports	103	6.5
Conditions in the laboratory	81	5.1
Poor equipment	72	4.6
Inadequate manuals	64	4.1
Unusable	61	3.9
Order in laboratory	51	3.2
Cook-book manuals	47	3.0
Students do not cooperate during group work	40	2.5
Serious work	30	1.9
No results at the end	29	1.8
Inexperienced teacher	28	1.8
Teacher does not help	19	1.2
Outside the regular schedule	12	0.8
No computers	11	0.7
Tiresome	10	0.6
Uncomfortable	7	0.4
Too easy	4	0.3
Miscellaneous	19	1.2
Total	**1576**	**100.0**

Discussion

Ability to cooperate in a group is considered one of the key competencies (Rychen and Salganik, 2001; Key competencies supplementary statement for Biological Science, 2001).

From the results presented in Table 1, we can conclude that students prefer to work in small groups with three or four students (51.8%), and in pairs (32.7%). Only about 10% of the students prefer to work in larger groups, and less than 6% prefer to work alone. A statistically significant difference was found between genders (χ^2 (3, N = 1023) = 17.8 $p \leq 0.000$), where boys outnumbered girls two-fold in their preference for working in larger groups. We found no statistically significant differences in preferences for group work between students from different types of school, or year of schooling (age). To accommodate the preferences of students should mean that a teacher of laboratory work can hardly fail if (s)he divides a class into groups of three or four students. Still not tested is a solution for dividing a class into groups differing in size, according to their preferences.

From the agreement with the answers presented in Table 2, we can construct an average imaginary student: (S)he will agree that biology is not the worst thing that can happen during his/

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her school time, and there is some reason for learning biology, even if the skills acquired do not significantly contribute to success in other subjects. (S) he prefers lessons where laboratory work is on the schedule, and is not afraid of possible injuries or of embarrassing him/herself during the work. Because the highest score was given to the statement: 'I like experimentation.' (M = 3.96; SD = 1.08), this could be a good starting point for including more laboratory and practical work in daily routine.

Boys and girls do not differ in the general directions of their expressed attitudes; they like or dislike the same things, but they differ in the strength of their attitudes (Table 3). For teaching practice this could mean that we can work with boys and girls as individual groups, but we should be aware of possible differences between genders. It is up to the teacher to decide what (s) he would prefer, but from the results we can predict that a group of boys will be more enthusiastic in laboratory work than a group of girls. In practice, it can mean that we would prefer to combine boys and girls in mixed groups, whenever possible, to balance these differences.

Because the sample was greatly biased towards students from the first three years of schooling, we made comparisons only among these first three stages and omitted 4th and 5th years. In the high school programme, Biology can be chosen as an optional matura subject in 4th year, and 5th year Biology is offered only in vocational schools when students who finished the three-year vocational programme wish an additional two years of study to graduate in a technical programme. Just as with the difference between boys and girls, different age classes do not differ in the general direction of their expressed attitudes; they like or dislike the same things, but they differ in the strength of their attitudes (Table 4). It was difficult to draw consistent conclusions from the results, but we think that the differences are at least partly a result of the syllabus, where some topics are recognized as more interesting than others. From a practical point of view, it could mean that teachers should put fresh life into some of the topics.

The difference between students from different types of schools is statistically significant for eight statements (Table 5). We can see that students in vocational and technical schools value biology more than students in general high schools. One possible explanation is that the correlation between Biology and other subjects, including working practice is stronger in the curriculum of such schools than in the more general programme of an academic high school. The other possible reason is that, at the vocational and technical schools, biology teachers often teach in addition to biology one or two other related subjects like Microbiology, Human Anatomy, Dendrology, etc., which allow them to connect theory with practice. The possible explanation why students of the academic high school programme are less afraid of injuries may lie in the fact that at vocational and technical schools students in some courses work with industrial machines and technology.

We received 2,454 positive answers concerning laboratory work (Table 6). In general, we can readily conclude that for the major number of students such work is interesting; they see it as useful in gaining better knowledge with greater insight into what is going on in teaching, and in a way they like. From the teaching viewpoint, it can only mean that laboratory work should be on the schedule as often as possible.

We received 1,576 answers with negative statements about laboratory work (Table 7), which is 878 (35.8%) less than the 2,454 answers expressing positive opinions. The number of negative opinions is lowered even more when we recognise opinions that there is too little laboratory and field work and nothing negative as positive attitudes. We interpret this to mean that students have some problems finding serious complaints concerning laboratory work. Support for this conclusion is that the major concern is about the safety of such work (403, 25.6%). When we combine their expressed fears with the lowest agreement (M = 1.79, SD = 0.97) with the statement 'I am afraid of injuries during laboratory work' from the Likert type questionnaire (Table 2), we can take their fears as a minor obstacle that could easily be overcome with good laboratory practice. More concern arises from 218 (13.8%) answers grouped around the word 'boring'. About one third of the answers (70) contain words like 'sometimes' or 'can be'. We can interpret these answers as meaning that students generally like laboratory work but that such work must be dynamic, with no long waiting times for results, which is not always the situation in biology experimentation. Because

processes can be slow and procedures long, the students are sometimes under time pressure. As a side effect, reports have to be done as homework, which produces another negative opinion. The possible solution is to prepare a new generation of laboratory activities where students would be more engaged and results obtained in a shorter time. Introduction of a computer based laboratory is one possible solution (Šorgo and Kocijančič, 2004, 2006).

Conclusions

From the results, we can conclude that from the students' perspective the preferred way of teaching biology would be a mixture of interesting lectures and laboratory activities where they would have the opportunity to find solutions to the problems on their own through work in small groups. This is in direct opposition to common knowledge about prevailing teaching practice in Biology, where lectures are the dominant method of instruction.

It has been argued elsewhere (Ivanuš Grmek and Javornik Krečič, 2004) that teachers would prefer to conform their teaching practices to best fit preferred outcomes expected on the final exams, as is the case with the matura exams, which are a prerequisite for entering university studies in Slovenia, or the vocational matura which is a prerequisite for entering tertiary vocational education. Because of the objectivity of such testing, test questions where divergent or original answers are possible are eliminated from the test pool. As a result the questions that dominate are those at the level of knowing facts and processes and comprehension. Even when the teachers are not under pressure from external examinations, lower-end knowledge guarantees success even to underachieving students. So it is no wonder that teachers would discard from their teaching practices those that do not result in success. The rationale behind such behaviour is that in such a way they can hardly fail, when their environment pushes them to achieve the highest grades. Unfortunately, adequate laboratory work and outdoor activities do not contribute substantially to achieving lower end knowledge; their power lies instead in higher order domains and in good and pleasant learning experiences during schooling. The second possible reason is the overloaded syllabus, where the easiest solution for covering every topic is direct lecturing. The third still unproven possible reason might be in the conformism of teachers. Laboratory work needs more time for preparation, grading laboratory work is more challengiging then grading paper and pencil tests, and during lectures the number of unexpected situations is significantly lower than during laboratory work.

To overcome loss of interest in Biology among students, immediate action is needed. Bridging the gap between students perspectives on and opinions about good teaching practice and actual teaching practice should follow three tracks: the first involves changes in the syllabus, in such a way that less is more; the second calls for rewriting manuals and textbooks, and the third recommends a change in the teaching practice of individual teachers. If for the first two teachers can make the excuse that this is out of their sphere of competence, there can be no excuses for avoiding immediate changes in their methods of teaching.

norway grants

Acknowledgement

We gratefully acknowledge the financial support within the project Science Educational Centre for Sustainable Development (SI0039-GAN-00087-E-V1 – Norwegian FM), supported by a grant from Norway through the Norwegian Financial Mechanism.

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