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1 SUMMARY

In this report (WP5 Validation & Quality Assurance) we focus on a qualitative and quantitative teacher- and student-centered validation of the pedagogical effectiveness of the SCeTGo system. The report informs about the methodology and usability evaluation of the SCeTGo project, including the outcomes of the validation activities carried out in the framework of the SCeTGo project. The adapted validation methodology (see Quality Assurance Scheme D5.3) was applied to the SCeTGo system firstly at schools as well as at universities and later on at informal learning settings (HEUREKA). An extensive validation was performed; participating institutions from Greece, Sweden, Finland, Spain, and Romania organized a series of national validation events in the framework of workshops conducted with teachers, pupils, university students, museum educators (HEUREKA) and experts from other areas of education (e.g. researchers from university). We propose a validation according to the project goals (further information is given in the Quality Assurance Scheme D5.3). Thereby we favour a mixed model approach on a quantitative (questionnaires) and a qualitative (interviews) basis. The validation of the SCeTGo system was conducted in two phases. In validation phase A (pilot phase) prototypes of the miniatures were validated, whereas we presented revised miniatures together with the developed scenarios to different target groups in phase B. Finally, we collected results from both phases of the SCeTGo project and analyzed them systematically. Results are presented in detail in chapter 5. In conclusion, outcomes could support that the SCeTGo approach offers a modern science center experience in school classrooms.
Results show that miniatures and developed scenarios complement each other in a perfect way, thereby providing an easy application to school life. With reference to technical acceptance usability features are easy to operate and there are no real obstacles that teachers and students have to overcome in order to use the system. This ensures that the SCeTGo project has the potential to be applied in school environments and that the introduction of augmented reality technologies into the classroom is in line with the needs of educators. It provides teachers with a tool in order to facilitate students' learning.

2 INTRODUCTION

2.1 Objectives of the project

In contrast to Virtual Environments that completely immerse users into a virtual world, Augmented Reality (AR) combines the real world with artificial, computer generated elements. The mixture of real and virtual information, as a new kind of user experience conducted in a science centre, has been shown to positively influence students' intrinsic motivation, as well as cognitive learning, especially of low achieving students. It thereby can help to maintain pedagogical effectiveness [1, 2, 3]. However, the implementation of AR in school environments as a new way of learning was so far only realized and evaluated in very few cases [4, 5]. The basic objectives of the WP5 (Validation & Quality Assurance) are to adapt a tried and tested AR methodology of the consecutive projects CONNECT [6,7] and EXPLOAR [8, 9] to the needs of user groups in school classrooms as well as informal environments. The SCeTGo project is offering an innovative approach to the needs of teacher instruction in the classroom, by adapting an existing AR system for science centres and other informal learning settings [2, 6]. In the framework of SCeTGo a series of miniature exhibits were developed (Bolzmann experiment, Doppler experiment, Mini Wing experiment, Double

Cone experiment, Double Slit experiment), illustrating various physical phenomena which enable learners to visualize the invisible (e.g. electric or magnetic fields, molecular movements) through AR technology. In this manner learners have the chance to control conditions in order to uncover and visualize physical phenomena. In so doing they participate in an active learning form in groups that enables students to investigate physical phenomena instead of simply memorizing facts. Pupils enhance their experimental and analytical skills together with an appropriation of knowledge with regard to natural sciences.
Consequently, the scope of WP5 (Validation and Quality Assurance) is the validation of the SCeTGo approach in various formal and informal settings (school, university, science center) together with the developed scenarios (further information is given in the Scenarios Adaptation and Development Report D3.1.) with different target groups (school students, university students, teachers, educators and researcher).

According to the Project Management Structure & Plan (D1.1), the validation of the SCeTGo project aimed at getting feedback of the users concerning the educational usefulness and its impact on science education. For that purpose the following questions were addressed in the framework of the Quality Assurance Scheme (D5.3) as part of the validation process:

Does the SCeTGo approach…

1. … raise interest in science and science motivation?
2. … reach to induce engagement of students in experimental science learning?
3. … lead to satisfying learning outcome, especially considering problem-solving and critical thinking skills?
4. … offer teachers an enrichment of their everyday teaching practice?

We conducted a series of validation events in different European countries of participating institutions (Greece, Sweden, Finland, Spain, and Romania) in order to ensure that the objectives are achieved and the pedagogical effectiveness of SCeTGo project is given.

2.2 Participants

The SCeTGo consortium consists of experts from different areas of education, comprising expertise from didactics and pedagogy from school, university and science center education.

Participating institutions are:

- Schools and universities in Greece, Romania, Sweden, Spain and Finland.
- The science center HEUREKA (Finland)

3 Methodology - Validation Design

3.1 Empirical Evaluation Instruments & Data Analysis

Validation events were offered to two different user groups: Students from school and university as final consumer groups of the SCeTGo approach and teachers, science museum staff and researchers of the participating organizations as a “provider” group. Both groups have their own requirement and operate with the SCeTGo system in a different way.
We have to consider teachers needs, if we intend to make AR computer-mediated learning technology attractive to teachers: Teachers still act as key players in the use and acceptance of

any new educational technology and there remains an enormous gap between developing AR technologies and its implementation in school [3]. Consequently, we adapted the validation instruments to the demands of the “provider” and the “user” group. Thereby this validation report is one of the few attempts to investigate the role of teachers’ and students` acceptance of AR in school environments.
A detailed overview of the validation process and its instruments is given in the Quality Assurance Scheme (D5.3). A knowledge test in a pretest-posttest design to get insight into students’ cognitive achievements could not be conducted. A statistical power analysis revealed that requirements (sample size: number of participants) were not given to guarantee a valid statistical analysis. As part of the economic validation (VALNet; Economic Aspects) we asked for the integration costs of the ICT-based SCeTGo approach into the school system and the integration costs in general. Results for the integration costs in general are not shown, as we did not find a significant difference between the two questions.

3.2 Quantitative Methods – Questionnaires

The quantitative validation is based on pen-and-paper questionnaires. We applied a battery of items predicated on valid subscales, focusing on motivation, engagement and pedagogical aspects. Furthermore with regard to teachers` validations we assessed technological and economic aspects. Table 3-1 gives an overview of the instruments applied. A detailed description of the scales used is provided in the Quality Assurance Scheme (D5.3).

Table 3-5.1.1-1: Overview of the instruments for the validation procedure.

Questionnaire	***Subscales applied (Number of items)***	***Adapted from:***	***Ref. to research question(s) No.:***
	Students		
VALNet	*Pedagogical Aspects (8)*	*MENON Network 2001*	*1,4*
***IMI** (Intrinsic Motivation Inventory)*	*Perceived competence (6)*	*Deci & Ryan 1985, University of Rochester 2010*	*1,2*
***SMQ** (Science Motivation Questionnaire)*	*Personal Relevance (10) Self-determination (4)*	*Glynn et al. 2009, Glynn & Koballa 2010*	*1,2*
Student engagement	*Behavioral engagement (5) Emotional engagement (5)*	*Skinner et al. 2008*	*1,2*
Knowledge test	*[ad-hoc test] (20)*	*[ad-hoc test]*	*3*
Teachers			
VALNet	*Pedagogical Aspects (5) Technological Aspects (3) Economic Aspects (6)*	*MENON Network 2001*	*4*
***IMI** (Intrinsic Motivation Inventory)*	*Interest/Enjoyment (7) Value/Usefulness (7)*	*Deci & Ryan 1985, University of Rochester 2010*	*4*

3.3 Qualitative Methods –interviews

Additional to the quantitative tools, workshop leaders conducted interviews that followed a fixed interview grid. The content deals with the questions described in Table 3-2. We

addressed questions with regard to teachers' and students` motivation to use the system in consideration of usability and pedagogical aspects. A complete interview grid and a detailed description of questions is provided in the Quality Assurance Scheme (D5.3; App. 3, 4).
Interviews were performed as follows: After the successful implementation of validation events, workshop leaders consulted participants willing to be interviewed. Interviews had an average duration of 20 minutes. To guarantee homogeneity of data, interviewers followed general principles according to descriptions of Lamnek [10]. All questions were adjusted in an open form and interviews were incorporated in a trustful situation. Interviews were analysed following Mayring`s qualitative content analysis [11]. A category was formed, if not less than two interviewees referred to the same aspect.

Table 3-2: Summarized overview of the questions of the interview grid.

Questions	***Teachers***	***Students***
1. a) How did you take notice of the SCeTGo workshop?	*x*	-
1. b) Did you look forward to the SCeTGo lesson?	-	*x*
2. a) What have you expected from the SCeTGo workshop/lesson?	*x*	*x*
3. Did the SCeTGo workshop/lesson come up to your expectations?	*x*	*x*
4. a) Are you motivated to take use of the SCeTGo approach in your future lessons?	*x*	-
4. b) Did the lesson raise your interest in science?	-	*x*
5. a) What do you think are the most positive features of the SCeTGo approach?	*x*	-
5. b) What do you think are the most positive aspects of this learning scenario, of this way of teaching?	-	*x*
6. Is there something you didn't understand, concerning the usage of the SCeTGo/computer-assissted exhibits?	*x*	*x*
7. Are you satisfied with the SCeTGo workshop/lesson?	*x*	*x*

3.4 Validation events – Overview

In general a validation event was conducted as follows:

1. Presentation of the SCeTGo project.
2. Introduction to Inquiry-Based Science Education (IBSE).
3. Introduction to Augmented Reality (AR).
4. Presentation of the SCeTGo suitcase.
5. Demonstration of each miniature (participants could test all miniatures by themselves).
7. Filling out questionnaires.

In phase B miniatures were presented with the corresponding scenarios. Details of the unique events are given in chapter 4.

The projects` implementation comprised three phases:

1. Teachers training seminars: Introduction of the SCeTGo approach to partners of participating institutions.

   Partners were trained by consortium members in order to become workshop leaders and to get skilled with the SCeTGo system, the miniatures and all other relevant tools (webcam, markers etc.). The workshop included a demonstration of the 5 miniatures (Bolzmann experiment, Doppler experiment, Mini Wing experiment, Double Cone experiment, Double Slit experiment) and a practical part, where participants had the possibility to make own experiences.

2. Phase A (pilot phase): First cycle of implementation (01.07.2010 – 01.02.2011) conducted at schools/universities

   Validation events were offered to pre-service teachers and teachers (1) and students from school (2). During events, participants got information about the project, the Augmented Reality (AR) technology and its application in classrooms. Teachers (1) were given an introduction about technological aspects, including an explanation about the handling of the tool. They got used to the SCeTGo suitcase and its handling, it stores all necessary elements for the existing five exhibits. Also included in the suitcase is a laptop with a touch screen, a webcam and a little stand. A detailed description of the suitcase and the application of the different miniatures is found in the SCeTGo user manuel. Additionally participant could interact with all exhibits and AR features that were developed in the framework of the SCeTGo system.
   In contrast to teachers` validation, only one miniature was shown to each students` group (2) to get a detailed validation of each miniature.

3. Phase B: Second cycle of implementation (01.02.2011 – 01.12.2011) conducted at schools/universities/ science center

   In the second phase, science museum staff and researchers (from universities and schools) (1) of the participating organizations were included as a “provider” group and students from university as a user group (2). In order to enhance quality of the interactive visualization technology of the miniature exhibits, miniatures were revised according the the validation outcomes conducted during phase A. Additionally animations of physical processes in the classroom were accomplished by pedagogical scenarios, that are tangential to the curriculum. An inquiry-based learning scenario was performed as follows:

   Phase 1: Question Eliciting Activities

   Phase 2: Active Investigation

   Phase 3: Creation/ Formation

   Phase 4: Discussion

   Phase 5: Reflection

   This way the SCeTGo setup assures an innovative inquiry-based learning approach that is tailored to students` needs and implements not only “hands-on”, but also ‘minds-on’ experiments. Moreover, it allows teachers a successful application within school curricula without the need to a time consuming preparation of teaching material. In phase B revised miniatures with the corresponding learning scenarios (further information is given in the Scenarios Adaptation and Development Report D3.1.) were presented to both groups (1&2).

4 Execution of the validation events

Table 4-1 shows a summary of validation events conducted between 01/07/2010 – 01/02/2011 (phase A) and 01/02/2011 – 01/12/2011 (phase B). A detailed description of each event is provided in Table 4-2.

Table 5.1.1-1:Summarized overview of the validation events conducted in implementation phase A and B.

	Students` questionnaires	Students` interviews	Teachers` questionnaires	Teachers` interviews	Researchers` interviews	Museum staffs` Question-naires
Romania	513	35	27	17		
Finland	-	-	72	29		
Total Phase A	513	35	99	46	-	
Sweden	73	8	9	3	-	-
Spain	-	-	20	2	-	-
Greece	55	5	17	15	14	-
Romania	64	-	19		-	-
Finland	112	-	3	-	-	22
Total Phase B	304	13	68	5	14	22
Total: SCeTGo A&B	817	48	167	51	14	22

Table 5.1.1-2: Conducted validation events in phase A and B

Phase	Partner	Place	Date	Participants
A	Romania	Cluj Napoca (CCD Cluj)	2- 3/11/2010	35 physics teachers
A	Romania	17 schools from the Cluj county	4-11/11/2010	513 students
A	Finland	Heureka	25-26/11/2010	124 students, from the University of Helsinki, department of teacher education 2nd – 3rd class
B	Greece	Project meeting in Athens	1- 3/12/2010	12 project team members
B	Spain	University of Barcelona (UB) – Faculty of Pedagogy	17/5/2011	20 pre-service science teachers (secondary level)
B	Sweden	NO-Biennalen Halmstad	12/04/2011	25 teachers
B	Sweden	Gröndalskolan (school), Värnamo, Sweden	04/2011	73 school students (9^{th} grade)
B	Sweden	Arabyskolan (school) Växjö, Sweden	31/5/2011	
B	Greece	Pathway Summer school, Crete , Greece	5 - 8/7/2011	app. 35 teachers
B	Greece	EDEN Open Classroom conference in Athens (Pallina)	27-29/10/2011	app. 18 teachers

B	Greece	Greek higher Military academy	18/11/2011	app. 70 university students, 7th semester (3 courses)
B	Romania		11/2011	64 school students (3 classes)
B	Romania		11/2011	19 teachers
B	Finland	Heureka	11/2011	11 participants, museum staff
B	Finland	Heureka	24-25/11/2011	143 university students

5 Results

5.1 Phase A, Quantitative Research

5.1.1 Survey of Teachers (formal learning settings)

During the implementation phase A of the SCeTGo system (01/07/2010 – 01/02/2011), all miniatures were introduced to 72 Finish pre-service science teachers and 27 Romanian in-service science teachers at schools within a professional development framework. Data assessed by questionnaires as part of the quantitative analyses are presented.

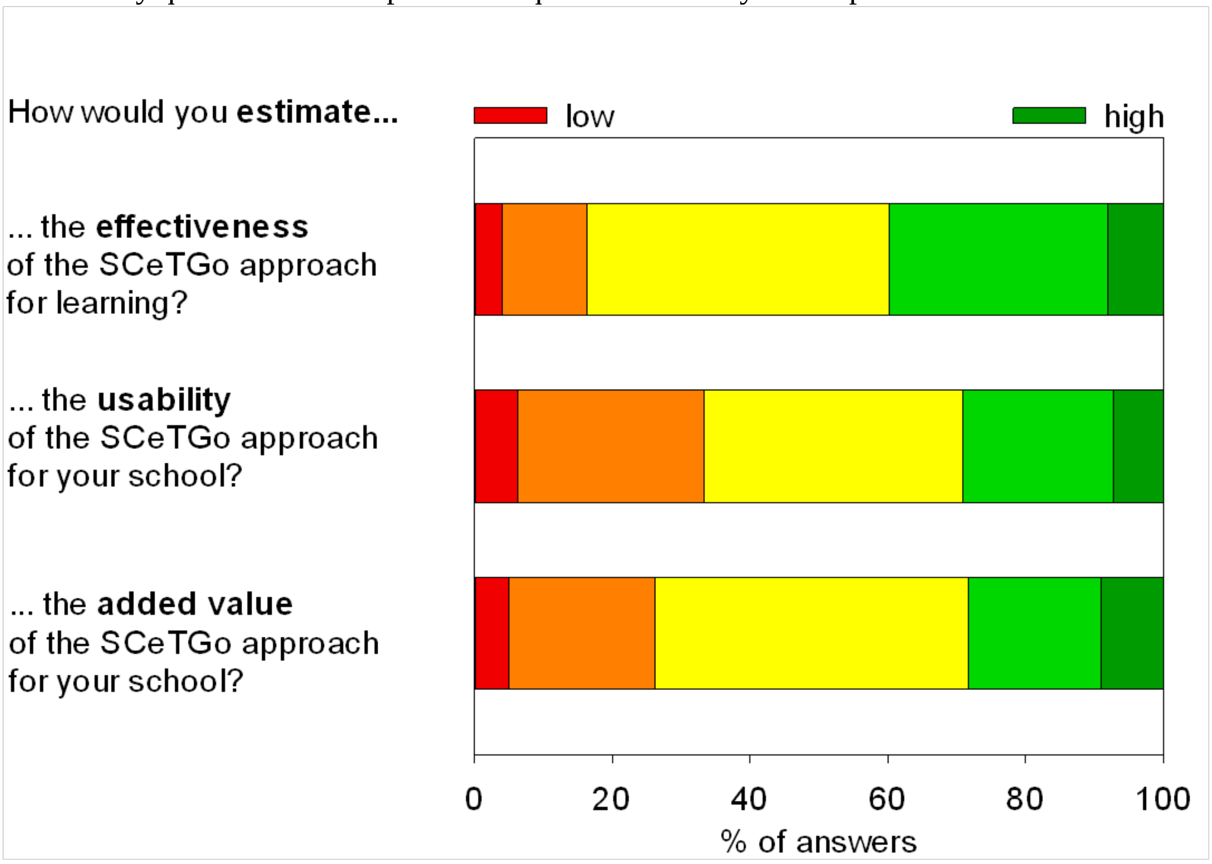

Fig. 5.1.1.1: Evaluation of Pedagogical Aspects I (VALNet)

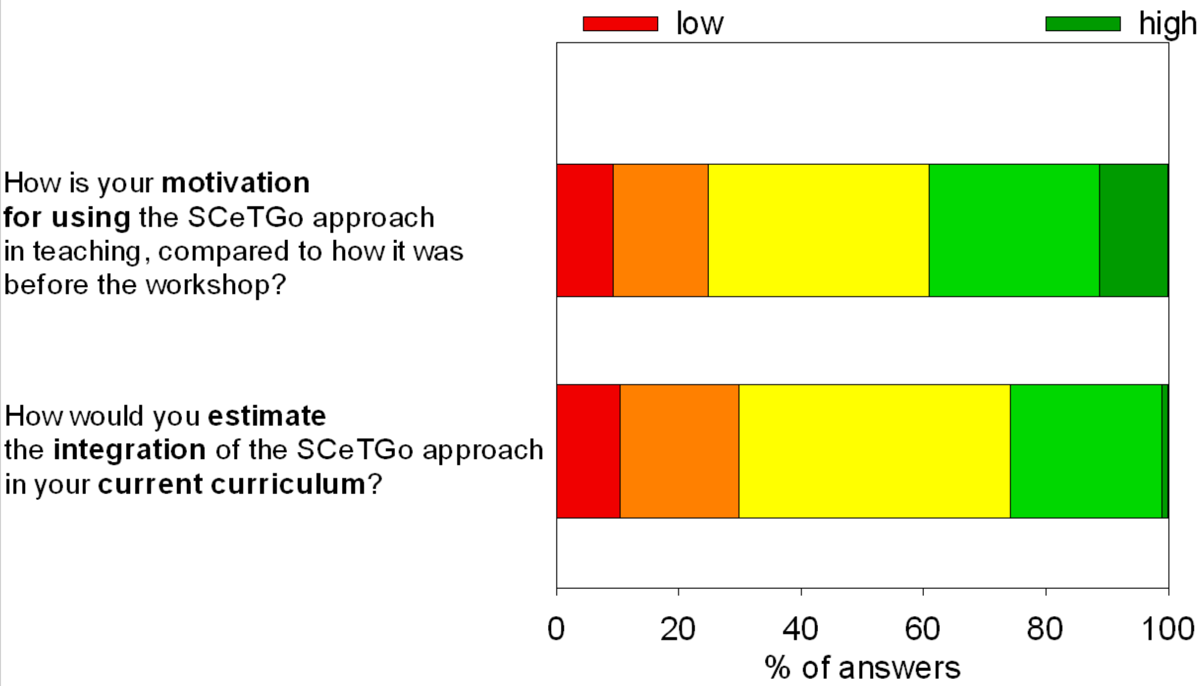

Fig. 5.1.1.2: Evaluation of Pedagogical Aspects II (VALNet)

To validate pedagogical, technological as well as economical aspects of the SCeTGo approach, we analysed teachers' answers to the VALNet questionnaire. Concerning pedagogical aspects, the majority of teachers (> 50%) think that the SCeTGo approach is effective for learning, usable for and adding value to their schools (Fig. 5.1.1.1). Furthermore, the motivation to use the approach in teaching increased compared to before workshop participation. Teachers estimated the integration of the SCeTGo approach in the current as medium to high (Fig. 5.1.1.2). Thus, the pedagogical aspects of the approach were rated in a very satisfying way, indicating that teachers consider the approach to be pedagogical valuable.

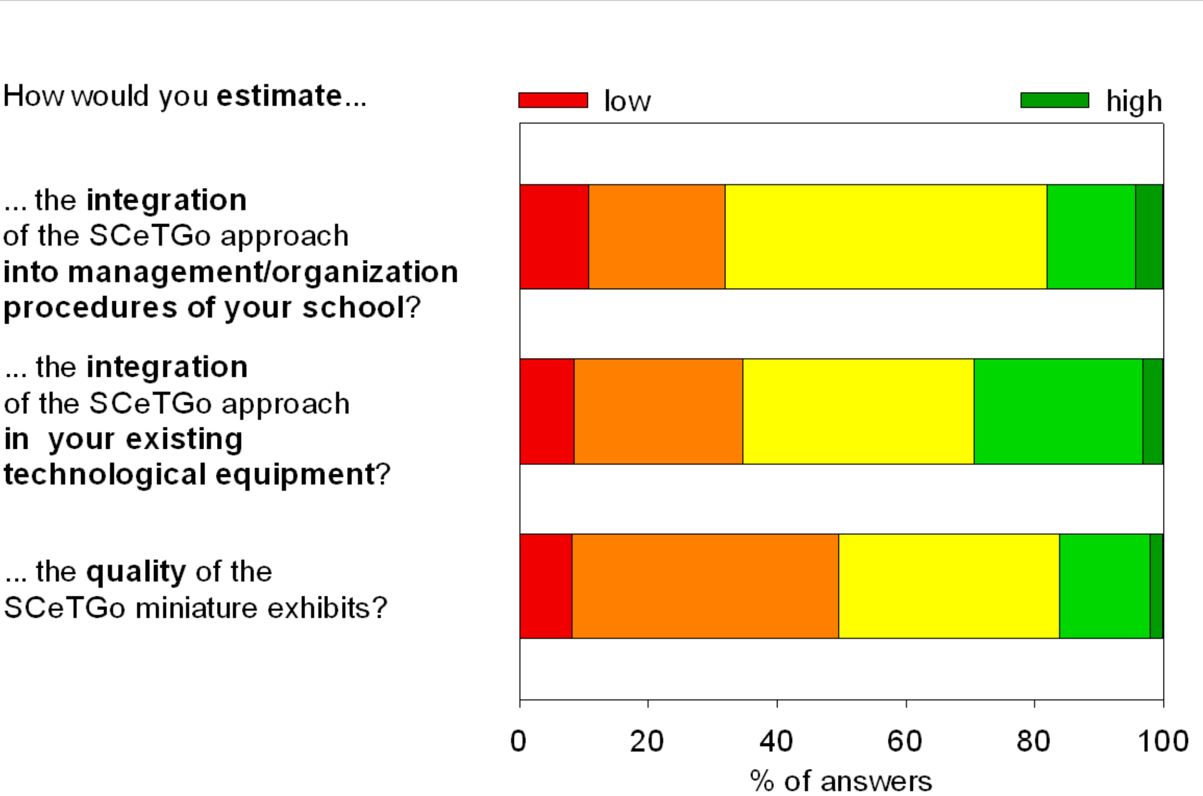

Fig. 5.1.1.3: Evaluation of Technological Aspects (VALNet)

Almost 70% of workshop participants rated the integration of the SCeTGo approach into organization procedures and in the existing technological equipment as medium high to high. Slightly less teachers (50%) estimated the quality of the SCeTGo miniature exhibits as medium high to high (Fig. 5.1.1.3). This is a very positive result.

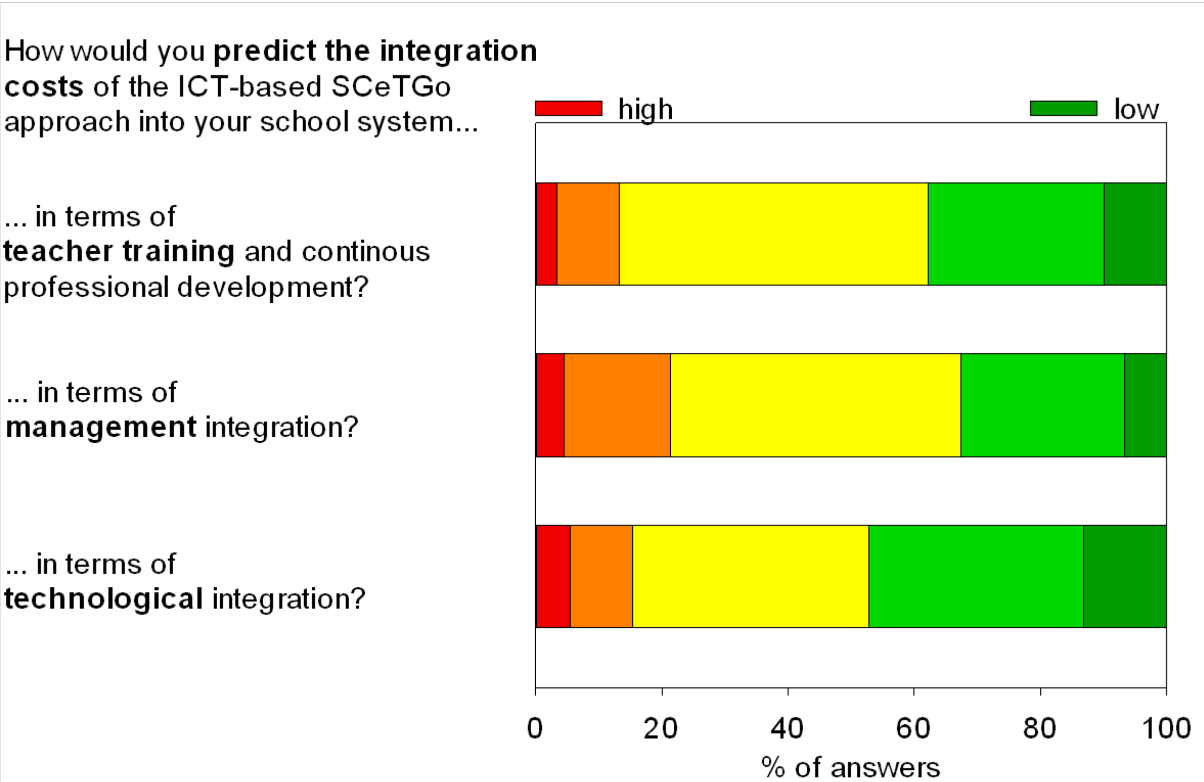

Fig. 5.1.1.5.1.1.4: Evaluation of Economical Aspects (VALNet) I

The majority of teachers predicted the integration costs of the ICT-based SCeTGo approach as medium (Fig. 5.1.1.4). Potential reasons might be that not only the SCeTGo suitcase, but also the ICT-equipment would have to be bought before using the SCeTGo approach in a proper way.

Fig. 5.1.1.5: Evaluation of Economical Aspects II

Interestingly the evaluation of economical aspects shows, that users are willing to pay more for one miniature in comparison to the amount of money they would pay for all miniatures (Fig. 5.1.1.5). This result proposes that they are more interested in the purchase of a single miniature than buying a whole set.

Fig. 5.1.1.6: Evaluation of Interest/Enjoyment (Intrinsic Motivation Inventory)

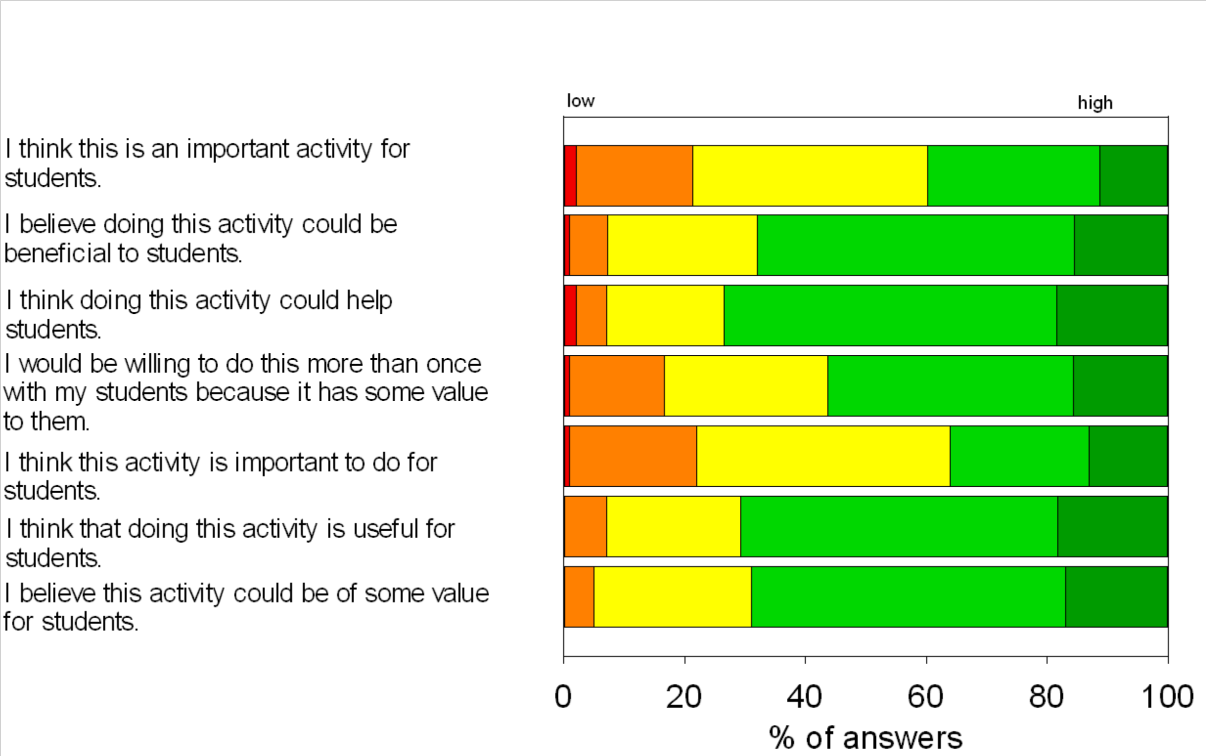

Fig. 5.1.1.7: Evaluation of Value/Usefulness (Intrinsic Motivation Inventory)

To measure teachers intrinsic motivation, two subscales of the Intrinsic Motivation Inventory (IMI) were administered. On average, results show that teachers rated the value and usefulness of the SCeTGo approach better than interest and enjoyment. A possible reason for the relatively low interest and enjoyment may be that the approach mainly addresses younger target groups (students) and therefore, teachers might not have been challenged when working with the miniatures. However, value and usefulness were almost never rated low, so this is still a favourable result.

By validating the teacher workshops, we also wanted to find an answer to our 4th research question: Does the SCeTGo approach offer teachers an enrichment of their everyday teaching practice? Overall, the results of the validation of teacher workshops underlines the importance and quality of the SCeTGo approach for instruction. Therefore, the approach may indeed be a valuable enrichment for teaching practice.

5.1.2 Survey of Students (school)

Altogether, 512 students attended the validation events in phase A. Different to the teacher workshops, students worked with only one of the SCeTGo miniatures in each workshop to get a detailed validation of each miniature. Miniatures have been shown to adequate age groups between 14 and 18 years (Doppler Effect, grade 7-10; Miniwing grade 9, Double Cone 9, Boltzmann Constant grade 10; The Double – Slit Experiment grade 11). Each student filled out a questionnaire with regard to the miniature applied (Boltzmann experiment, 194 student questionnaires; Doppler experiment, 67 student questionnaires; Mini Wing experiment, 83 student questionnaires; Double Cone experiment, 55 student questionnaires; Double Slit experiment, 47 student questionnaires). Data analyses could show that results are similar for all miniatures, therefore we present the results for the Boltzmann miniature as an example because most students attended this workshop. Only the Double Slit miniature was rated slightly worse than the other miniatures. Therefore, these figures are shown additionally (Fig. 5.1.2.16 - Fig. 5.1.2.21). A complete overview of the results is given in the appendix.

5.1.2.1 Boltzmann Experiment

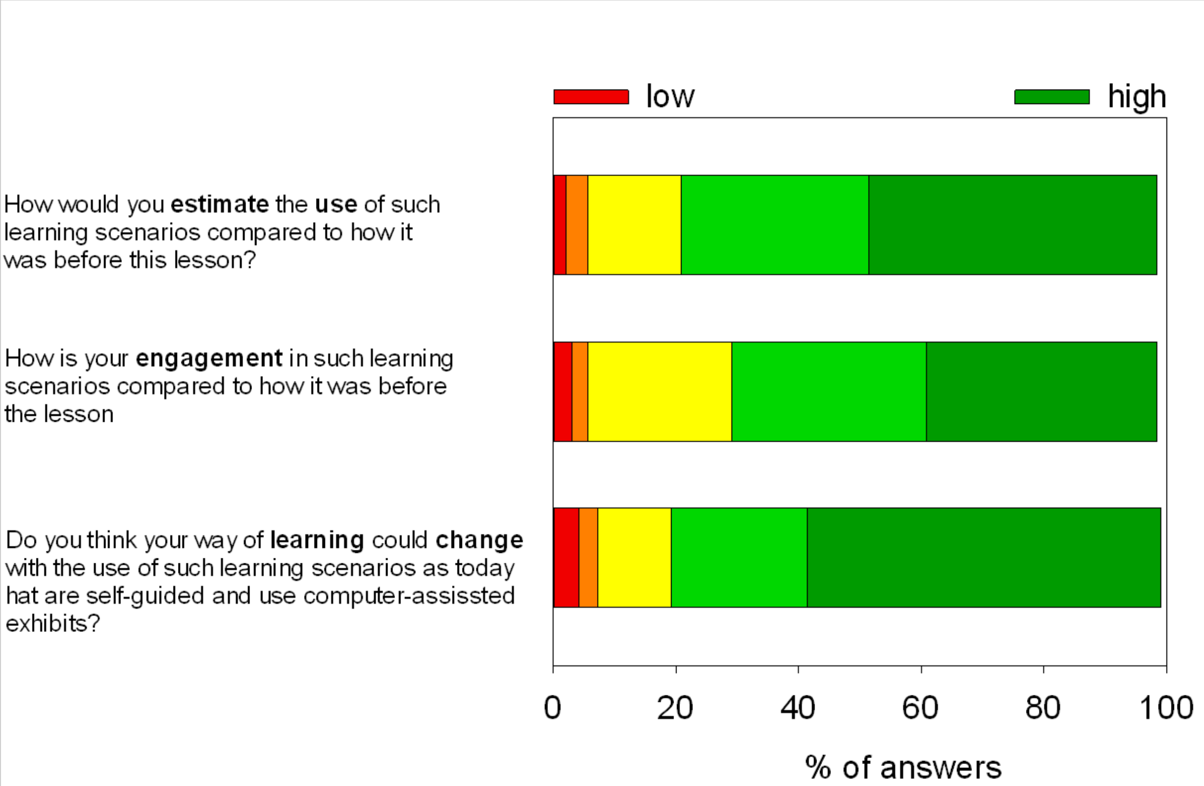

Fig. 5.1.2.1: Evaluation of Pedagogical Aspects I (VALNet)

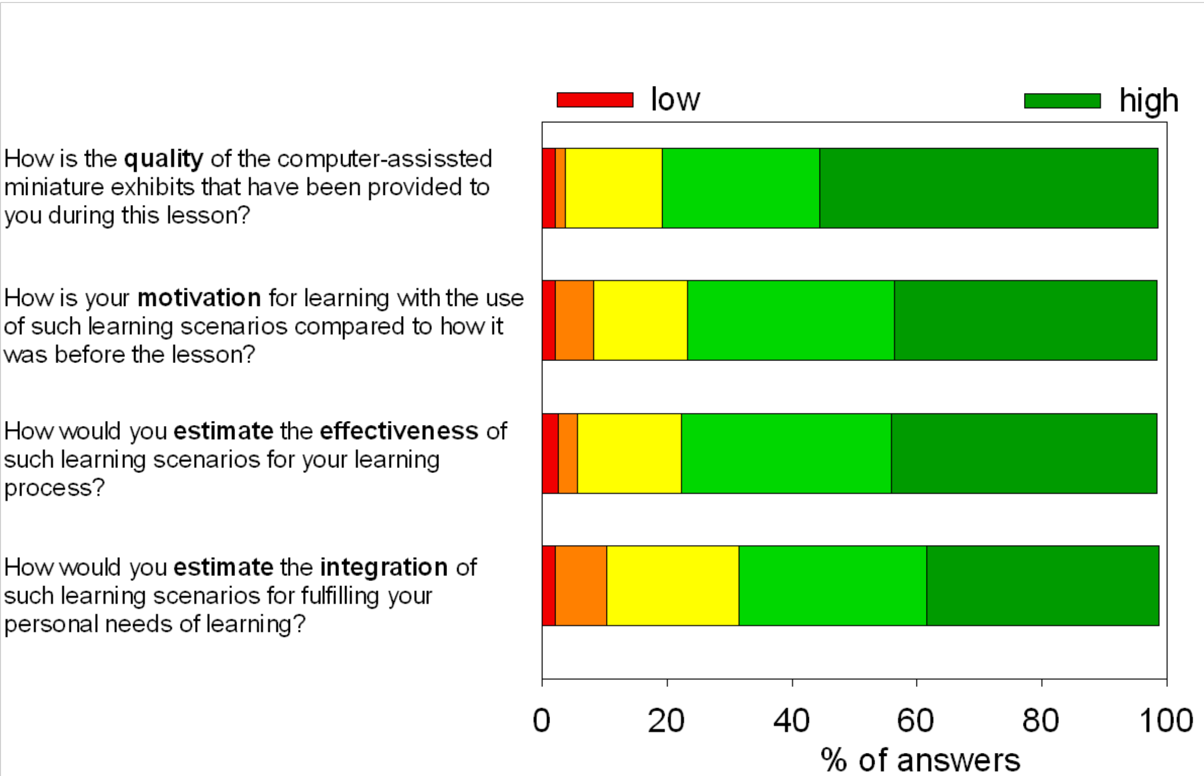

Fig. 5.1.2.2: Evaluation of Pedagogical Aspects II (VALNet)

Students were asked to assess the pedagogical aspects of the miniature they worked with. Results (Fig. 5.1.2.1 and Fig. 5.1.2.9) show that the majority of students consider the use of the learning scenario (app. 80%), its effectiveness for the learning process (app. 70%), and its integration for fulfilling personal needs of learning (app.70%) as medium high to high. About

80% of the students estimated the quality of the miniature they worked with as medium high to high. Similar ratings were given for the students' engagement in learning scenarios in contrast to before the workshop, the possibility of a change of their ways of learning and their motivation for learning by using such learning scenarios. In summary, the pedagogical aspects of the miniatures were assessed in a very satisfying way and underline the findings from the teachers' workshop validation: The SCeTGo approach may be a valuable enrichment for teaching practice. Referring to the first research question, the results show that students' interest in experimental science learning and science motivation could be raised or increased.

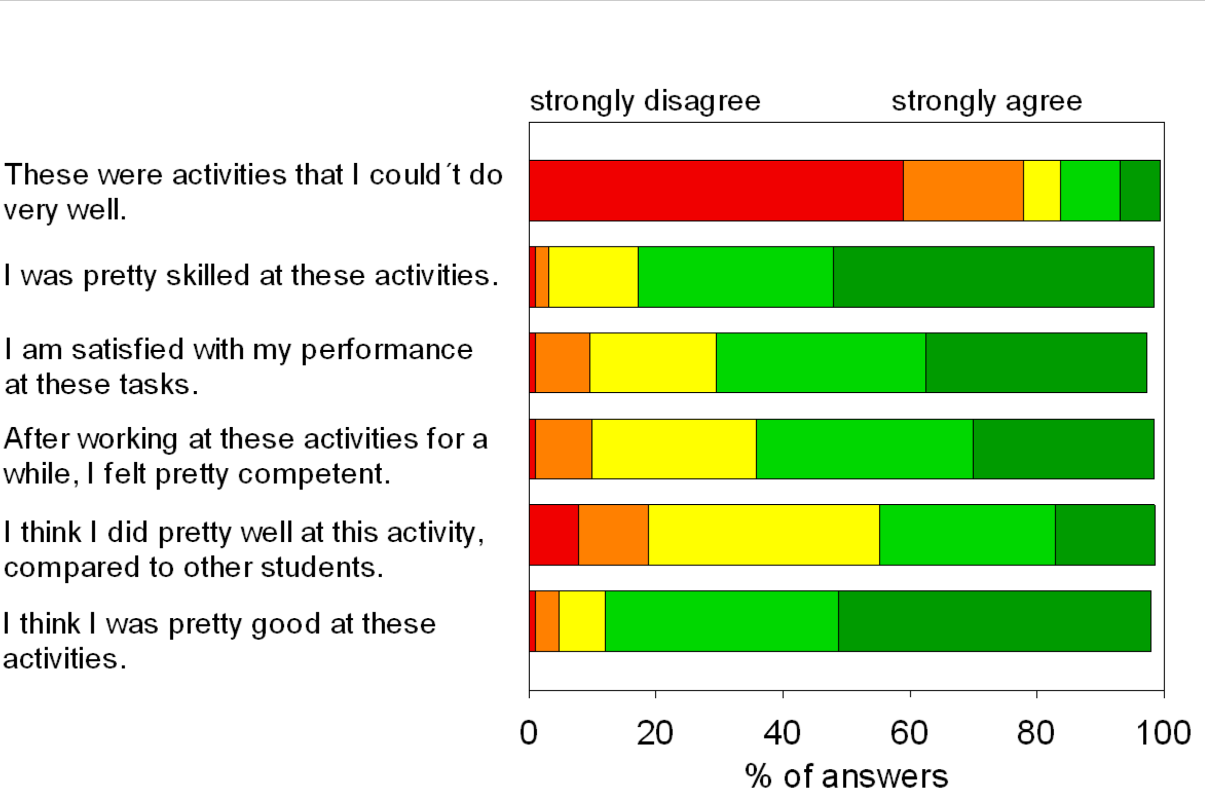

Fig. 5.1.2.3: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

With regard to perceived competence it stands out that students were self confident in reference to the task, only a minority (‹20%) thought that they could not do the activity very well.

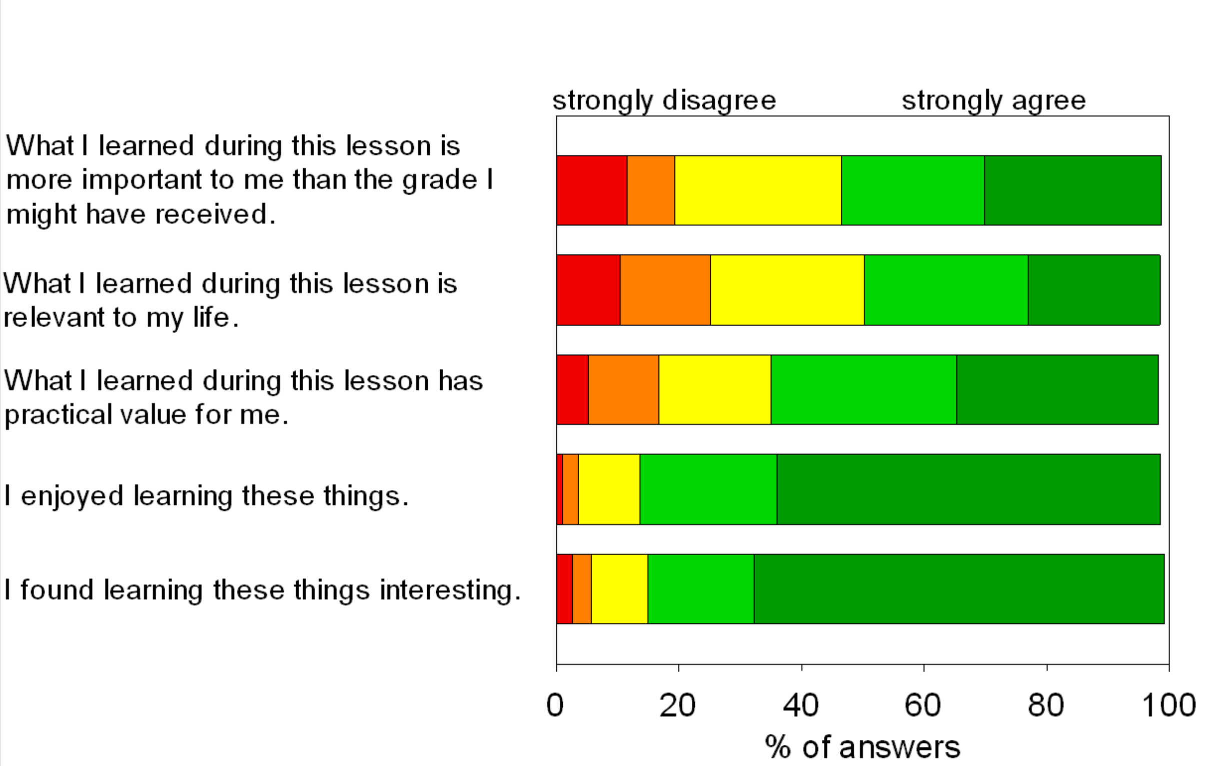

Fig. 5.1.2.4: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

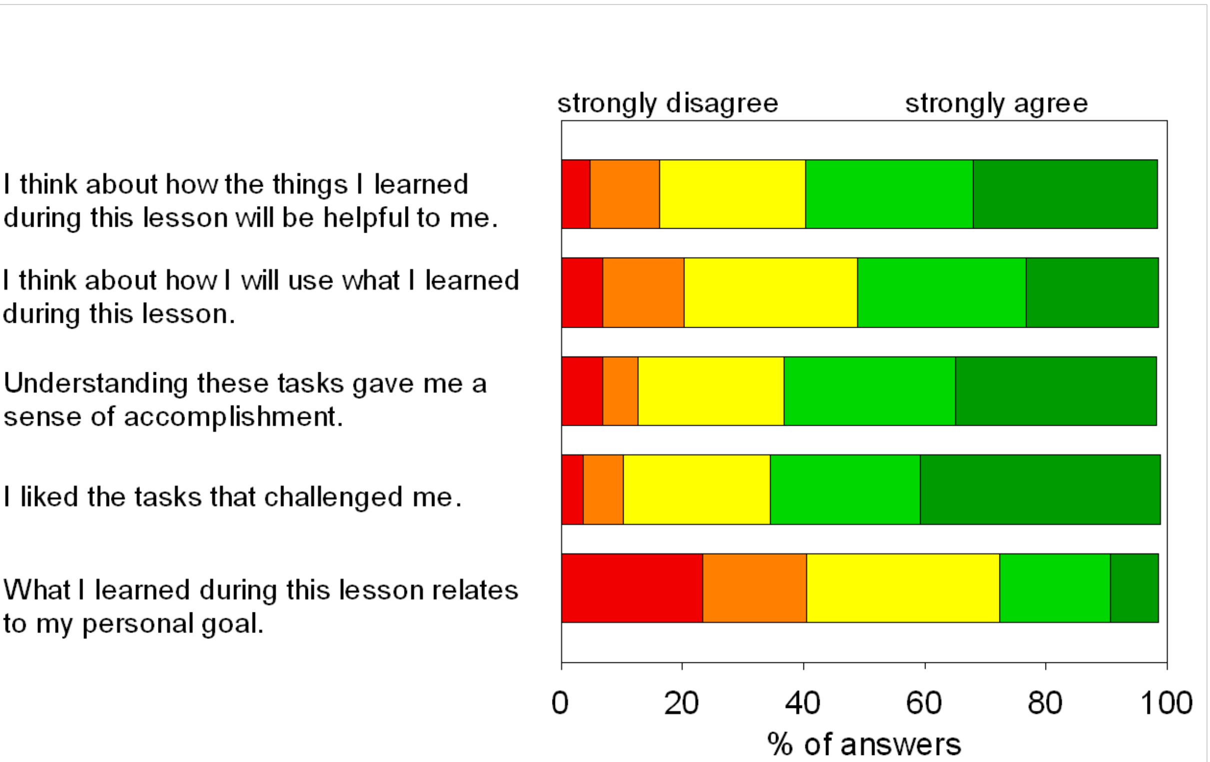

Fig. 5.1.2.5: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

We also administered the subscale “Personal relevance” of the Science Motivation Questionnaire (SMQ). Overall, the miniatures seem to have a high personal relevance to the students, although about 40% think that it does not relate to their personal goal. This seems contradictory as the majority stated that the lesson was relevant to their lives and has practical value to them.

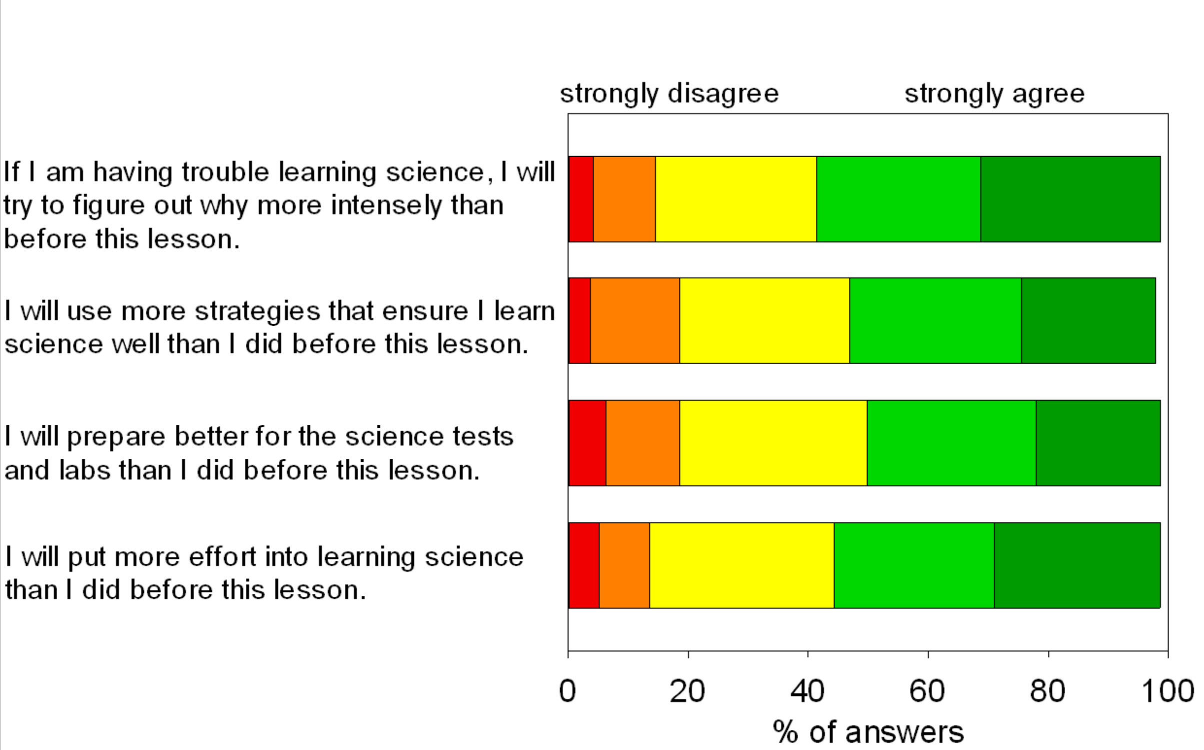

Fig. 5.1.2.5.1.2.6: Evaluation of Self-determination (Science Motivation Questionnaire)

In reference to their self-determination (Fig. 5.1.2.13) results were satisfying, more than 50% of students agreed with the questions asked.

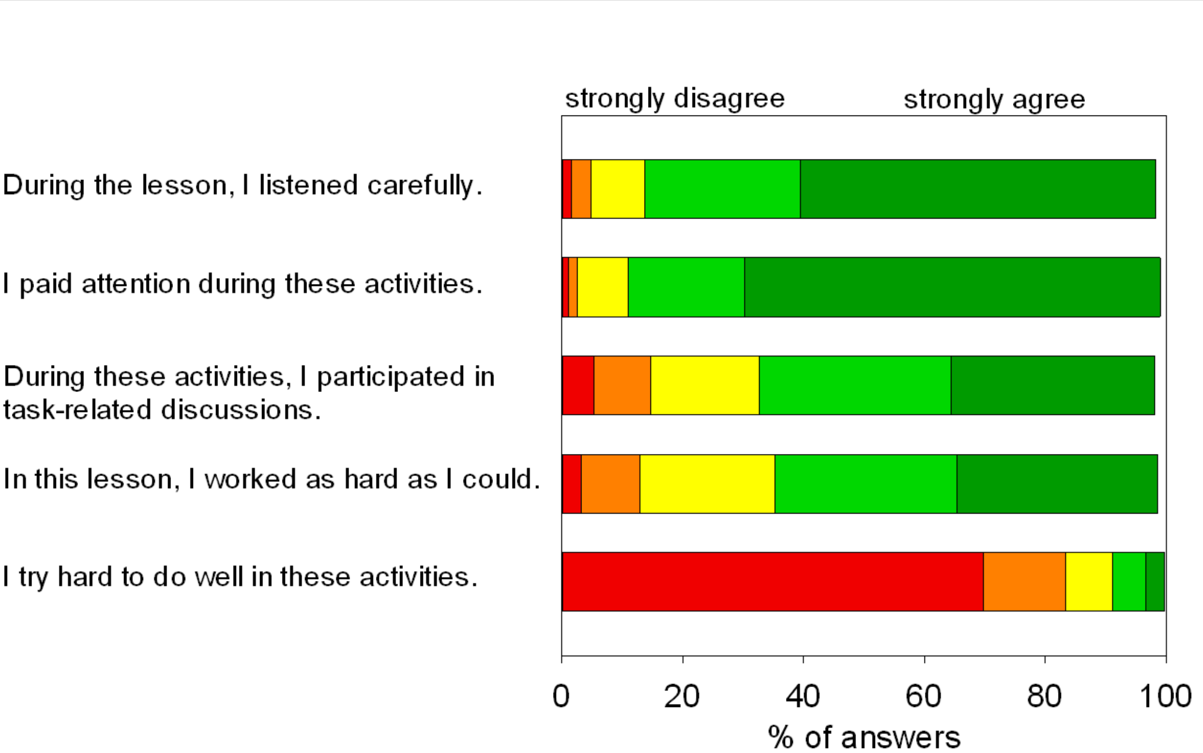

Fig. 5.1.2.7: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

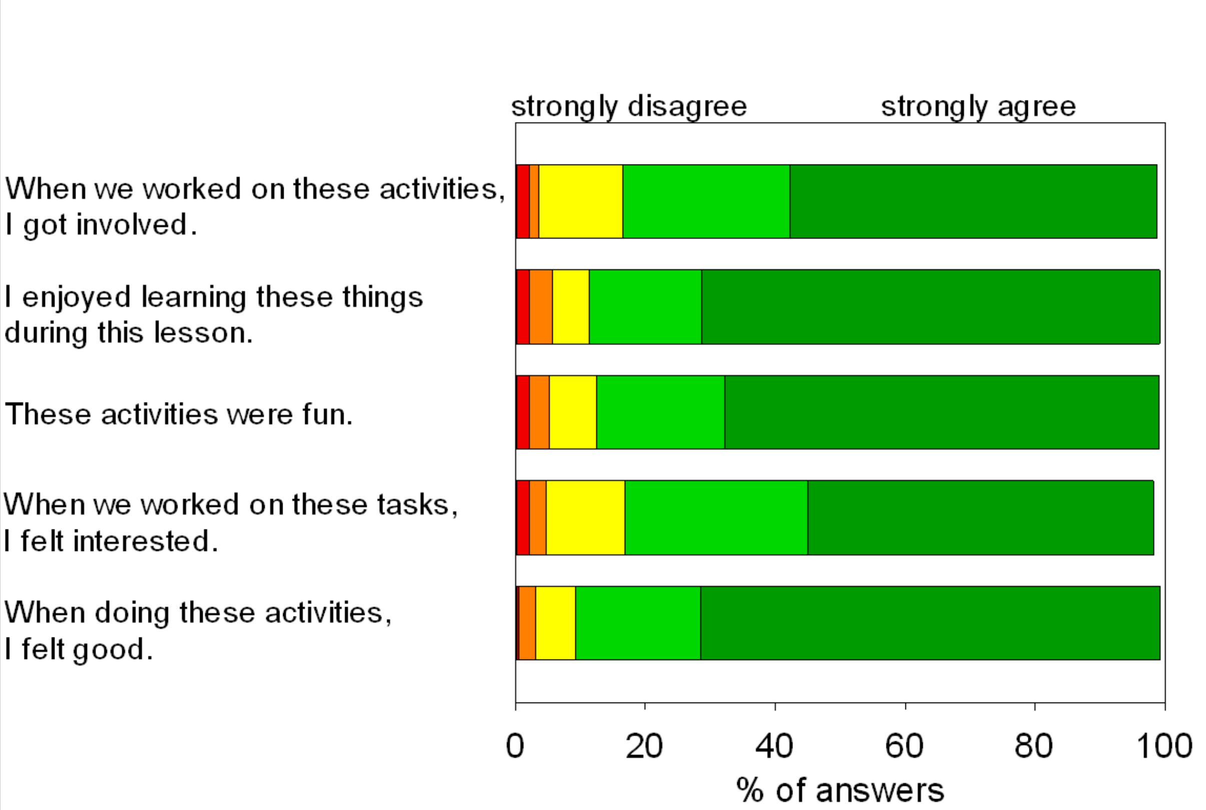

Fig. 5.1.2.8: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

Positive results can be found for students' behavioural and emotional engagement. Over 50% of the students showed a high behavioral engagement when working with the miniatures (Fig. 5.1.2.14). Especially the emotional engagement was rated very positive and indicates that students were very enganged while working with the miniatures (Fig. 5.1.2.15).
Overall, the results show that the SCeTGo approach raised interest in science and science motivation (research question 1), induced and increased engagement of students in experimental science learning (research question 2) and may also serve as an enrichment of everyday teaching practice (research question 4).

5.1.2.2 Double Slit Experiment

The Double Slit miniature was rated slightly worse (app. 10%) than the others miniatures. The evaluation of perceived competence may give an answer why it was evaluated not as good as the other miniatures. Fig. 5.1.2.16 is shown additionally to the Boltzmann experiment.

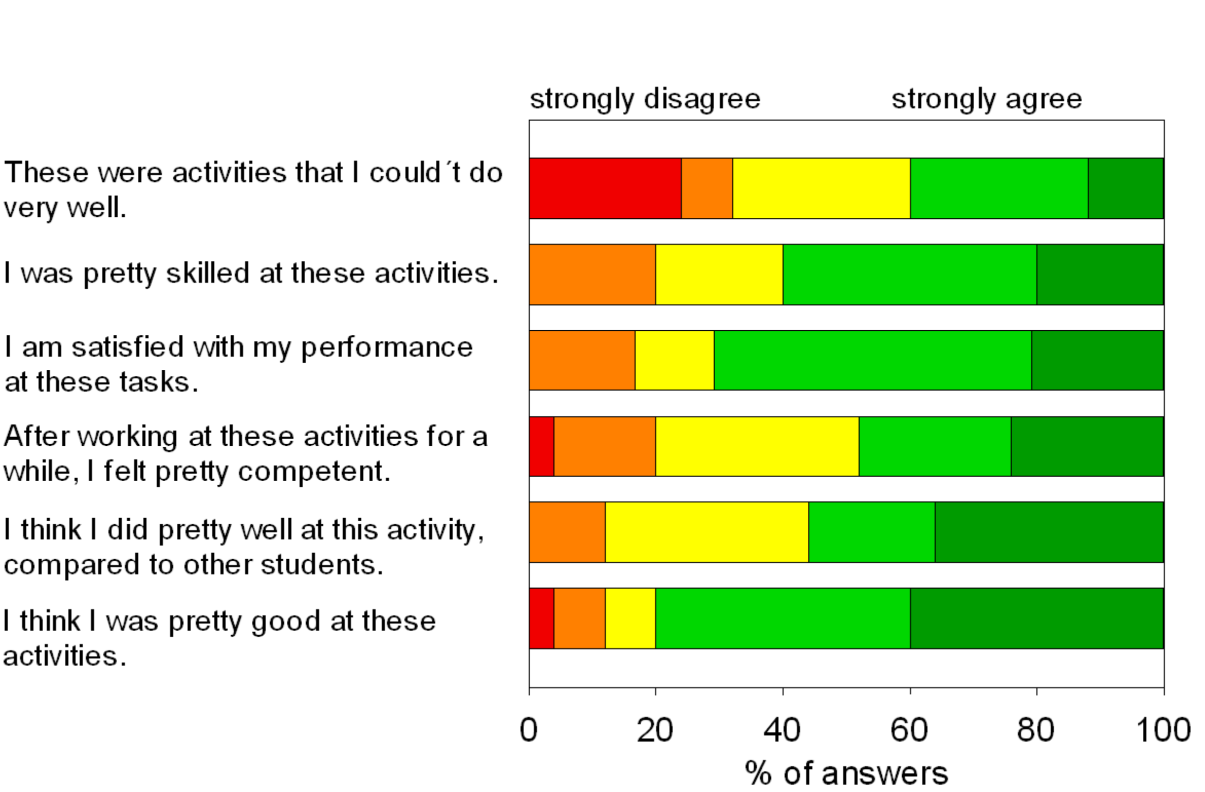

Fig. 5.1.2.9: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

Fig. 5.1.2.16 confirms that 40% of students agreed that they could not do the activity very well. The evaluation of perceived competence indicate that students were overburden with the activity, especially in comparison to the Bolzmann experiment, where only a minority (‹20%) thought that they could not do the activity very well (Fig. 5.1.2.10). The Double Slit experiment was conducted with students of grade 11, the age group should be adequate. However, in phase A learning scenarios were missing, what could explain that students were overstrained.

5.2 Phase A: Qualitative Research

5.2.1 Survey of Teachers (formal learning settings)

The SCeTGo system miniatures were introduced to 72 Finish pre-service science teachers and 27 Romanian in- service science teachers at schools during the implementation phase A. Out of this group 29 Finnish pre-service science teachers (gender:♀ 22, ♂ 7; age: Ø 26.8, range: 19-51 years) and 19 Romanian in- service ones (gender:♀=16; ♂=3; age: 45.8 range: 33-55 years) teaching physics, were asked about their attitudes towards SCeTGo and its carrying out in school.

We present a summarising content analysis (Table 5.2-1) integrating the results of individual interviews that have been conducted with the sample reported above.

A category was formed, if not less than two interviewee referred to the same aspect. Percentage to not refer to numbers of participants, but to the total number of answers given.

Participants were asked, if they were motivated to use the SCeTGo system in their future lessons. 75% agreed, 19% would not integrate the SCeTGo approach in instruction, 6% were undecided. Furthermore, in-service teachers and pre-service teachers, who indicated to use the exhibits, pointed out the most convincing features of SCeTGo: A visualisation of abstract phenomena was mentioned most frequently (38%), followed by an easy handling and a support during teaching (22%). In addition, they emphasized that they liked the hands-on activities (14%). However, only in a minority SCeTGo was estimated superior to books (4%).

All in-service and pre-service science teachers and practicing science teachers, who were not willing to take use of the SCeTGo exhibits were asked for their motives: In majority, interviewees referred to the prototype status of the miniatures (39%). Furthermore, they predicted miniatures to be to costly for an application in school (23%). Also some instructors found it to be difficult to understand all phenomena or would only apply some of the exhibits to practice (15%). In-service and pre-service science teachers highlighted several reasons, why they were motivated to take use of the SCeTGo exhibits: A majority of interviewees considered the less demanding theory in context of physical phenomena as a positive feature of SCeTGo (15%), followed by the illustrating visualization (13%). Interactivity (12%) and an innovative approach (10%) were positively emphasized. In addition inquiry based learning was stated as a positive aspect (10%). Further features referred to were a use of new technologies (9%), together with a great demonstration of physical phenomena (9%), a new teaching strategy (8%) and a user oriented design (7%). A connection to the curriculum, as well as a prevention of misconceptions was only mentioned in 4% of cases. Question 6 shows that the majority did not have problems, concerning the usage of the SCeTGo exhibits (65%). However, a minority felt uncomfortable to use the software (14%). The same ratio of interviewees found the physical phenomena difficult to understand and need more information (11%).

In summary questionnaires conducted in phase A could confirm that teachers evaluated the miniatures in combination with an AR technology as a valuable tool for instruction.

With regard to the specific objectives of the project (see 2.1) the qualitative analysis revealed that SCeTGo simplifies instruction, what implies that miniatures have a high value to teachers. Thereby, an AR enhanced learning system, as SCeTGo contributes to a new form of education.

Table 5.2.1-1:Summarizing content analysis of interviews conducted during the workshop with teachers in pilot phase A according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	%
Gender	Male	10	21
	Female	38	79
0 a) Subjects I'm a physics teacher and I have a master degree in astrophysics.	Physics	28	50
	Chemistry	4	8
	Biology	5	13
	Subject not related to natural sciences	14	29
What level do you teach:	Primary	10	21
	Inferior secondary/ gymnasium	20	42
	Upper secondary/ highschool	18	38
0 b) Citizenship	Finland	29	60
	Romania	19	40
0 c) Age	20 – 25	8	17
	25 – 30	15	25
	30 – 35	6	13
	35 – 40	9	19
	40 – 45	6	13
	45 – 50	4	8
	50 -55	3	6
0 d) Applied miniatures	All miniatures applied (Doppler Effect, Double Cone, Mini-wing, Young's Double Slits, Molecule Movement)	48	100
1. How did you take notice of the SCeTGo	Part of an university course	22	46
	Teacher trainer informed me	8	16

workshop?	Personal interest No answer given	2 16	4 33
2. What have you expected from the SCeTGo workshop, concerning knowledge, attitudes, and values?	No anwer No expectations Interesting and basic knowledge Application to a new teaching form Understanding the usage	2 18 11 11 7	4 37 22 22 14
3. Did the SCeTGo workshop come up to your expectations, concerning knowledge, attitudes, and values?	Yes No In between	20 3 7	67 10 23
4. Are you motivated to take use of the SCeTGo approach in your future lessons?	No answer Yes No	3 36 9	6 75 19
If "yes": What exactly convinced you, to make use of the SCeTGo approach?	Hands-on approach Miniatures help with teaching Superior to books Easy handling Visualisation of abstract phenomena	7 11 2 11 19	14 22 4 22 38
If "no": Please mention the reasons, why you don't want to make use of the SCeTGo approach!	Tools need more development Would only use some of them Did not understand all phenomena Too expensive Too much effort	5 2 2 3 2	38 15 15 23 14

5. What do you think are the most positive aspects of the SCeTGo approach?	Innovative approach	9	10
	Easy to understand	14	15
	Great demonstration	8	9
	visualise invisible aspects of a phenomenon	12	13
	Use of new technologies in school	8	9
	New strategy	7	8
	Interactivity	11	12
	User oriented design	6	7
	Inquiry based learning	9	10
	Connection to the curriculum	4	4
	Prevention of misconceptions	4	4
6. Is there something you didn't understand, concerning the usage of the SCeTGo exhibits?	No	24	65
	Difficult to understand	4	11
	Feel uncomfortable to use the software	5	14
	Need more information	4	11
7. Are you satisfied with the SCeTGo workshop?	Yes	27	56
	No	8	17
	In-between	13	27
If "yes": What did you like?	Easy to use	12	17
	Application of a new technology	17	24
	Impressive tool/ technology	15	21
	Great idea	9	13
	Good teaching approach	11	15

	Great demonstration	8	11
If “no”: What should be enhanced in future workshops?	Longer demonstration	4	9
	Software does not work to 100%	9	19
	Miniatures are so far only prototypes	6	13
	Instructors need more knowledge	8	17
	More explanations	8	17
	User manuals should be added	5	11
	Learning scenarios were missing	3	6
	User sheets for pupils should be added	4	9

8. Any comments?

Positive comments:

- It's cheaper than going to a science centre.
- Have to try it with pupils.
- Looking forward to see how it works in future.
- You can see things/phenomena you normally could not see.
- Great connection to real life.

Recommendations for improvements:

- Miniatures should work more accurately.
- There are still some bugs in the system.
- The Presentation is hard to organize in a classroom (everyone wants to see and wants to touch).
- Augmentations are not self-explanatory - more explantion is needed.
- Each exhibit should be accompanied by a user manual and educational activity.
- Teachers need proper training prior to usage concerning the technical and the scientific part.
- Great potential, but needs to be „revised“.
- To be sold at schools it has to work 100 %.
- Some of the scenarios can not be implement as part of the existing curriculum.
- It is necessary to adapt the scenarios for the lower secondary level.
- New miniatures with regard to the leaning surface and the friction force should be developed.
- Miniatures are only at the beginning of a long way.
- A hand book with SCeTGo scenarios or a brochure would facilitate the usage of miniatures.

5.2.2 Survey of Students (school)

As part of students' validation of phase A miniatures were presented to 512 Romanian pupils, 6% of the participants were interviewed. Hereby, we show a summarising content analysis, integrating the results of individual interviews that have been conducted with 32 Rumanian students (gender: ♀ 23, ♂ 9; age: Ø 15.4, range: 12-17 years). A category was formed, if not less than two interviewee referred to the same aspect. Percentage to not refer to numbers of participants, but to the total number of answers given. All students asked if they were satisfied with the lesson answered in the affirmative. As shown in question 7.2 students were satisfied with the lesson, because they liked most contact with experts (26%). Furthermore they favored learning with real objects and real experiments (17%), same ratio of interviewees preferred a student-centered learning approach. In addition a lesson, different to everyday, school was looked upon as favorably as the innovative approach (11%). The multimedia aspect was mentioned in 10% of cases, to a lesser extend it was stated that learning with miniatures was fun (7%). Additionally, students were asked if the lesson raised their interest in science. Most of students answered positively (88%). Nobody negated the question and only a minority of students were unsure about this question (13%). The lesson raised students` interest in science for different reasons. In a majority something extraordinary, different from everyday class (30%) was stated as a cause. An interactive approach, as well a simplification of theory, easier in comparison to normal lessons was mentioned to a same amount (26%). In addition, a different way of learning provided by the exhibits was pointed out (18%).
Overall, the feedback given by pupils within the individual interviews was mostly positive.
According the data students really liked working and learning with the miniatures. They did not suggest any improvements. Students rated pedagogical effectiveness with regard to an increase in interest in natural science and enjoyment of the lesson positively.
In particular, the hands-on approach of the miniatures, the student-centered lessons and the multimedia aspects was accentuated. The application of the SCeTGo miniatures raised students` interest and activated the majority of participants to get more involved in science contents. The high percentage of interested students shows that most of them were inspired by the exhibits and the AR technology. With regard to the projects` objectives we could confirm that the SCeTGo approach raise interest in science and science motivation and reach to induce engagement of students in experimental science learning.

Table 5.2.2-1: Summarizing content analysis of interviews conducted during the workshop with students (school) in pilot phase A according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	%
Gender	Male	9	28
	Female	23	72
0 a) Grade/ Semester	6	3	9
	7	0	0
	8	5	16
	9	8	25
	10	6	19

	11	10	31
0 b) Citizenship	Romania	32	100
0 c) Age	12 14 15 16 17	3 5 8 6 10	9 17 25 19 31
0 d) Applied miniatures	Doppler Effect Double Cone Mini-wing Young's Double Slits Molecule Movement	6 6 6 7 7	19 19 19 22 22
0 e) Did you know in advance, that the lesson today would be a special self-guided one with computer-assisted miniature exhibits?	Yes No In between	11 14 7	34 44 22
1.Did you look forward to the lesson?	Yes No In between No answer	28 0 2 2	88 0 6 6
1.1 Reasons why not:	Preferation of other subjects (arts)	1	3
1.1 Reasons why yes:	Innovations Fun Contact with experts	14 13 3	44 41 9
2.Expectations	Advertisement for university Something extraordinary	1 16	2 36

	Easier theory No answer	23 5	51 11
3. Did the lesson come up to your expectations?	Yes No In between No answer	27 0 2 3	84 0 6 9
4. Did the lesson raise your interest in science?	Yes No In between	28 - 4	88 - 12
4.1. Reasons why not:	No answer	32	100
4.2. Reasons why yes:	Different way of learning Interactive approach Easier theory Something extraordinary	8 12 12 14	17 26 26 30
5. Most positive aspects of this learning scenario	Real objects Practical oriented Enough time IBSE Multimedia	14 25 3 4 6	44 78 9 13 19
6. Problems concerning the usage	Yes - technical No In between	5 27 -	16 84 -
7. Are you satisfied with the lesson?	Yes No In between	32 - -	100 - -
7.1 If not: Improvements	-	-	-

7.2 If “yes”: What did you like?	Real objects/experiments	11	18
	Different to everyday school	7	11
	Multimedia	6	10
	Student-centred learning	11	18
	Contact with experts	16	26
	Fun	4	6
	Innovations	7	11
8. Any comments	-	-	-

5.2.3 Suggestions for improvement

Suggestions for improvement were summarised to optimise the revision of the SCeTGo suitcase and to improve each miniature and the corresponding scenarios developed (5.2.3-1).

Table 5.2.3-1: Suggestions for improvement of the SCeTGo system

Doppler Effect Experiment: - It is not easy to understand that the actual frequency emitted doesn’t change. I would expect to see both what frequency the source emits and what the frequency the receiver perceives. - The sound is horrible; I would prefer the single tone sound. - The Sound stays behind movement.
Double Cone Experiment: - The whole system needs a few moderations so it can be steadier. - I didn't understand the maths/ physics behind it. - The miniature is very abstract (should be connected to real world). - It requires too high physics. The mathematical background is to complicated. - The double cone can be adapted to lower secondary school by deleting the trigonometric formula. - The angle calculation should be more accurate. - The model should be bigger.

- The formula may confuse students.
Mini-wing Experiment: - I didn't find the bridge between eyes and ears, I need more explanations. - The exhibit is too difficult to explain in a meaningful way. - What is the model behind it? What are the arrows for? - The direction of the wind flow should be shown. - More variation, different wing shapes should be provided. - What is the optimum angle for rising. - How did they model this? - Better visualisation.
Young's Double Slits Experiment: - Phenomena behind the equipment are quite hard to understand (if you are not a physical teacher for physics). - I would expect to be able to see all three cases (photons, electrons and marbles), be able to change the distance between the slit and between the double slit and the screen. I would also like to change colours so the students would be able to make some calculations instead of just playing with the exhibit. - I wasn't happy with the screen showing the mathematical formula. - It is just a mathematical representation. - Different colors should be used. - What is the context to real life (too abstract)? - Use different obstacles. - View angle (behind, up).
Molecule Movement Experiment: - Better appearance of the heat source etc. - Bigger temperature differences, molecules could change colors. - Molecules doesn't move right all the time - Movement should be more fluent. - Temperature could be shown on the screen. - Thermometer didn't work accurate.
Suggestions for new experiments: - buoyancy, central force, rotation moment - geography, weather (how clouds and rain forms)

- gravity, conductance, magnetism, biology (circulation of blood) - sound waves while speaking - structure of atoms and molecules - chemical compounds - states of water, surface tension - gravitation - how the light reflects from mirror

5.3 SCeTGo Suitcase Revision

Based on the results of the validation and the feedback given in phase A (Table 5.2.3-1), the SCeTGo suitcase was updated for phase B. Miniatures were revised and improved and an update of the software was carried out. Improvements conducted are summarized in note form in Table 5.3-1.

Table 5.2.3-1:Revision of the SCeTGo suitcase after implementation phase A

Doppler Effect Experiment: - Screen showing scale factor and additional data to allow students to calculate with the numbers have been added, formula has been included. - Exchange of microphone with a virtual person (has been changed back, since person was hard to recognize).
Double Cone Experiment: - New cones were printed to allow for colour coding. - Parameters are shown on the screen.
Mini-wing Experiment: - New wing types cylinder and plate were added. - Cylinder were supplemented as a third wing shape. - Drag arrow were changed to point backwards. - Fan was integrated to control airflow. - Molecules have been added to the fan. - Airplane has been added to the Augmented View.
Young's Double Slits Experiment: - Tangible model was changed to improve tracking and stability and to allow the slits to be set in different positions

- Electron canon to bridge the gap from the particles to waves was added (before that there were two separated exhibits (balls and waves). They were merged to one exhibit which consists of balls, electron canon and waves. - In Version A the slit could be brought in three different distances to the back screen, in version B it is freely movable.
Molecule Movement Experiment: - Boltzmann graph “Molecule Movement” added. - New Fridge model has been created (old one caused problems with tracking). - Markers were improvements for better tracking stability (markers were heavily used since kids needed to touch them).
Additional changes made: - Markers were improvements for better tracking stability (markers were heavily used since kids needed to touch them). - Inlay was adapted due to new models. - Software was updated: • Help files were updated. • Video was updated. • Exhibit Selection UI, installer, and updater were updated.

5.4 Phase B: Quantitative Research

In the implementation phase B of the SCeTGo project (01/02/2011 – 01/12/2011) we included science museum staff (Heureka, Finland) and researchers of the participating organizations (universities and schools), as well as university students. We presented revised miniatures with the corresponding learning scenarios (further information is given in the Scenarios Adaptation and Development Report D3.1.) in the validation events (see 3.2).

5.4.1 Survey of Science Teachers (formal learning settings)

In the framework of different implementation events (see chapter 4) we introduced the SCeTGo system to 9 Swedish, 20 Spanish, 17 Greek, 19 Romanian and 3 Finnish science teachers. Altogether 68 science teachers filled out the questionnaires (gender: ♀41, ♂27; age: Ø 26.8, range: 23-60 years). Results are presented as follows.

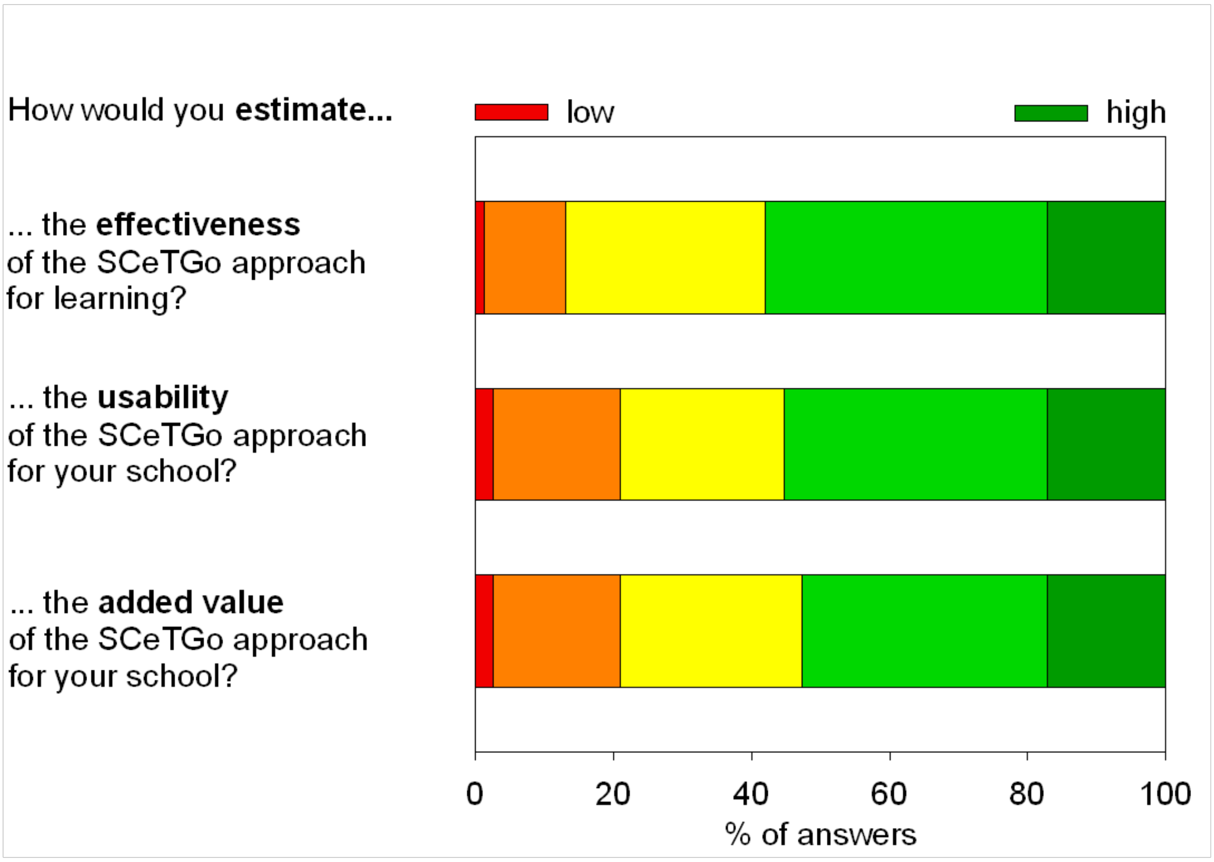

Fig. 5.4.1.1:Evaluation of Pedagogical Aspects I (VALNet)

Fig. 5.4.1.1 demonstrates that over 50% of the teachers estimated the effectiveness for learning, the usability for the school and the added value for the school in relation to the SceTGo approach at a high level. In addition, a less amount of teachers pointed out that the SceTGo approach was effective, usable and adding value at an average level. Furthermore, only a minority estimated the effectiveness for learning at a low level (15%). Moreover, the usability and the added value were assessed as low only by a very small amount of teachers (‹ 3%).

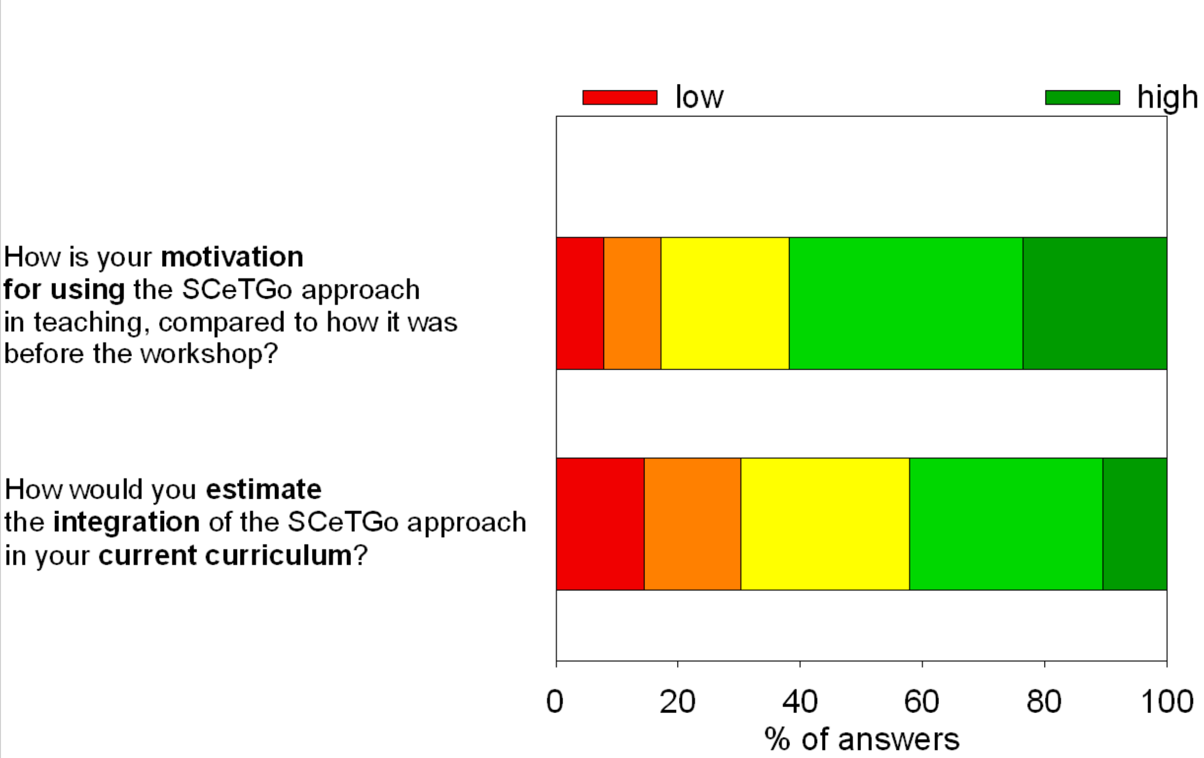

Fig. 5.4.1.2: Evaluation of Pedagogical Aspects II (VALNet)

As shown in Fig. 5.4.1.2, the motivation for using the SceTGo approach in teaching, compared to how it was before the workshop, was assessed as high by the majority of teachers (62%). Futhermore, 21% were motivated at an average and not even 20% of the teachers considered that their motivation was low (17%).

Although the motivation for using the SceTGo approach was highly valued, the integration of it in the current curriculum was estimated to be low by nearly one third of the teachers (30%). However, it was estimated at a high level by 42% and another 28% stated that it was integrated at an average.

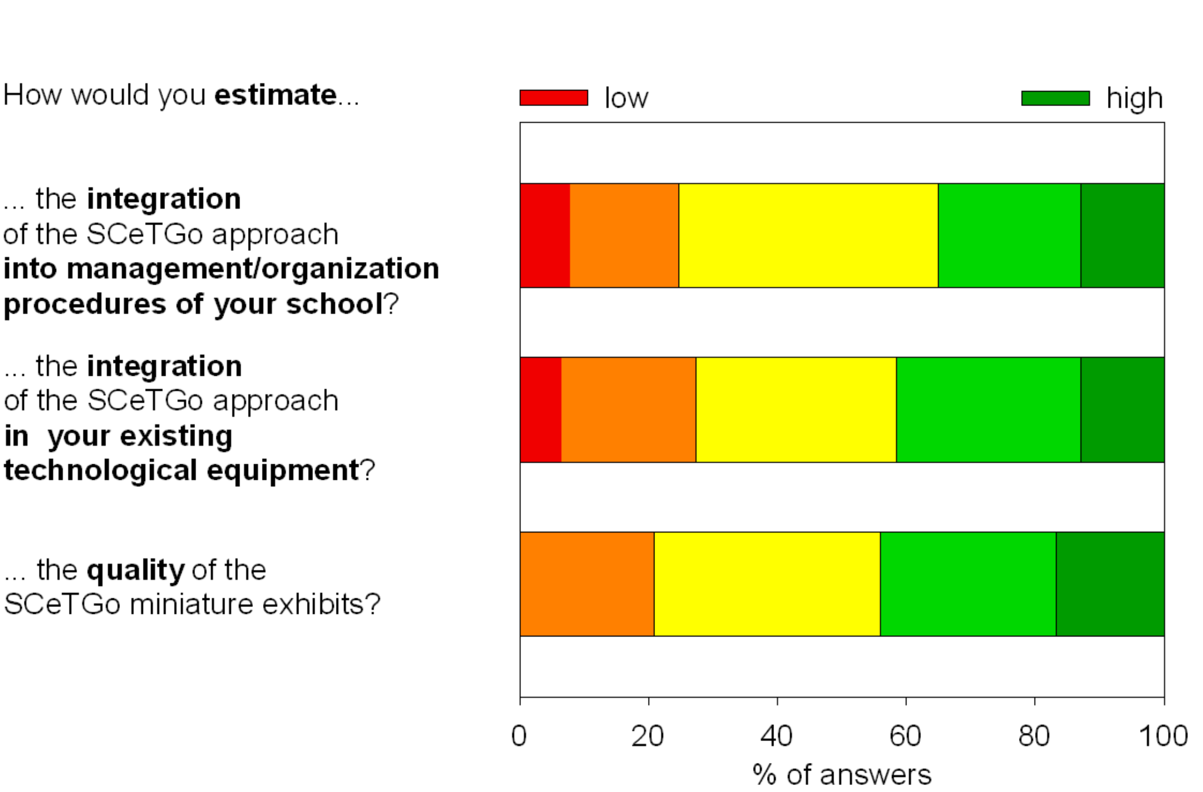

Fig. 5.4.1.3: Evaluation of Technological Aspects (VALNet)

Fig. 5.4.1.3 illustrates that opinions about the integration of the SceTGo approach into management/organization procedures of the respective school varied. Over one third of teachers valued it to be high (35%), 40% pointed out that it was integrated at an average level and it was shown by further 25% that the integration of it was rated to be low. Comparing it to the integration in the existing technological equipment, more teachers estimated it to be high (42%). Furthermore, Fig. 5.1.1.2 shows that another 31% of teachers thought it was fairly integrated in the existing technological equipment. In addition, 27% of teachers stated that the integration in the existing technological equipment was low. In contrast to the latter estimations about integration, the estimated quality of the SceTGo miniature exhibits was highest (44%) in this part of the evaluation. In addition, a considerable amount of teachers assessed the quality at an middle rate (35%). Moreover, no interviewee stated the quality to be very low, only 21% estimated it to be of lower quality.

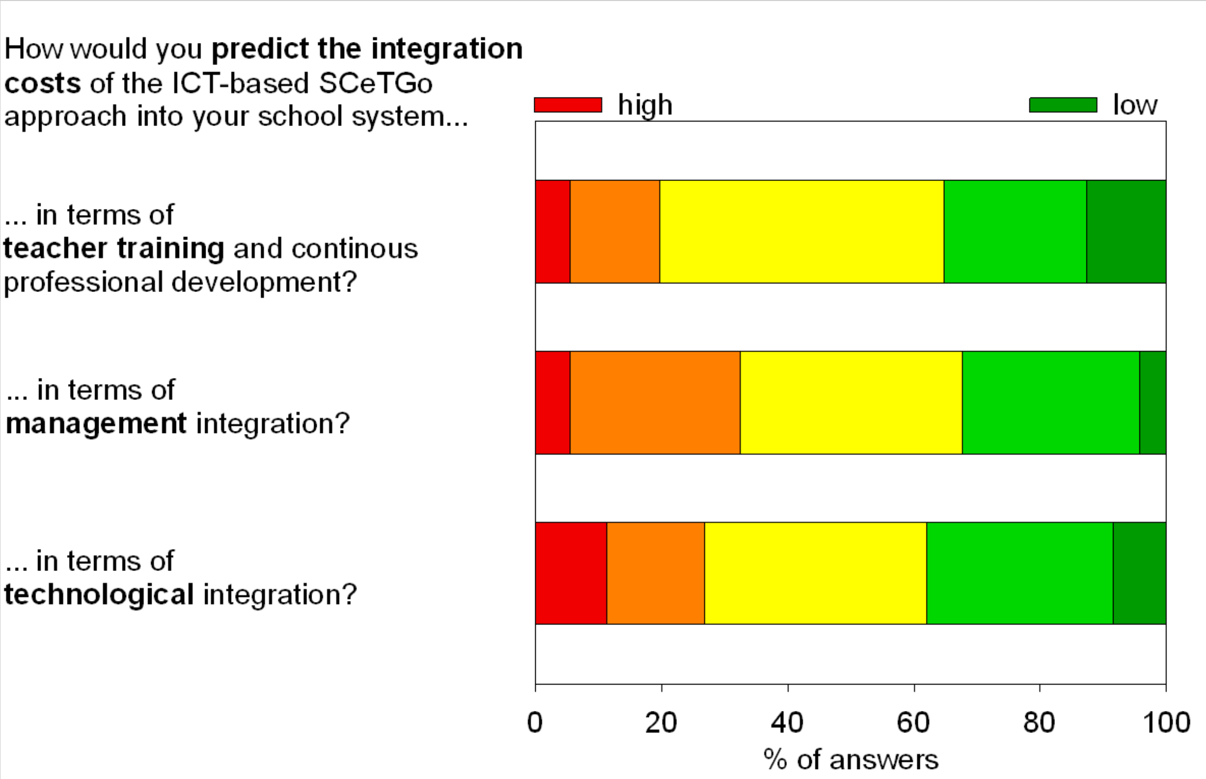

Fig. 5.4.1.4: Evaluation of Economical Aspects (VALNet) I

As it is confirmed by Fig. 5.4.1.4, most of the teachers predicted that the integration costs in terms of teacher training would be at an average level (45% of teachers). Furthermore, one third of teachers predicted these costs to be low (35%) and the smallest amount of interviewees forecasted that the costs would be high (20%). In terms of management integration, the costs were predicted to be low by 32%. Moreover, 35% of teachers pointed out that costs concerning management integration would be at a middle rate, whereas another third of teachers said they would be high (32%). In terms of technological integration, the pattern is similar to the previous one. The highest percentage of teachers predicted the costs to be low in this case (38%). In addition, 27% stated that the costs concerning technological integration would be high. All in all, the results were similar to each other and show only fractional differences which indicates that opinions about integration costs differ and that the interviewees do not have definite notions about this issue.

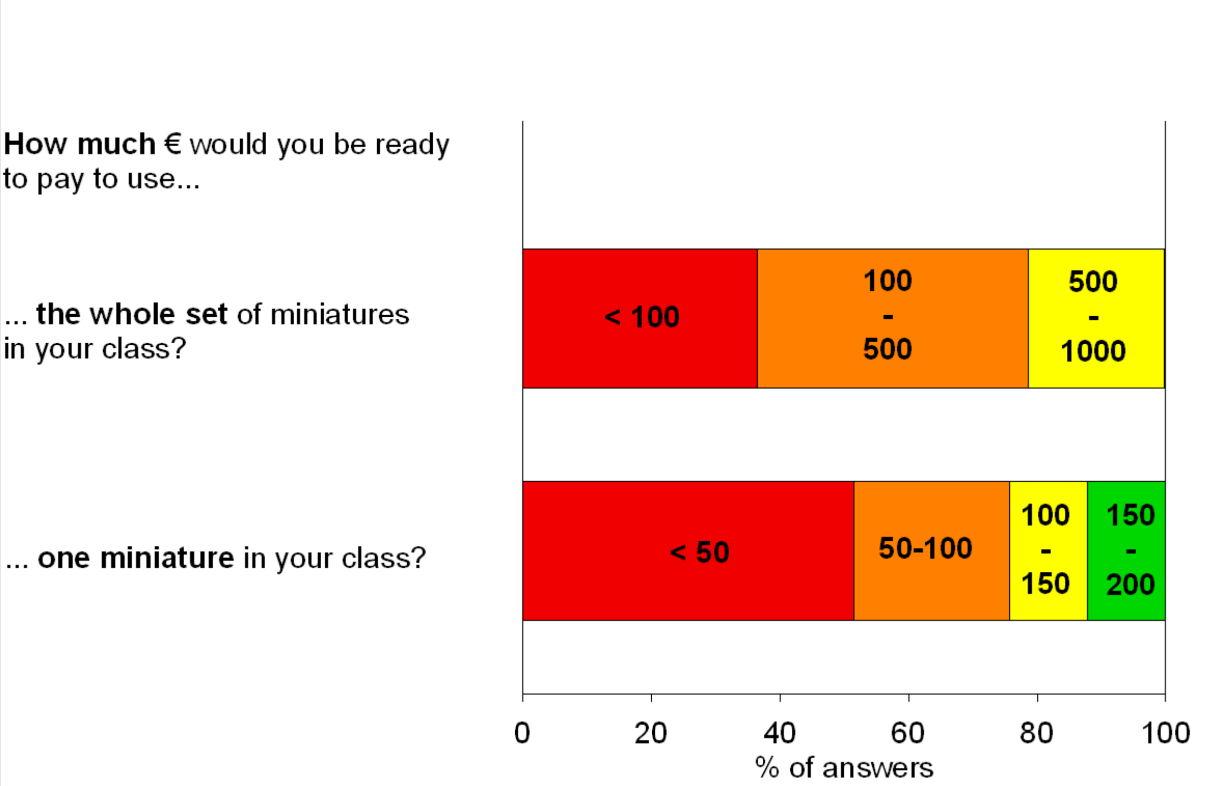

Fig. 5.4.1.5: Evaluation of Economical Aspects II

As shown in Fig. 5.4.1.5, most of the 33 teachers would spend 100-500 € for the whole set of miniatures in order to use it in their class (42%). A similar amount, however, would not pay more than 100 € for the whole set (36%). Furthermore, least teachers would spend 500-1000€ for the whole set (21%). For one miniature, over the half of them would not pay more than 50 € (52%). Moreover, 24% of teachers would spend between 50-100 €. In addition, an equal number of teachers would pay 100-150 or 150-200 € (12%). Due to a mistranslation only 33 teachers answered this question.

Fig. 5.4.1.6: Evaluation of Interest/Enjoyment (Intrinsic Motivation Inventory)

As it is shown in Fig. 5.4.1.6, the majority of teachers enjoyed doing the activity or thought it was interesting. To specify this, 46% of teachers highly enjoyed the activity; additionally, 31% enjoyed it much. The same results were shown when teachers were asked if they found the activity boring. In this case for example, 71% did not think that the activity was boring at all. Due to a mistranslation only 59 teachers answered this question.

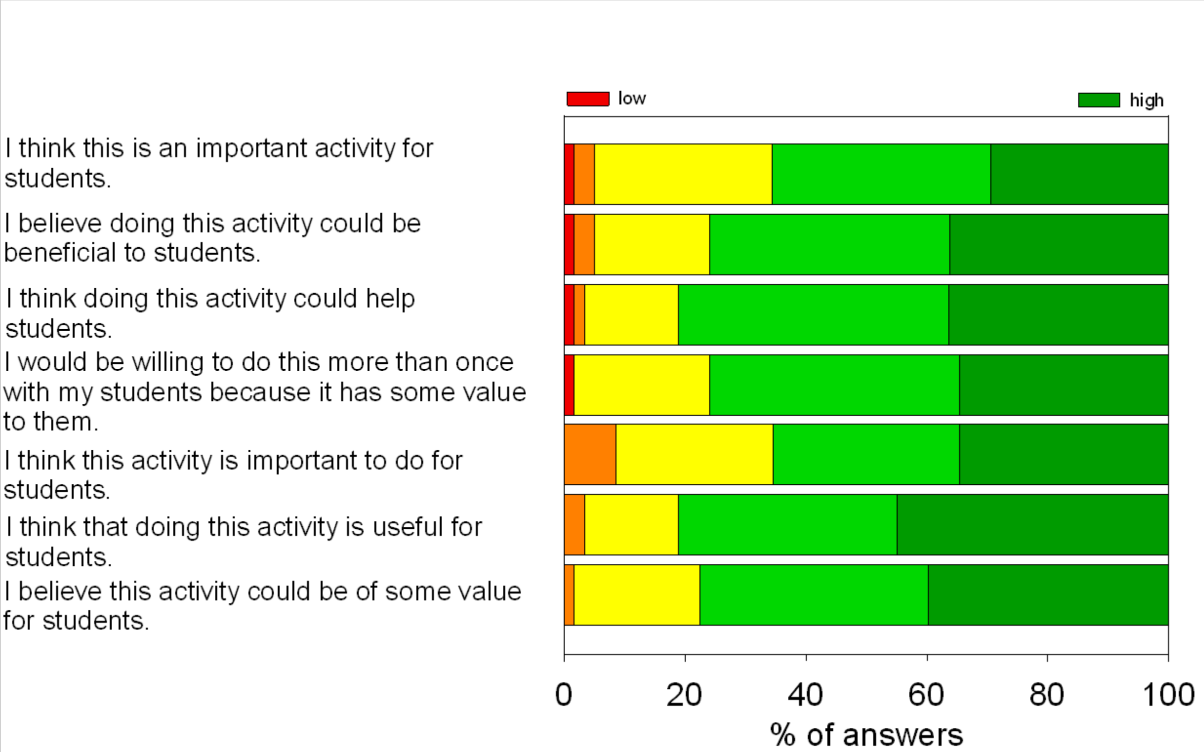

Fig. 5.4.1.7: Evaluation of Value/Usefulness (Intrinsic Motivation Inventory)

As Fig. 5.4.1.7 demonstrates, the huge majority of teachers evaluated the activity positively. Thus, 45% of the teachers, for example, pointed out that the activity is very useful for students. In the same case, 36% stated that they found it useful. Furthermore, between 16% and 29% rated the activity positively at an average level. In addition, only a very small amount of teachers evaluated the activity negatively (2%-5%). Due to a translation error only 59 teachers answered this question.
In summary the quantitative results of teachers` evaluation in phase B a very satisfying.

5.4.2 Survey of Educators (informal learning settings)

In addition to teachers and students we also validated workshops with experts in the field of IBSE from the Heureka science centre. 22 member of the science center staff filled out the questionnaires (gender: ♀13, ♂5; age: Ø 37, range: 21-57 years). Comparable to the teachers` questionnaires we administered the VALNet subscales for pedagogical, technological and economic aspects and the subscales Value/Usefulness and Interest/Enjoyment of the Intrinsic Motivation Inventory.

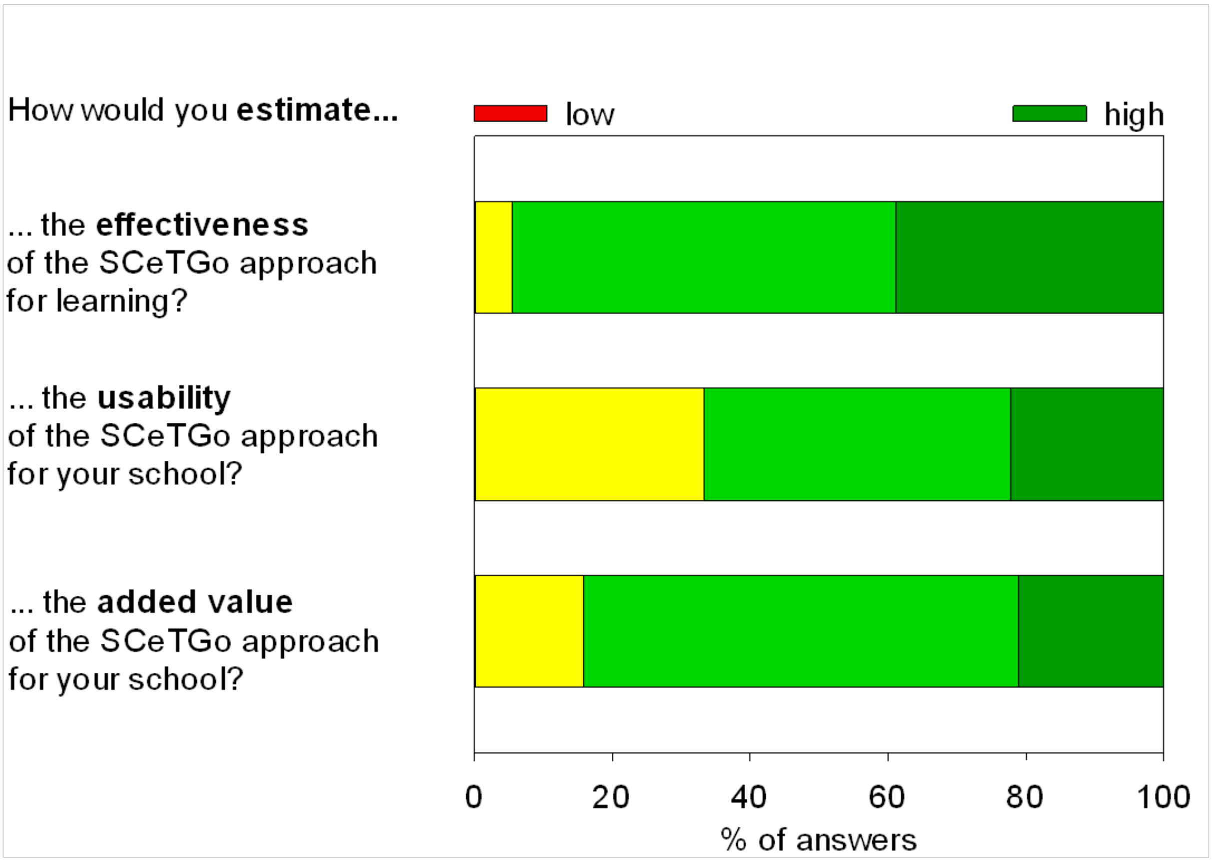

Fig. 5.4.2.1: Evaluation of Pedagogical Aspects I (VALNet)

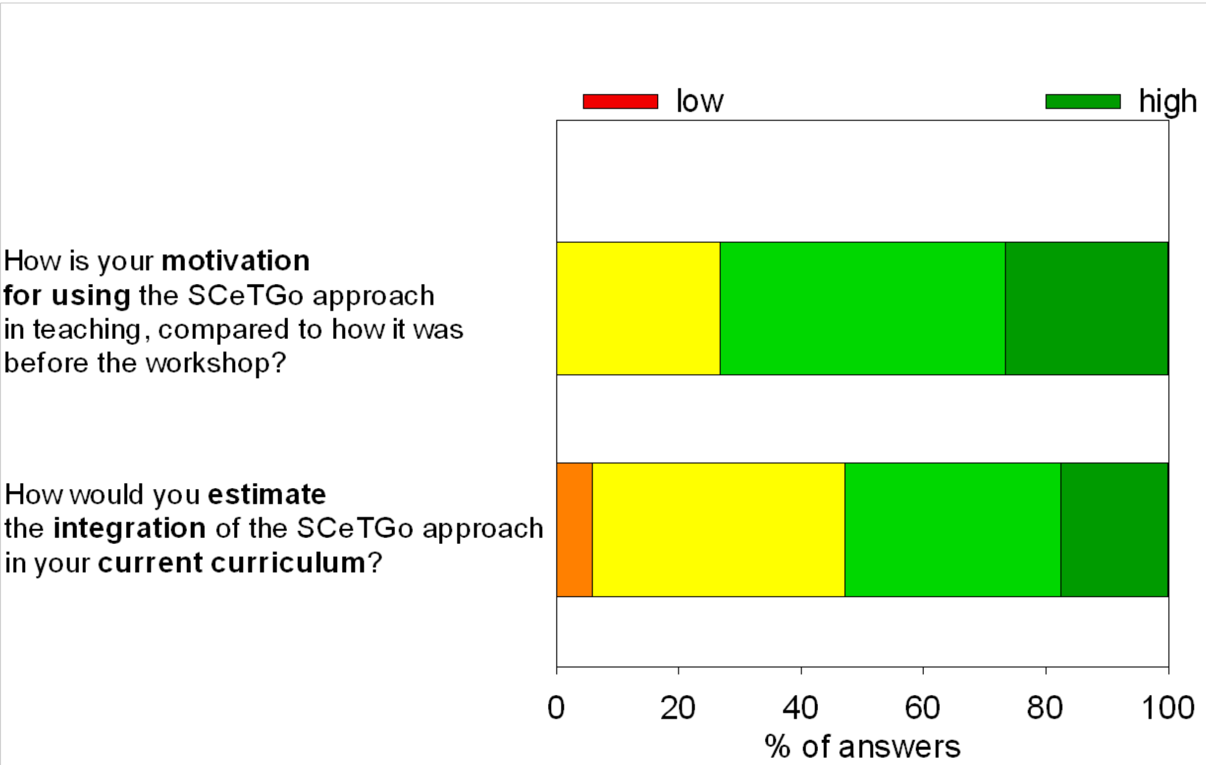

Fig. 5.4.2.2: Evaluation of Pedagogical Aspects II (VALNet)

Concerning pedagogical aspects (Fig. 5.4.2.1 and Fig. 5.4.2.2), the majority of educators rated the SCeTGo approach as very positive. This refers for example to its effectiveness for learning, its usability and value for their schools. Most of the educators are more motivated after the workshop than before to use the SCeTGo approach, and that half of them think positive about an integration it in the curriculum. Thus, the pedagogical aspects of the approach were evaluated in a very satisfying way, indicating that experts, similar to teachers, consider the approach to be pedagogical valuable.

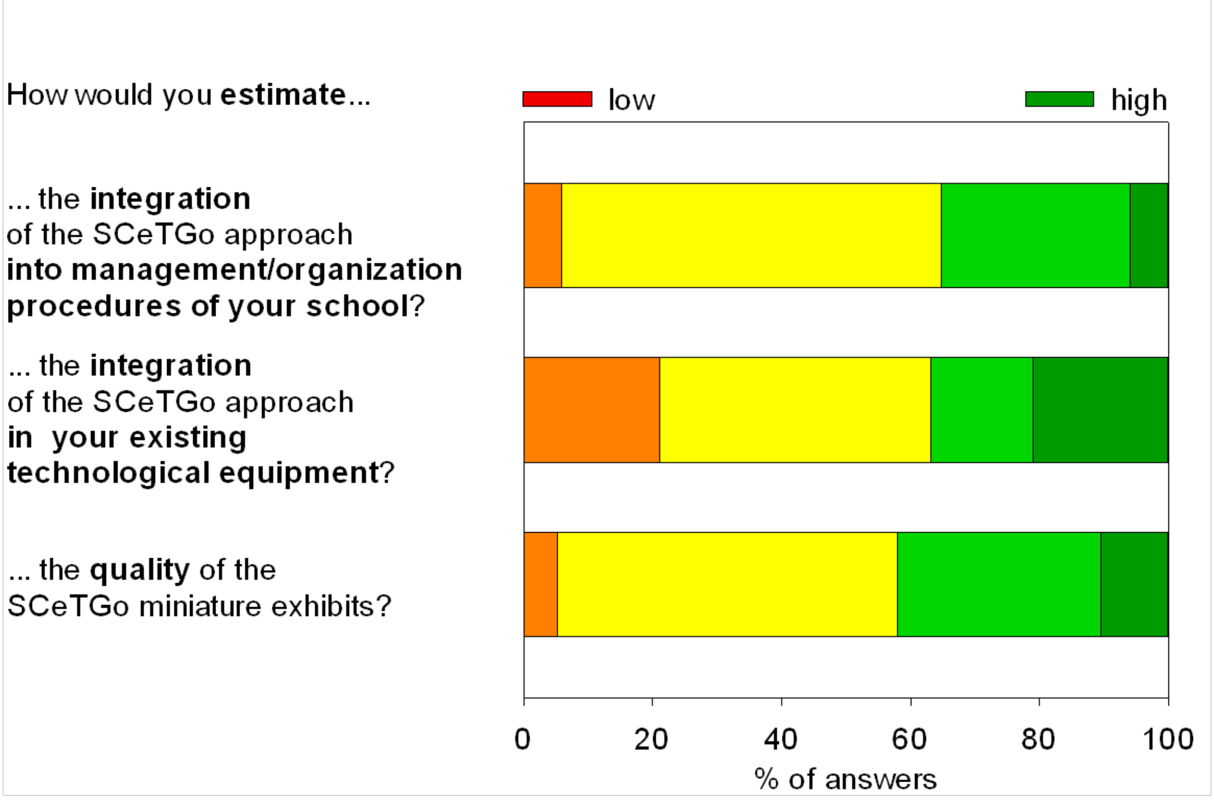

Fig. 5.4.2.3: Evaluation of Technological Aspects (VALNet)

Fig. 5.4.2.3 indicates that there are mostly seen only medium chances for integration of the SCeTGo approach into management/organization procedures of the school and in the existing technological equipment. The quality of the SCeTGo miniature exhibits was seen also mostly medium.

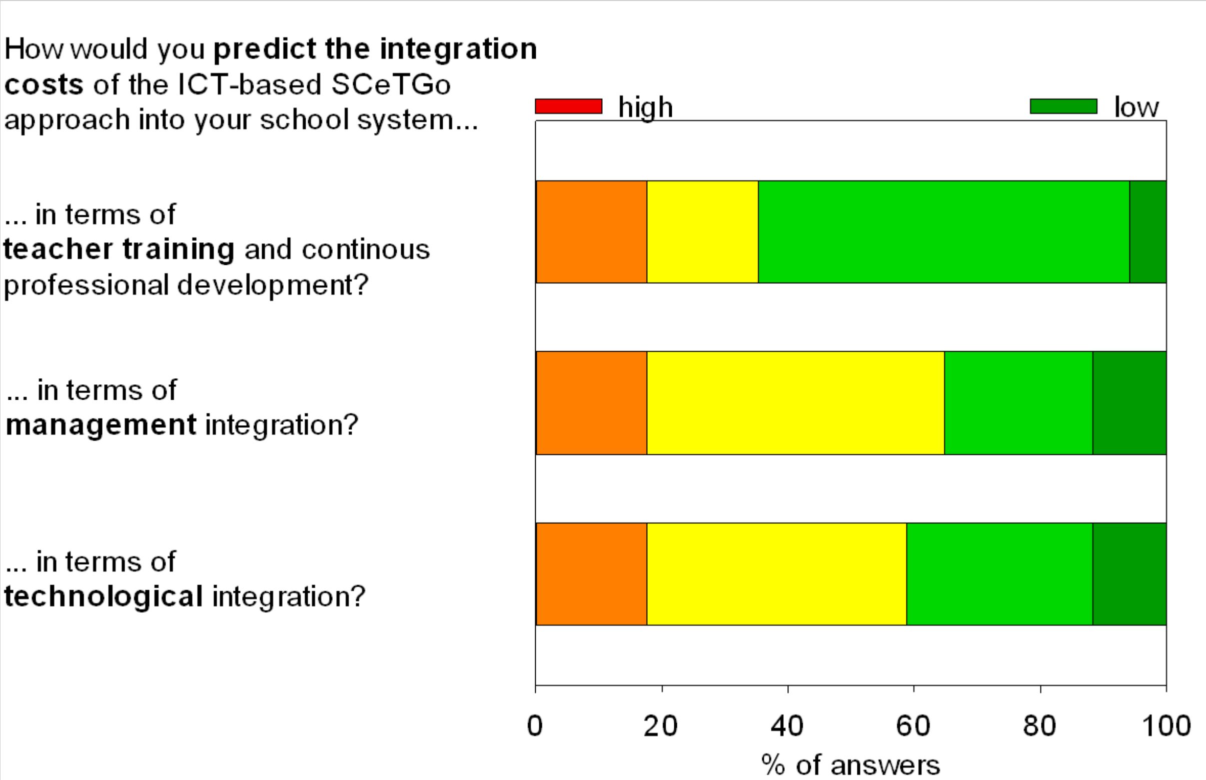

Fig. 5.4.2.4: Evaluation of Economical Aspects (VALNet) I

Most of participants predicted the integration cost the of ICT-based approaches into their school system as low or medium (Fig. 5.4.2.4). Management integration and technological integration is estimated to be higher than costs in terms of teacher trainings.

Fig. 5.4.2.5: Evaluation of Interest/Enjoyment (Intrinsic Motivation Inventory)

Furthermore, the majority was very satisfied with regard to interest and enjoyment (Fig. 5.4.2.5) which is also in line with the results of the teachers.

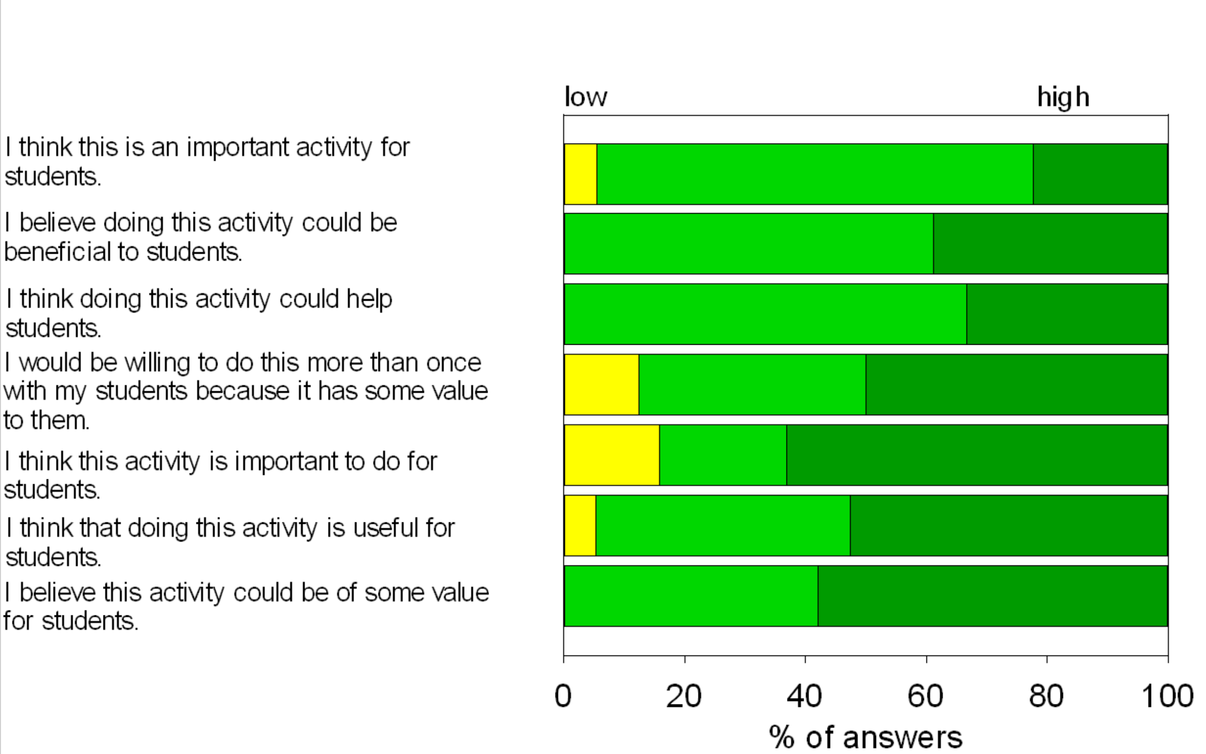

Fig. 5.4.2.6: Evaluation of Value/Usefulness (Intrinsic Motivation Inventory)

Every participant estimated the effectiveness as well as the usability and the added value of the SCeTGo approach high or at least medium (Fig. 5.4.2.6). Most of the participants thought, that this activity is useful and important for students. Only a few had an medium opinion, a negative answer was not given.

5.4.3 Survey of Students (school & university)

In Phase B the students' evaluation was divided in two groups divided by age. The first group consists of 97 school students (64 male, 31 female) in average 15 years old from Romania and Sweden. The second group comprised 200 university students, they were in average 24 years old and participated in SCeTGo validation events in Finland and Greece.

A comparison of these two groups is very interesting and important for our project as it covers the whole age range of students we are interested in.

All in all we can say according to the evaluation results that the SCeTGo miniatures are appropriate for both age groups. The complete evaluation results are shown in the appendix. In this chapter of the report we point out the most meaningful evaluation results, figures presenting interesting aspects are shown.

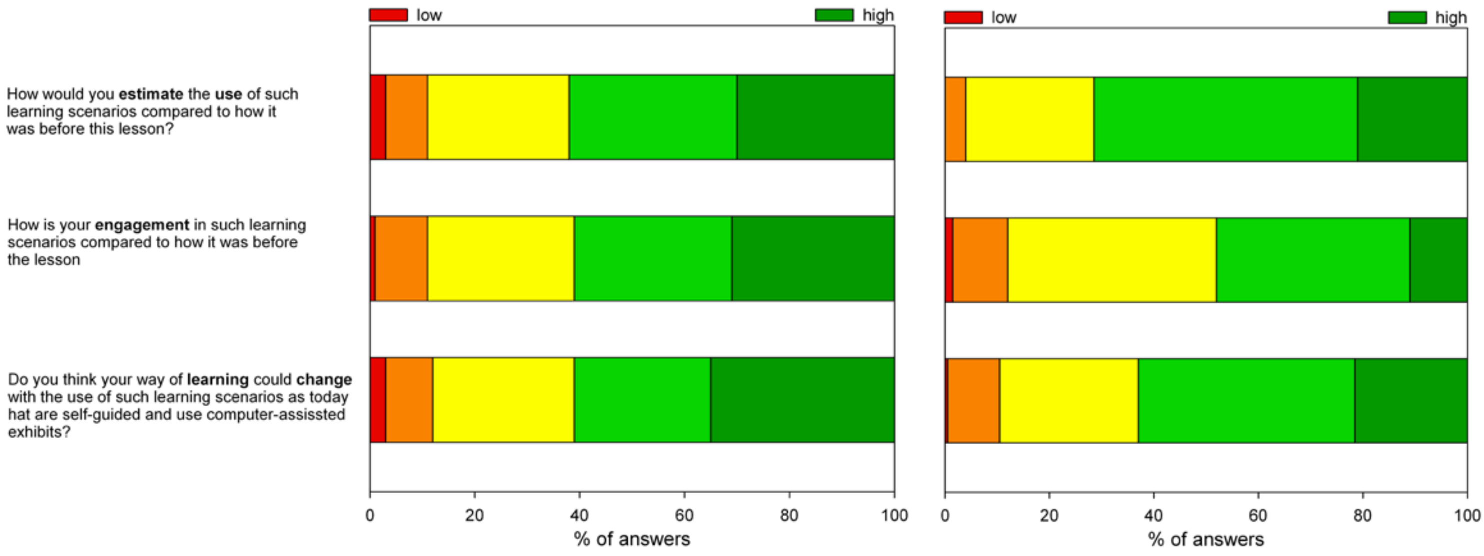

Fig. 5.4.3.1:Evaluation of Pedagogical Aspects I (VALNet); left: students (school), right: students (university)

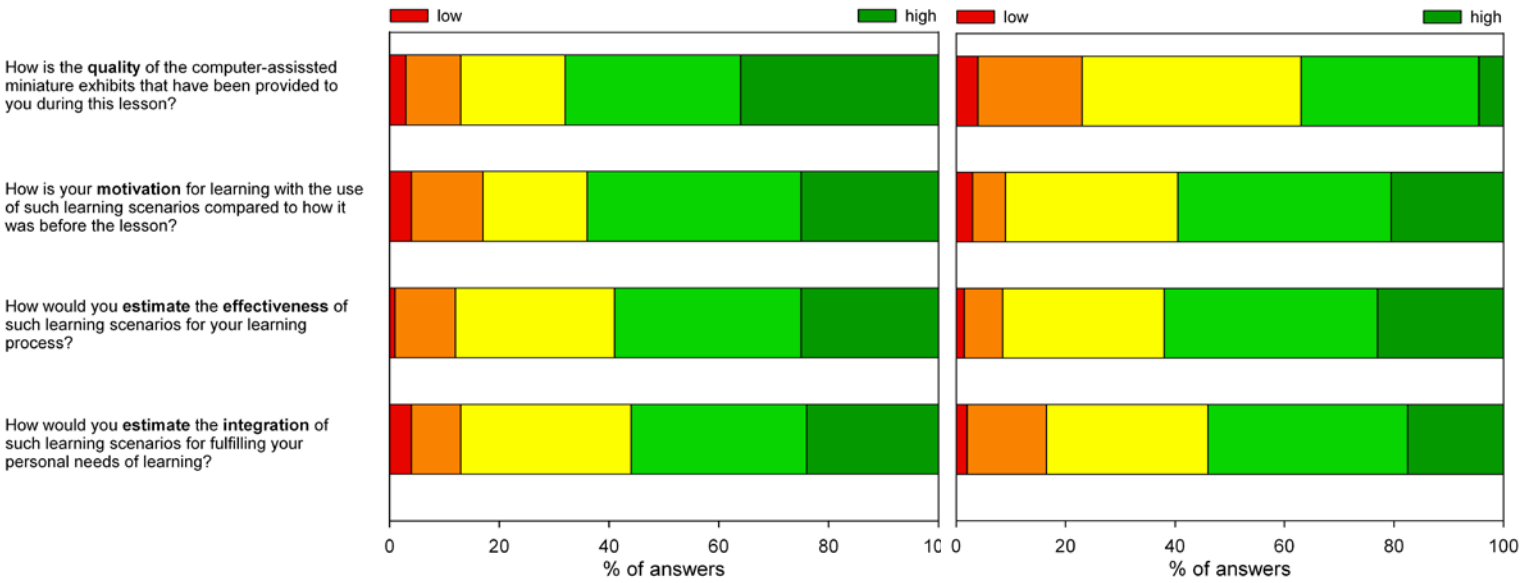

Fig. 5.4.3.2: Evaluation of Pedagogical Aspects II (VALNet); left: students (school), right: students (university)

In both groups more than 60% enjoyed learning with the SCeTGo miniatures and found them fascinating (see Appendix). Interesting for the SCeTGo approach is that 51% of the younger students and 59% of the older ones (totally) agreed to the aspect that they like challenging tasks. This means that independent from age and cognitive development students like the SCeTGo pedagogical approach of inquiry based learning. This is an appropriate pedagogical method which is suitable for motivating students and raises their interest in science. In line with that around 60% of the students reported that their way of learning could change by the use of such learning scenarios and by self-guided and computer assisted exhibits. The lesson the students participated is important as the students say that they use and get engaged in that learning scenarios after the lesson more than before (Fig. 5.4.3.1.).

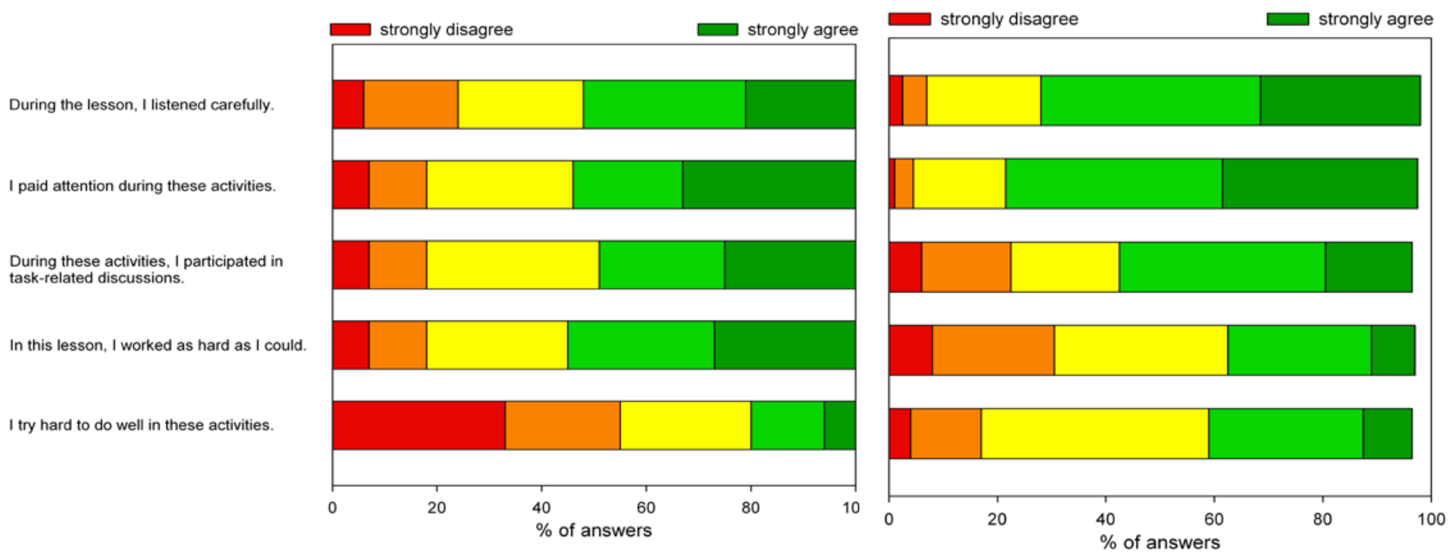

Fig. 5.4.3.3:Evaluation of Behavioral Engagement (Student Engagement Questionnaire); left: students (school), right: students (university)

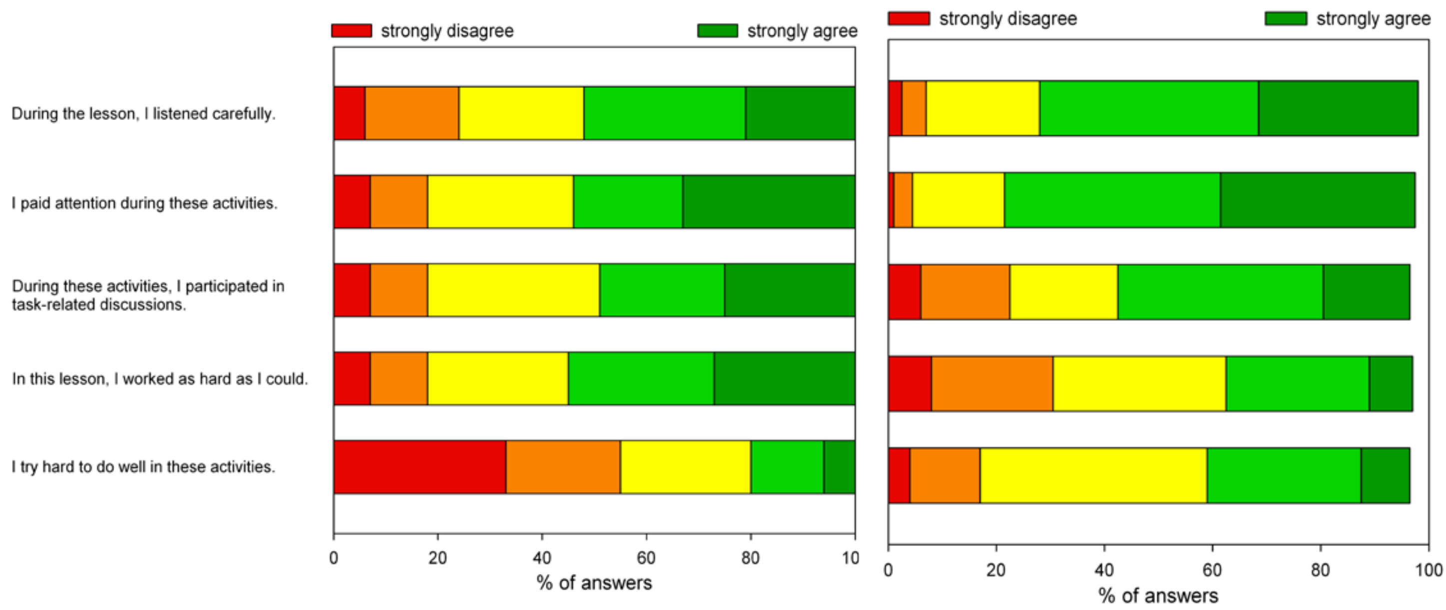

Fig. 5.4.3.4: Evaluation of Emotional Engagement (Student Engagement Questionnaire); left: students (school), right: students (university)

Comparing the results of behavioural tendencies during the lesson the age difference is the most important parameter for the results (see Fig. 6.1.3.3).
The younger students listened more careful (52%), paid more attention (54%) and worked harder (56%) than the older ones (60%; 76 %; 34.5 %). The older students, however, tried harder to do well (37.5 %) and discussed more during the activities (54 %) than the younger ones (21%; 50%). However results could also indicate that younger students set more values to positive answers with regard to a social desirability.
Nevertheless the situational emotions of the students directly after the lesson showed that both groups enjoyed the activities very much (Fig. 5.4.3.4.).
Except from the last item “When doing these activities, I felt good” the students rated their feelings during the lesson on a very similar level positive to very positive independent from age. 67% of the younger students (very) agreed that they felt good while 54% of the older

students rated that in this way. Nevertheless 73% of the last student group enjoyed the learning of these things, 62.5% had fun and 63.5% felt interested.

5.5 Appendix; Phase B, Qualitative Research

5.5.1 Survey of Teachers (formal learning settings)

Teachers interviewed in the implementation phase B came from Greece (25%), the UK (25%), Spain (17%), Austria (17%), Hungary (8%) or Romania (8%). Most of them were between 25 and 45 years old.

The majority of teachers were male (75%) only 25% were female. Most of them answered that they taught physics (35%) followed by mathematics (24%). Another 12% of the answers was related to the subjects chemistry, astronomy. Also 12% were teacher trainers. In addition, 6% of the answers pointed out that the teachers interviewed taught computer science.

Most of the interviewees were upper secondary or highschool teachers (67%). Furthermore, 25% answered that they were inferior secondary (gymnasium) teachers and an minority of 8% stated that they taught in primary school. In most answers it was mentioned that teachers took notice of the SCeTGo workshop either via e-mail, or due to the pathway project, or because they were part of the summer schools' program or took part at a teacher training course (15% each). Concerning expectations about knowledge, attitudes, and values most answers were related to the application to a new interactive didactic tool (33%). In further 25% of the answers is was pointed out that teachers wanted to know how to use AR in school activities. In addition, 17% of the given answers referred to the understanding of the usage.

Most teachers answered that the SCeTGo workshop came up to their expectations concerning knowledge, attitudes, and values (67%). No answer stated that anyone was discontent. Additionally, 33% of the answers referred to the fact that some teachers' opinions were in between 'yes' or 'no'. Most of the answers showed that teachers were motivated to use the SCeTGo approach in future lessons (83%). As the answers showed, most convincing concerning the usage of the SCeTGo approach were that it was a hands-on approach, it demonstrated abstract phenomena, that the miniatures helped with teaching, that it was easy to handle, and that it offered a great visualization (15% each). Teachers who were undecided about their motivation to use the SCeTGo approach in their future lessons explained that the approach was still in an early implementation phase (33% of answers).

The most positive aspects of the SCeTGo approach were that it augmented reality, that it had an edutainment-approach and that it visualized the invisible (14% each). 75% of the answers given showed that the teachers had no problems understanding the usage of the SCeTGo exhibits. Most teachers were satisfied with the SCeTGo workshop (67%). Nobody answered that they were discontent. A huge amount of answers referred to the fact that teachers liked the good teaching approach (44%) and that it was easy to use (22%).

Parts which could be enhanced in future workshops were, for example, to have discussions for improvements, a better link between the miniatures and the inquiry methodology of learning, and better/ more explanations and introductions.

Table 5.5.1-1: Summarizing content analysis of interviews conducted during the workshop with teachers in pilot phase B according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	%
Gender	Male	9	75
	Female	3	25
0 a) Subjects I'm a physics teacher and I have a master degree in astrophysics.	Mathematics	4	24
	Physics	6	35
	Chemistry	2	12
	Astronomy	2	12
	Computer Science	1	6
	Teacher trainer	2	12
What level do you teach:	Primary	1	8
	Inferior secondary/ gymnasium	3	25
	Upper secondary/ highschool	8	67
0 b) Citizenship	Hungary	1	8
	Greece	3	25
	Romania	1	8
	Spain	2	17
	UK	3	25
	Austria	2	17
0 c) Age	25 – 30	2	17
	30 – 35	2	17
	35 – 40	4	33

	40 – 45 45 – 50 50 - 55 55 - 60	2 1 0 1	17 8 0 8
0 d) Applied miniatures	mini-wing mini-firetruck mini-cooler & heater all miniatures applied	6 6 4 5	29 29 19 24
1. How did you take notice of the SCeTGo workshop?	Teacher informed me Teacher trainer informed me Personal interest E-mail Due to the pathway project Part of summer schools' program Part of the course "Innovation and introduction to educational research in physics and chemistry"	1 1 1 2 2 2 2	8 8 8 15 15 15 15
2. What have you expected from the SCeTGo workshop, concerning knowledge, attitudes, and values?	To know how to use AR in school activities Application to a new interactive didactic tool Understanding the usage To see how the connection between inquiry based science education and a augmented reality technology works A wider understanding of the use of Information and communication technology in the classroom.	3 4 2 1 2	25 33 17 8 17

3. Did the SCeTGo workshop come up to your expectations, concerning knowledge, attitudes, and values?	Yes No In between	8 0 4	67 0 33
4. Are you motivated to take use of the SCeTGo approach in your future lessons?	Yes No In between	10 0 2	83 0 17
If "yes": What exactly convinced you, to make use of the SCeTGo approach?	Hands-on approach Demonstrate abstract phenomena Miniatures help with teaching Superior to books Easy handling Simple model of reality Great visualisation Undemanding integration in lesson plan	2 2 2 1 2 1 2 1	15 15 15 8 15 8 15 8
If "no": Please mention the reasons, why you don't want to make use of the SCeTGo approach!	Only useable for physics, miniatures for biology etc. are missing Time consuming Not very versatile (it doesn't allow the teacher to add up/modify/adapt its contents) Still in an early implementation phase Evidence of its usefulness is missing	1 1 1 2 1	17 17 17 33 17
5. What do you think are the most positive aspects of the SCeTGo approach?	Augmented reality Edutainment - approach (adaptive software, you can play with)	2 2	14 14

	Easy to understand	1	7
	Visualisation of the invisible	2	14
	Use of new technologies in school	1	7
	If it is accessible, it could be cheap	1	7
	Useful tool for science teaching	1	7
	Interaction with the experiments	1	7
	Combination between physical objects with virtual animations	1	7
	Easy to use	1	7
	The inquiry-based learning methodology	1	7
6. Is there something you didn't understand, concerning the usage of the SCeTGo exhibits?	No	9	75
	It was clear; but I still feel uncomfortable to use the software	1	8
	Need more information (Where can I buy it? How do I use it?)	1	8
	How exactly could I to use it in the classroom	1	8
7. Are you satisfied with the SCeTGo workshop?	Yes	8	67
	No	2	0
	In-between	2	17
If "yes": What did you like?	Good teaching approach	4	44
	Nice demonstration	1	11
	Suggests future of teaching	1	11
	Very engaging	1	11
	Easy to use	2	22

8. Any comments?

Recommendations for improvements:

- I just got a presentation, which I can get off the website. There was no feedback.
- Discussions for improvements were missing.
- I would have liked to see more clearly how these miniatures are related to the inquiry methodology of learning.
- Miniatures are so far only prototypes
- More explanations/theory
- Better introduction, especially of how to use in the class.
- More and longer practical parts.
- The project should allow teachers to actively participate in the design process of new experiments.
- Too much time is needed to perform the experiments with the SCeTGo miniatures, whereas teachers usually have a tight schedule.
- There are cheaper ways of doing Inquiry-Based Learning activities with students.
- I would be afraid of wasting time adjusting the camera.
- The SCeTGo proposal needs further development in order to be used in the classroom.
- It seems that teachers can’t adapt the minatures to their specific needs.
- They are OK for lower class levels, but for higher they need to be improved, for example for university students. The whole model should be implemented for older kids.
- The sessions were very time consuming.
- No information of the availability was given. I am not aware if it is possible to purchase such a kit at all.

Positive comments:

- I would like to know more, in general.
- A new method, wanted to see how these demonstrations work in real life and not just on the internet since I have already seen this.
- Create more miniatures, for example for biology, especially in the lower price categories.
- I would like to attend more of these workshops.

- I admire people who develop these kits.
- The workshop also made me think about the technical difficulties that would imply to train teachers on the use of the tool.
- I would like to know more and see examples of the methodology in which these experiences are based.
- I have a basic idea of what it is.
- It was very interactive.
- I will make use of the technology.
- I got what I expected, easy to use and quick to use packages.
- The homepage has enough information in order to use it.
- The Inquiry-Based Learning methodology can engage students.
- The SCeTGo experiments are easy to perform.
- The miniatures are well-thought and original.
- You can actually use and manipulate the exhibits and play for yourself, very easy to use, anybody can use it.

5.5.2 Survey of Projects` Partners

Table 5.5.2-1 shows the results of the project partner's evaluation of the SCeTGo.
The SCeTGo consortium comprises experts from different areas of information technology, but also expertise in didactics and pedagogy. Participants interviewed came from Finland, Romania, Spain, Sweden, 21% Greece and Germany. 43% of 14 participants interviewed have been female, and 57% were male.
All 14 interviewees confirmed that the project came up to their expectations, concerning knowledge, attitudes and values. Furthermore all of them said "yes" when they were asked whether they were motivated to use the SCeTGo in the future. Several different reasons for the approval were mentioned. 30 % said they believed the SCeTGo provided a good hands-on approach to various phenomena. In the same context 12% thought that this way of learning was overall better and more important than getting information out of books. Another 30% praised the easy handling of the experiments. Two of the interviewees believed that the SCeTGo helps to better understand complex and abstract phenomena. It was also mentioned that miniatures can be very useful in teaching. 18% of the questioned said it was a great option for visualising processes which are normally invisible. Although the project partners were basically motivated to take use of the SCeTGo, a few of them also believed there could be made some improvement. One person said the tools should be developed further while another interviewee stated that some of the phenomena could be hard to understand. When

asked about the most positive aspects of the project, two of the interviewees mentioned the practical approach to a complex phenomenon. Four of the project partners believed that the best aspect of the SCeTGo was the help in understanding it provided. Two people valued the opportunity of a nice demonstration as most significant. A big number of the project partners (33%) considered the visualisation of invisible phenomena as one of the most positive aspects of the SCeTGo. Two further advantages mentioned were the use of new technologies in school and the better corporation between school and research made possible by the SCeTGo.
Most of the project partners (71%) did not have any difficulties in understanding the usage of the SCeTGo exhibits. Two interviewees believed they still needed to learn how to use the tool properly. One of the questioned had a few technical concerns while another person found it difficult to connect new and old conceptions.
The project partners were also asked whether they were overall satisfied with the workshop. 93% answered "yes" while one person settled between "yes" and "no". None of the interviewees were entirely dissatisfied with the SCeTGo. When they were questioned about the reasons for their approval the project partners mentioned again the ease of use (29%), the great opportunity for practical demonstrations it delivered (7%) and the way it makes teaching easier (14%). 21% stated they were impressed by the tool and it's technology. 14% thought the SCeTGo was generally a great idea while another 14% believed the experiments were easy to understand. Furthermore the interviewees were asked about aspects they would like to see improved. One person believed that some of the miniatures were too abstract while another one of the interviewees stated that the miniatures were only prototypes so far and needed further development. Other points mentioned were the needed improvement of the instructor's knowledge (20%) and the necessity of making own experiences (20%). One of the interviewees stated that the demonstrations should be longer.
Concluding, the interviewees were asked about further comments on the workshop. Some of the project partners said they were looking forward to using the SCeTGo system in the future. One person expressed their wish that you could get more information from the exhibits "so the students [...] have something to work with". Other comments basically have been mentioned before.

Table 5.5.2-1:Summarizing content analysis of interviews conducted during the workshop with researchers of different fields of education, who are involved in the project in pilot phase B according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	%
Gender	Male Female	8 6	57 43
0 b) Citizenship	Finland Greece Romania Spain	2 3 2	14 21 14

	Sweden UK Germany	1 2 2 2	7 14 14 14
0 c) Age			
0 d) Applied miniatures	All miniatures were applied (Doppler Effect, Double Cone, Mini-wing, Young's Double Slits, Molecule Movement)	14	100
1. How did you take notice of the SCeTGo workshop?	-	-	-
2. What have you expected from the SCeTGo workshop, concerning knowledge, attitudes, and values?	Interesting and basic knowledge Application to a new teaching form Understanding the usage Great tool for pupils	3 11 2 1	18 65 12 6
3. Did the SCeTGo workshop come up to your expectations, concerning knowledge, attitudes, and values?	Yes No In between	14 - -	100 - -
4. Are you motivated to take use of the SCeTGo approach?	Yes No In between	14 - -	100 - -
If “yes”: What exactly convinced you, to make use of the SCeTGo approach?	Hands-on approach Demonstrate abstract phenomena Miniatures help with teaching Superior to books Easy handling To visualise the invisible	10 2 1 4 10 6	30 6 3 12 30 18

If “no”: Please mention the reasons, why you don’t want to make use of the SCeTGo approach!	Tools need more development Did not understand all phenomena	1 1	50 50
5. What do you think are the most positive aspects of the SCeTGo approach?	Practical approach Better understanding of complicate phenomena Nice demonstration Visualise invisible aspects of a phenomenon Use of new technologies in school Better cooperation between school and research.	2 4 2 5 1 1	13 27 13 33 7 7
6. Is there something you didn’t understand, concerning the usage of the SCeTGo exhibits?	No Still have to learn how to use the tool Technical concerns Difficult to connect new and old conceptions	10 2 1 1	71 14 7 7
7. Are you satisfied with the SCeTGo workshop?	Yes No In-between	13 - 1	93 - 7
If “yes”: What did you like?	Easy to use Impressive tool/ technology Great idea Good teaching approach Nice demonstration Easy to understand: 1	4 3 2 2 1 2	29 21 14 14 7 14
If “no”: What should be enhanced in	Longer demonstration	1	20

future workshops?	Miniatures are so far only prototypes Instructors need more knowledge Some miniatures are very abstract. Have to make experiences by myself	1 1 1 1	20 20 20 20
8. Any comments? – No – Looking forward to use is it. – Some miniatures are very abstract. – Generally I would expect to get more info from each exhibit so the students could have something to work with. – Exhibits should be more accurate			

5.5.3 Survey of Students (school & university)

As already mentioned in the quantitative analysis (5.4.3.) in phase B the students' evaluation was divided in two groups divided by age. The first group consists of school students (named as pupils) from Sweden (Table 5.5.2-1). The second group comprised university students that participated in SCeTGo validation events in Greece (Table 5.5.3-2). We compared both groups to covers the whole age range of students we are interested in.
In the younger group seven male pupils and one female pupil participated. All of them were in ninth grade, were 16 years old and came from Sweden. In comparison, the group of university students consisted of five men aged between 20 and 26 who were in their seventh semester at university and all came from Burundi (Africa).
With regard to the pupils, everyone applied every offered miniature (100%), which were the Doppler Effect, the Double Cone, the Mini-wing, the Young's Double Slits and the Molecule Movement. On the other hand, miniatures applied by the university students were the Doppler Effect (63%), the Mini-wing (25%) and the Molecule Movement (13%).
Most of the pupils looked forward to the lesson (50%) because they expected to learn about innovations (40%), to have fun (40%) and to have contact with experts (20%). Comparing them to the university students, less of the latter looked forward to the lesson (40%) but expected to learn about innovations equally to the pupils (40%). A second reason given by the university students was being informed about AR (20%). Furthermore, most of the pupils expected something extraordinary (37,5%). The other pupils who have given an answer to this question pointed out that they expected an advertisement for university (12,5%) or to get an easier theory (12,5%). The university students, on the other hand, gave different answers about their expectations. They expected to learn something new (20%) or to learn something about the underlying phenomenon (20%). Moreover, of all university students the interest in science was raised. However, to the pupils this applied only partially (37,5%). Pupils

explained that their interest was increased because it was a different way of learning (71%) and because it had an interactive aproach (29%). The interactive approach was also mentioned by the university students (20%). Furthermore, the university students pointed out that their interest was increased because of the scenario and the technology (40%), because it had an practical and not only theoretical approach (20%) and because it connected science (theory) with technology (20%). Additionally, the most positive aspects of this learning scenario mentioned by the pupils were the practical orientation and the multimedia (31% each). Further aspects were that the learning scenario contained real objects (19%), the IBSE (13%) and that they had enough time (6%). In comparison, the university students gave different answers. For them, the most positive aspects were that it was an experimental hands-on activity, that it raised interest in the way it is used to present science, the AR representations, the visualization of unseen properties and that the phenomenon could be better understood due to a connection with reality (20% each).

Table 5.5.3-1: Summarizing content analysis of interviews conducted during the workshop with university students in pilot phase B according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	Number of answers
Gender	Male Female	5 0	100 0
0 a) Grade/ Semester	7th semester (University)	5	100
0 b) Citizenship	Burundi (Africa) Greek	1 4	20 80
0 c) Age	20-26	5	100
0 d) Applied miniatures	Doppler Effect Mini-wing Molecule Movement	5 2 1	63 25 13
0 e) Did you know in advance, that the lesson today would be a special self-guided one with computer-assisted miniature exhibits?	 No	1 4	20 80
1. Did you look forward to the lesson?	Yes No No answer	2 1 2	40 20 40

1.1 Reasons why not:	No information	3	100
1.1 Reasons why yes:	Innovations Be informed about AR No answer	2 1 2	40 20 40
2. Expectations	To learn something new To learn about the underlying phenomenon No answer	1 1 3	20 20 30
3. Did the lesson come up to your expectations?	Exceeded expectations Yes	1 4	20 80
4. Did the lesson raise your interest in science?	Yes	5	100
4.1. Reasons why not:	No answer	-	-
4.2. Reasons why yes:	Interactive approach Scenario, technology Practical approach, not only theory Connects science (theory) with technology	1 2 1 1	20 40 20 20
5. Most positive aspects of this learning scenario	Experimental hands-on activity Raises interest in the way it is used to present science AR representations Visualization of unseen properties	1 1 1 1	20 20 20 20

	Better understanding of phenomena due to a connection with reality	1	20
6. Problems concerning the usage	Yes - Graphical representation of waves No In between - I understood everything that was presented to me, but this fact raised more questions about the phenomena)	 1 3 1	 20 60 20
7. Are you satisfied with the lesson?	Yes	5	100
7.1 If not: Improvements	-	-	-
7.2 If “yes”: What did you like?	Different to everyday practice Informal approach in a formal settlement AR representations Teaching method with innovative technology and multimedia	2 1 1 1	40 20 20 20

8. Any comments?

- Concern about the cost.
- I would prefer lessons to be done in this way.
- I liked the interactive presentation and I would prefer its application in future lessons.
- More lessons are needed for all the miniatures to be presented, more theory should support them.

5.5.4 Survey of Students (school)

Table 5.5.4-1:Summarizing content analysis of interviews conducted during the workshop with students (school) in pilot phase B according to MAYRING (2008). The categories to which the original answers to the interview questions were summarized are shown. Multiple nominations were possible.

Interview Questions	Categories	Workshop Validation	
		Number of answers	%
Gender	Male Female	7 1	88 22
0 a) Grade/ Semester	9	8	100
0 b) Citizenship	Sweden	8	100
0 c) Age	16	8	8
0 d) Applied miniatures	Doppler Effect Double Cone Mini-wing Young's Double Slits	8 8 8 8	100 100 100 100
0 e) Did you know in advance, that the lesson today would be a special self-guided one with computer-assisted miniature exhibits?	No	8	100
1.Did you look forward to the lesson?	Yes No No answer	4 3 1	50 38 13
1.1 Reasons why not:	No information	3	100
1.1 Reasons why yes:	Innovations Fun Contact with experts	2 2 1	40 40 20
	Advertisement for	1	13

2.Expectations	university Something extraordinary Easier theory No answer	 3 1 2	 38 13 25
3. Did the lesson come up to your expectations?	Exceeded expectations Yes No In between No answer	2 3 - 1 2	25 38 - 13 25
4. Did the lesson raise your interest in science?	Yes No In between	3 3 2	38 38 25
4.1. Reasons why not:	No answer	3	100
4.2. Reasons why yes:	Different way of learning Interactive approach	5 2	71 29
5. Most positive aspects of this learning scenario	Real objects Practical oriented Enough time IBSE Multimedia	3 5 1 2 5	19 31 6 13 31
6. Problems concerning the usage	Yes - technical No	 1 7	 13 88
7. Are you satisfied with the lesson?	Yes	8	100
7.1 If not: Improvements	-	-	-
7.2 If “yes”: What did you like?	Real objects/experiments	2	25

	Different to everyday school	3	38
	Multimedia	1	13
	Student-centred learning	2	25

8. Any comments?

- Suitable for science learning
- More usage in school
- Future-oriented technology
- Theory was too difficult

6 Discussion

In the context of SCeTGo AR is used for educational purposes as a computer-mediated learning system that aims at the integration of AR technology in science teaching. Thereby, SCeTGo provides an augmented visualization aid for education.
However, in recent years technology enhanced teaching systems were questioned considering their learning efficiency. Ardito et al. [12] demanded “a synergy between the learning process and a student’s interaction with the software.” Furthermore “ usability features should not only allow people to efficiently manipulate the interactive software, but should also be appropriate for the intended learning task.” The purpose of WP5 Validation & Quality Assurance was to get an insight in the educational value of the SCeTGo system as an AR technology for students and teachers in order to ensure utilization in classrooms.

First of all we will present a summary of students and educators feedback with regard to the pedagogical effectiveness, based on these results we will validate if the objectives of the project are achieved (see chapter 2.1). Subsequently, we will focus on the usability of the SCeTGo approach, because teachers` validation could show that a user-friendly design is an important pre condition for the acceptance of the SCeTGo system.

6.1 Students` Validation of Pedagogical Effectiveness

Pedagogical effectiveness was rated by students with regard to an increase in interest in natural science and enjoyment of the lesson.
Overall, the feedback given by pupils within the individual interviews was mostly positive.
According the data students really liked working and learning with the miniatures. They did not suggest any improvements. In particular, the hands-on approach of the miniatures, the student-centered lessons and the multimedia aspects was accentuated. The high percentage of interested students shows that most of them were inspired by the exhibits and the AR technology. Furthermore students mentioned that the SCeTGo experiments facilitates the understanding of physical phenomena.

6.2 Educators` Validation of Pedagogical Effectiveness

Teachers as well as educators from other fields of education from different countries evaluated SCeTGo and mentioned positive and negative aspects of the approach.
They evaluated the miniatures in combination with an AR technology as a valuable tool for instruction. Educators positively emphasized the interactive visualization by placing additional information (e.g. invisible molecules) into real surroundings. It simplifies the explanation of abstract phenomena as abstract phenomena are shown figuratively. Thus young people’s interest in science is reinforced. The SCeTGo approach was evaluated positively, as it allows the learner to interact dynamically with the miniature exhibits and fosters hands-on activities.
An active participation of the learner during the learning process is regarded as a basic prerequisite for acquiring knowledge [13]. The qualitative analysis revealed that SCeTGo simplifies instruction, what implies that miniatures have a high value to teachers.
Furthermore teachers mentioned that key competences are developed, not only in science, but also with regard to technological skills.

6.3 Validation of Projects` Objectives

1. Does the SCeTGo approach raise interest in science and science motivation?
   Yes. Especially students evaluated the SCeTGo approach positive.The application of the SCeTGo miniatures raised students` interest and activated the majority of participants to get more involved in science contents. It therefore could engage students to get more interested in science in general.

2. Does the SCeTGo approach reach to induce engagement of students in experimental science learning?
   Yes. The highly scored interest of participants to engage in such experimental exhibits and their learning contents are satisfyings. This additionally affirms the aimed pedagogical concepts of the SCeTGo project. Especially teachers as well as students positively emphasized the interactive visualization by placing additional information (e.g. invisible molecules) into real surroundings. It was evaluated positively, as it simplifies learning and allows the learner to interact dynamically with the miniature exhibits. An active participation of the learner during the learning process is regarded as a basic prerequisite for acquiring knowledge [15].

3. Does the SCeTGo approach lead to satisfying learning outcome, especially considering problem-solving and critical thinking skills?
   Yes. Also learning outcomes were not assessed (see chapter 3.1).; the SCeTGo approach provides teachers with a tool in order to facilitate students' learning. Scenarios favor an inquiry based learning, especially this approach should support problem-solving and critical thinking skills.

4. Does the SCeTGo approach offer teachers an enrichment of their everyday teaching practice?
   Yes. The overall acceptance of the workshops seems to be high and miniatures seem to be user-friendly.The validation could support that the SCeTGo approach offers a modern science centre experience outside the walls of the science centre in school classrooms. This shows that the SCeTGo project has the potential to be applied in school environments and introducing AR into the classroom is in line with the needs of educators.

6.4 Validation of Usability

Validation could show that next to pedagogical effectiveness a user-friendly design is an important pre condition in order to ensure users `acceptance. Usability plays a central role to meet the requirements of teachers and students and to adapt the AR technology to the specific needs of school environments. However requirements with regard to usability differ between the user group (students) and the “provider” group (educator).
Balog and Pribeanu [3] for instance, had shown the perceived usefulness and the perceived enjoyment as relevant factors for students' acceptance of an AR application, while the perceived ease of use was not a significant precursor for students' acceptance. Still in contrast to students, teachers are standing in front of a class while using an interactive software system. Therefore, teachers require a user friendly software, they could fully rely on. Consequently Ardito and collegues [12] argued that from the point of view of people, who are applying an interactive software system, usability should be the most important aspect. With

regard to usability features (technical demands, user-friendliness and handling) of the SceTGo approach most educators reviewed exhibits to be easy to handle.
Especially a rapid prearrangement of the setup was pointed out as a positive feature.
With reference to technical acceptance usability, features are easy to operate and there are no real obstacles that teachers have to overcome in order to use the system. Yet, teachers mentioned that a system needs to be extraordinary flawlessly operational, in order to be usable at school – in some cases this was already demanded from the prototypes.
Results emphasize that an AR system like SCeTGo has to operate absolutely reliable in order to be integrated in teachers` instruction.
Taking this into consideration, the SCeTGo technology still needs improvement to finally convince also critical teachers of its applicability. However, then the system verifies a successful future integration of exhibits based on AR-technology in instruction, which could be easily included in school lessons as long as they operate absolutely reliable.

6.5 Comparison of Pilot Phase A and B

The comparison of the qualitative and quantitative analysis of phase A and B shows that there has been a positive development of users´ attitude towards SCeTGo. From the beginning students had a high opinion of the SCeTGo approach. Teachers were convinced of its usefulness, however still sceptical about the software.
In phase B miniatures have been revised and scenarios have been added. Therefore not only pedagogical effectiveness, but also usability has been improved. The results of the analysis indicate that the handling and therefore the user-friendliness has improved in phase B. The high ratio of recommendations with regards to its educational efficiency reflects the positive attitude towards the SCeTGo system in general as long as the software run in a proper way.

6.6 Critical Remark with Regard to Teachers' Acceptance of AR

Science teachers play a crucial role for the implementation of AR technologies in school. Results indicate a high interest for new technologies and new learning/teaching strategies amongst teachers in school environments in general.
Nevertheless participating teachers were not randomly chosen, since they selected the teachers training courses in order to get to know state-of-the-art technologies and to get new ideas for improvement of their instruction. Based on motivational reasons, it is not surprising that most of the participants are encouraged to use this approach further on. As workshop participation was an optional offer, it could be the case that teachers not interested in new technologies in general decided not to participate.

7 CONCLUSION

In summary projects objectives are achieved, students enjoyed working and learning with the miniatures and most of the teachers assessed pedagogical effectiveness as well as technological aspects throughout positive. SCeTGo proposes an inquiry-based approach with a learner-specific constructivistic idea of learning. It enriches the repertoire of learning offers to more innovative teaching methods due to an AR inclusion with the specific aim to improve quality of learning. Thereby, it brings AR enhanced learning experiences out of the science centre into a school classroom, by offering the experience of a modern science centre in school and thus crosscutting the boundaries between formal and informal learning. In conclusion, SCeTGo seems to be appropriate to integrate AR in schools and offers conditions to have an impact on education in long term.Thereby, through its implementation in schools an AR enhanced learning system, as SCeTGo contributes to a new form of education.

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9 Appendix

Appendix 1.1: Instructional guidelines

Dear workshop/lesson leader,

please stick to the following instructions for validating your SCeTGo event.

Before the workshop:

1. Inform your SCeTGo contact person about the planned event (workshop/lesson, place, date, agenda, duration, number of participants, type of participants) via mail:

Remark: Dear responsible SCeTGo partner, please fill in your email-address here!

2. Make sure that your SCeTGo contact person did provide the following files in your mother-language:

Event information form
Questionnaire
Interview grid

3. Copy the questionnaire for all of your workshop participants. Copy the interview grid for at least 10 % of your workshop participants!

4. Schedule about 10-15 min for completing the questionnaire in your workshop and extra time for the interviews according to the number of interview partners (about 15 min per interview).

During the workshop:

1. Hand out the questionnaire to all participants immediately after the workshop.

2. Collect the questionnaire again after the participants completed it.

3. Ask at least 10 % of your participants to conduct a personal interview with you and make notes during the interview on the grid or use a dictaphone.

5. Complete the event information form so that we can structure the validation process.

After the workshop:

Send event information form, completed questionnaires and interview grid to the following address as soon as possible. Your contact person is responsible to coordinate the translation into English.

Remark: Dear SCeTGo partner, please fill in your address here!

Thank you!

Appendix 1.2: Event Information Form

Event Information Form for Workshop/Lesson Leaders	
Dear workshop/lesson leader, please complete this information form after your workshop/lesson and send it together with the completed questionnaires and interview grids to your SCeTGo contact person: **Dear SCeTGo partner, please list your address here!**	
Name and profession of workshop/lesson leader(s)	
Location of workshop/lesson (e.g. Science center, Stockholm, Sweden)	
Duration of workshop/lesson	
Number and description of participants (in-service teachers, students, …)	
Please briefly describe the agenda of the workshop/the topic of the lesson!	
How was the attitude of participants during the workshop/lesson?	
Which exhibits were part of the workshop/lesson?	
o MiniWing o Doppler Effect o Double-slit o Darwinism/Lamarck o Bolzmann o Double Cone o CERN o other(s): ______________________________	
Did something unexpected happen during the workshop? Any problems?	
Any further remarks?	

Appendix 1.3: Interview Grid for Teachers

SCeTGo Interview Grid – TEACHERS

Dear Interviewer,

Please pick out **10 % of the attendees** of your workshop for an individual interview.

The interview should

- **be conducted individually,**
- **take place in a calm atmosphere**
- **and with no additional listeners.**

Before the interview will start, please **inform the attendee**

- about the **expected duration (15min)** of the interview
- that his/her data are going to be **treated anonymously**.
- Ask him/her to tell you if he/she is not sure if he/she has understood something correctly.

Please take notes of the answers.

Name of interviewer	
Place	
Date, time	
Duration of interview	
Gender of interviewed person	☐ male ☐ female

0.a) What is your speciality - which subjects do you teach?	0.b) What level do you teach: ☐ primary ☐ inferior secondary/ gymnasium ☐ upper secondary/ highschool
0.c) What is your citizenship?	0.c) How old are you?
0.d) Please name the exhibits you have worked with today!	

1. How did you take notice of the SCeTGo workshop?
ANSWER:
2. What have you expected from the SCeTGo workshop, concerning knowledge, attitudes,

and values?
ANSWER:
3. Did the SCeTGo workshop come up to your expectations, concerning knowledge, attitudes, and values?
ANSWER:
4. Are you motivated to take use of the SCeTGo approach in your future lessons? **If "no":** Please mention the reasons, why you don't want to make use of the SCeTGo approach! **If "yes":** What exactly convinced you, to make use of the SCeTGo approach?
ANSWER:
5. What do you think are the most positive aspects of the SCeTGo approach?
ANSWER:
6. Is there something you didn't understand, concerning the usage of the SCeTGo

exhibits?
ANSWER:
7. Are you satisfied with the SCeTGo workshop? **If "no":** What should be enhanced in future workshops? **If "yes":** What did you like?
ANSWER:
8. Any further comments?
ANSWER:
Thank you for participating in the interview!

Appendix 1.4: Interview Grid for Students (school/university)

SCeTGo Interview Grid – STUDENTS

Dear Interviewer,

Please pick out **10 % of the attendees** lesson for an individual interview. **The interview should** – **be conducted individually,** – **take place in a calm atmosphere** – **and with no additional listeners.**	**Before the interview** will start, please **inform the attendee** – about the **expected duration (15min)** of the interview – that his/her data are going to be **treated anonymously**. – Ask him/her to tell you if he/she is not sure if he/she has understood something correctly. Please take notes of the answers.

Name of interviewer	
Place	
Date, time	
Duration of interview	
Gender of interviewed person	☐ male ☐ female

0.a) In which grade/semester are you?	0.b) What is your citizenship?

0.c) How old are you?

0.d) Please name the exhibits you have worked with today!

0.e) Did you know in advance, that the lesson today would be a special self-guided one with computer-assissted miniature exhibits?

1. Did you look forward to the lesson? Please, name the reasons.

ANSWER:
2. What have you expected from the lesson?
ANSWER:
3. Did the lesson come up to your expectations?
ANSWER:
4. Did the lesson raise your interest in science?
If "no": Please mention the reasons, why you are not interested in science more than before the lesson! **If "yes":** What exactly raised your interest?
ANSWER:
5. What do you think are the most positive aspects of this learning scenario, of this way of teaching?
ANSWER:
6. Is there something you didn't understand, concerning the usage of the computer-

assisted miniature exhibits?
ANSWER:
7. Are you satisfied with the lesson? **If "no":** What should be improved in future lessons? **If "yes":** What did you like?
ANSWER:
8. Any further comments?
ANSWER:
Thank you for participating in the interview!

Appendix 1.5: Questionnaire for Teachers and Educators

SCeTGo Workshop Validation
Questionnaire for Teachers

This questionnaire was created for the validation of SCeTGo workshops. To analyze the quality of the SCeTGo project and its activities all participants are asked to fill in this questionnaire carefully. Thank you!

First, we need some core data about you:

Your gender: ☐ male ☐ female

Your age: __________

Your home country: ______________

Your role: ☐ School teacher; your subjects: ___________________

What level do you teach: ☐ primary

☐ inferior secondary/ gymnasium

☐ upper secondary/ highschool:

☐ University teacher; your discipline: _____________________

Please tick only one box per question!

Pedagogical validation	**Low**				**High**
How would you estimate ... ... the added value of the SCeTGo approach for your school?	☐	☐	☐	☐	☐
... the usability of the SCeTGo approach for your school?	☐	☐	☐	☐	☐
... the effectiveness of the SCeTGo approach for learning?	☐	☐	☐	☐	☐
... the integration of the SCeTGo approach in your current curriculum?	☐	☐	☐	☐	☐
How is your motivation for using the SCeTGo approach in teaching compared to how it was before the workshop?	☐	☐	☐	☐	☐
Technological validation	**Low**				**High**
How would you estimate... ... the quality of the SCeTGo miniature exhibits?	☐	☐	☐	☐	☐
... the integration of the SCeTGo approach in your existing technological equipment (e.g. software compatibility, computer availability)?	☐	☐	☐	☐	☐
... the integration of the SCeTGo approach into management/organization procedures of your school?	☐	☐	☐	☐	☐
<< please continue on the next page >> **Economic validation**					

Integration costs	Low				High
How would you predict the integration costs of the ICT-based SCeTGo approach into your school system?					
a) in terms of technological integration	☐	☐	☐	☐	☐
b) in terms of management integration	☐	☐	☐	☐	☐
c) in terms of teacher training and continous professional development?	☐	☐	☐	☐	☐
How would you predict *in general* the integration costs of ICT-based approaches into your school system?					
a) in terms of technological integration	☐	☐	☐	☐	☐
b) in terms of management integration	☐	☐	☐	☐	☐
c) in terms of teacher training and continous professional development?	☐	☐	☐	☐	☐
Cost (one miniature)	**<50**	**50-100**	**100-150**	**150-200**	**more:**
How much € would you be ready to pay to use the miniatures in your class (tentative)	☐	☐	☐	☐	☐
Cost (set of 5 miniatures)	**< 100**	**100-500**	**500-1000**	**1000 - 1500**	**more:**
How much € would you be ready to pay to use the whole set of miniatures in your class (tentative)	☐	☐	☐	☐	☐
Potential value / usefulness	**strongly disagree**				**strongly agree**
I believe this activity could be of some value to students.	☐	☐	☐	☐	☐
I think that doing this activity is useful for students.	☐	☐	☐	☐	☐
I think this activity is important to do for students.	☐	☐	☐	☐	☐
I would be willing to do this more than once with my students because it has some value to them.	☐	☐	☐	☐	☐
I think doing this activity could help students.	☐	☐	☐	☐	☐
I believe doing this activity could be beneficial to students.	☐	☐	☐	☐	☐
I think this is an important activity for students.	☐	☐	☐	☐	☐
<< please continue on the next page >>					
Intrinsic motivation	**strongly disagree**				**strongly agree**

I enjoyed doing this activity very much.	☐	☐	☐	☐	☐
This activity was fun to do.	☐	☐	☐	☐	☐
I thought this was a boring activity.	☐	☐	☐	☐	☐
This activity did not hold my attention at all.	☐	☐	☐	☐	☐
I would describe this activity as very interesting.	☐	☐	☐	☐	☐
I thought this activity was quite enjoyable.	☐	☐	☐	☐	☐
While I was doing this activity, I was thinking about how much I enjoyed it.	☐	☐	☐	☐	☐

Appendix 1.6: Questionnaire for Students (school/university)

SCeTGo Lesson Validation

Questionnaire for Students

This questionnaire was created for the validation of SCeTGo lessons. To analyze the quality of the SCeTGo project and its activities all participants are asked to fill in this questionnaire carefully. Thank you!

First, we need some core data about you:

Your gender: ☐ male ☐ female

Your age: ___________ Your grade/semester: _____________

Your home country: ______________

Your role: ☐ School student; favourite subjects: ____________________

☐ University student; your subject(s): ______________________

☐ Other; Reason for visit: ____________________________________

Please tick only one box per question!	**Low**				**High**
Do you think your way of learning could change with the use of such learning scenarios as today that are self-guided and use computer-assisted exhibits?	☐	☐	☐	☐	☐
How is your engagement in such learning scenarios compared to how it was before this lesson?	☐	☐	☐	☐	☐
How would you estimate the use of such learning scenarios (self-guided, use of computer-assisted exhibits) in the process of innovation in learning?	☐	☐	☐	☐	☐
How would you estimate the integration of such learning scenarios for fulfilling your personal needs of learning?	☐	☐	☐	☐	☐

How would you estimate the effectiveness of such learning scenarios (that are self-guided and use computer-assisted exhibits) for your learning process?	☐	☐	☐	☐	☐
How is your motivation for learning with the use of such learning scenarios compared to how it was before the lesson?	☐	☐	☐	☐	☐
How is the quality of the computer-assissted miniature exhibits that have been provided to you during this lesson?	☐	☐	☐	☐	☐
Please tick only one box per question!	**strongly disagree**				**strongly agree**
I tried hard to do well in these activities.	☐	☐	☐	☐	☐
I think I was pretty good at these activities.	☐	☐	☐	☐	☐
I enjoyed learning these things during this lesson.	☐	☐	☐	☐	☐
What I learned during this lesson is relevant to my life.	☐	☐	☐	☐	☐
In this lesson, I worked as hard as I could.	☐	☐	☐	☐	☐
These activities were fun.	☐	☐	☐	☐	☐
After working at these activities for a while, I felt pretty competent.	☐	☐	☐	☐	☐
Understanding these tasks gave me a sense of accomplishment.	☐	☐	☐	☐	☐
I will use more strategies that ensure I learn the science well, than I did before this lesson.	☐	☐	☐	☐	☐
When we worked on these tasks, I felt interested.	☐	☐	☐	☐	☐
During these activities, I participated in task-related discussions.	☐	☐	☐	☐	☐
I liked the tasks that challenged me.	☐	☐	☐	☐	☐
I am satisfied with my performance at these tasks.	☐	☐	☐	☐	☐
What I learned during this lesson has practical value for me.	☐	☐	☐	☐	☐
What I learned during this lesson is more important to me than the grade I might have received.	☐	☐	☐	☐	☐
I will prepare better for the science tests and labs than I did before this lesson.	☐	☐	☐	☐	☐

I paid attention during these activities.	☐	☐	☐	☐	☐
I think about how I will use what I learned during this lesson.	☐	☐	☐	☐	☐
These were activities that I couldn’t do very well.	☐	☐	☐	☐	☐
If I am having trouble learning the science, I will try to figure out why more intenseley than before this lesson.	☐	☐	☐	☐	☐
When we worked on these activities, I got involved.	☐	☐	☐	☐	☐
I was pretty skilled at these activities.	☐	☐	☐	☐	☐
I enjoyed learning these things.	☐	☐	☐	☐	☐
I think about how the things I learned during this lesson will be helpful to me.	☐	☐	☐	☐	☐
During the lesson, I listened very carefully.	☐	☐	☐	☐	☐
I will put more effort into learning the science than I did before this lesson.	☐	☐	☐	☐	☐
I think I did pretty well at this activity, compared to other students.	☐	☐	☐	☐	☐
What I learned during this lesson relates to my personal goals.	☐	☐	☐	☐	☐
When doing these activities, I felt good.	☐	☐	☐	☐	☐
I found learning these things interesting.	☐	☐	☐	☐	☐

Appendix 1.7: Intrinsic Motivation, Science Motivation, and Student Engagement items (sorted)

<table>
<tr><td>Perceived competence
I think I was pretty good at these activities.
I think I did pretty well at this activity, compared to other students.
After working at these activities for a while, I felt pretty competent.
I am satisfied with my performance at these tasks.
I was pretty skilled at these activities.
These were activities that I couldn’t do very well.</td><td rowspan="2">Personal relevance
I found learning these things interesting.
I enjoyed learning these things.
What I learned during this lesson has practical value for me.
What I learned during this lesson is relevant to my life.
What I learned during this lesson is more important to me than the grade I might have received.
What I learned during this lesson relates to my personal goals.
I liked the tasks that challenged me.
Understanding these tasks gave me a sense of accomplishment.
I think about how I will use what I learned during this lesson.
I think about how the things I learned during this lesson will be helpful to me.</td></tr>
<tr><td>Behavioral engagement
I tried hard to do well in these activities.
In this lesson, I worked as hard as I could.
During these activities, I participated in task-related discussions.
I paid attention during these activities.
During the lesson, I listened very carefully.</td></tr>
<tr><td>Emotional engagement
When doing these activities, I felt good.
When we worked on these tasks, I felt interested.
These activities were fun.
I enjoyed learning these things during this lesson.
When we worked on these activities, I got involved.</td><td>Self-determination
I will put more effort into learning the science than I did before this lesson.
I will prepare better for the science tests and labs than I did before this lesson.
I will use more strategies that ensure I learn the science well, than I did before this lesson.
If I am having trouble learning the science, I will try to figure out why more intenseley than before this lesson.</td></tr>
</table>

10 Results

10.1 Appendix; Phase A, Quantitative Research

10.1.1 Survey of Science Teachers (formal learning settings)

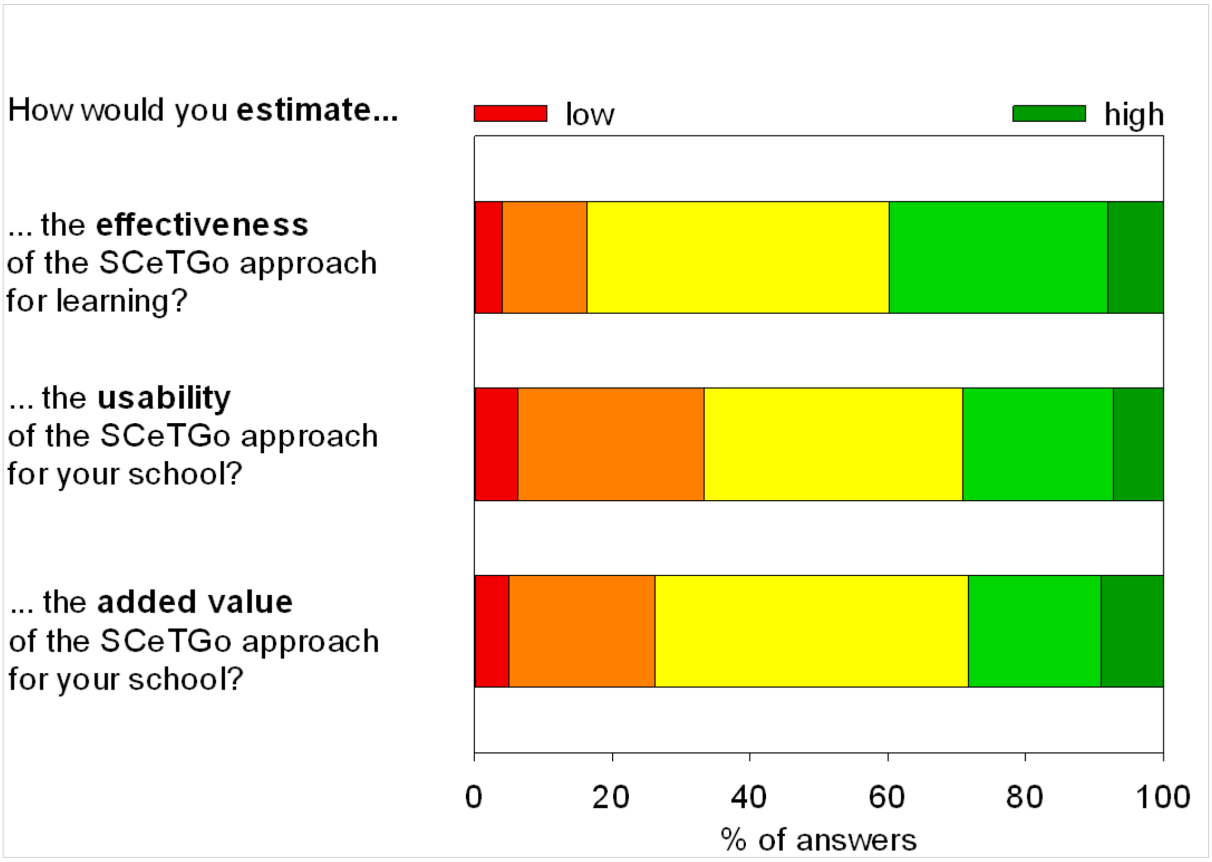

Fig. 2.1.1.1: Evaluation of Pedagogical Aspects I (VALNet)

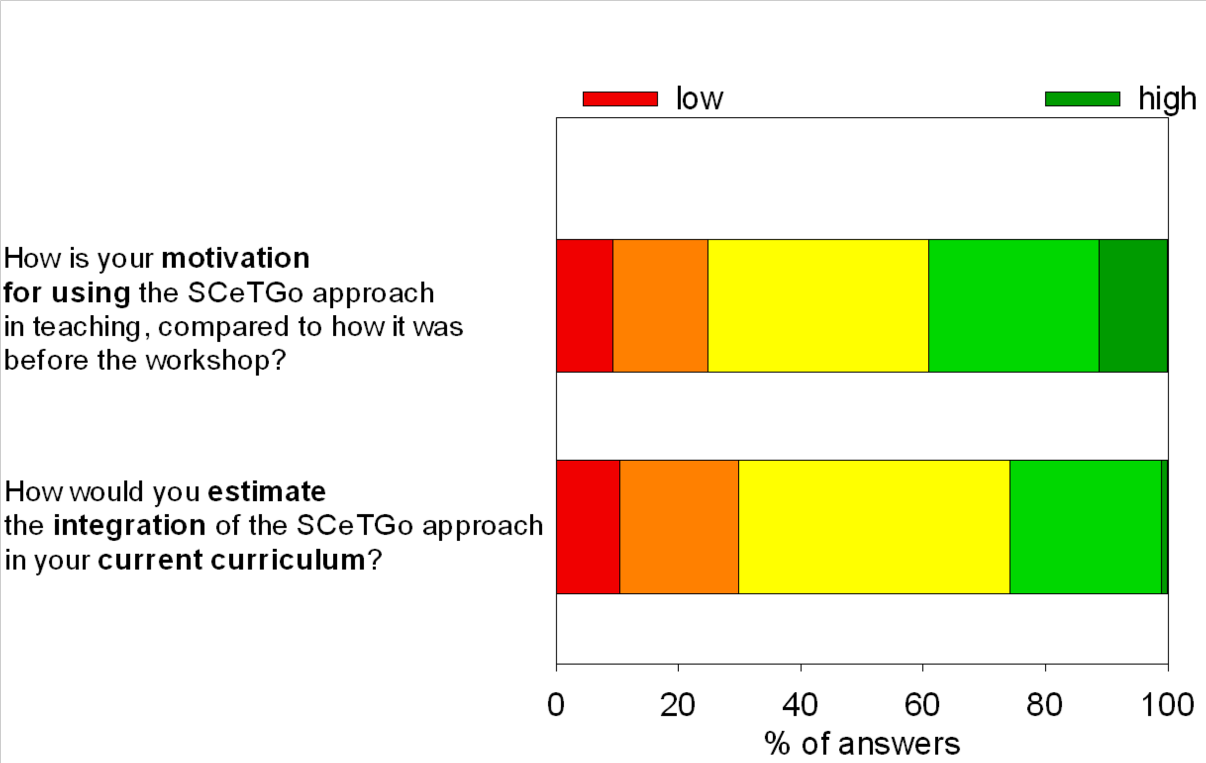

Fig. 2.1.1.2: Evaluation of Pedagogical Aspects II (VALNet)

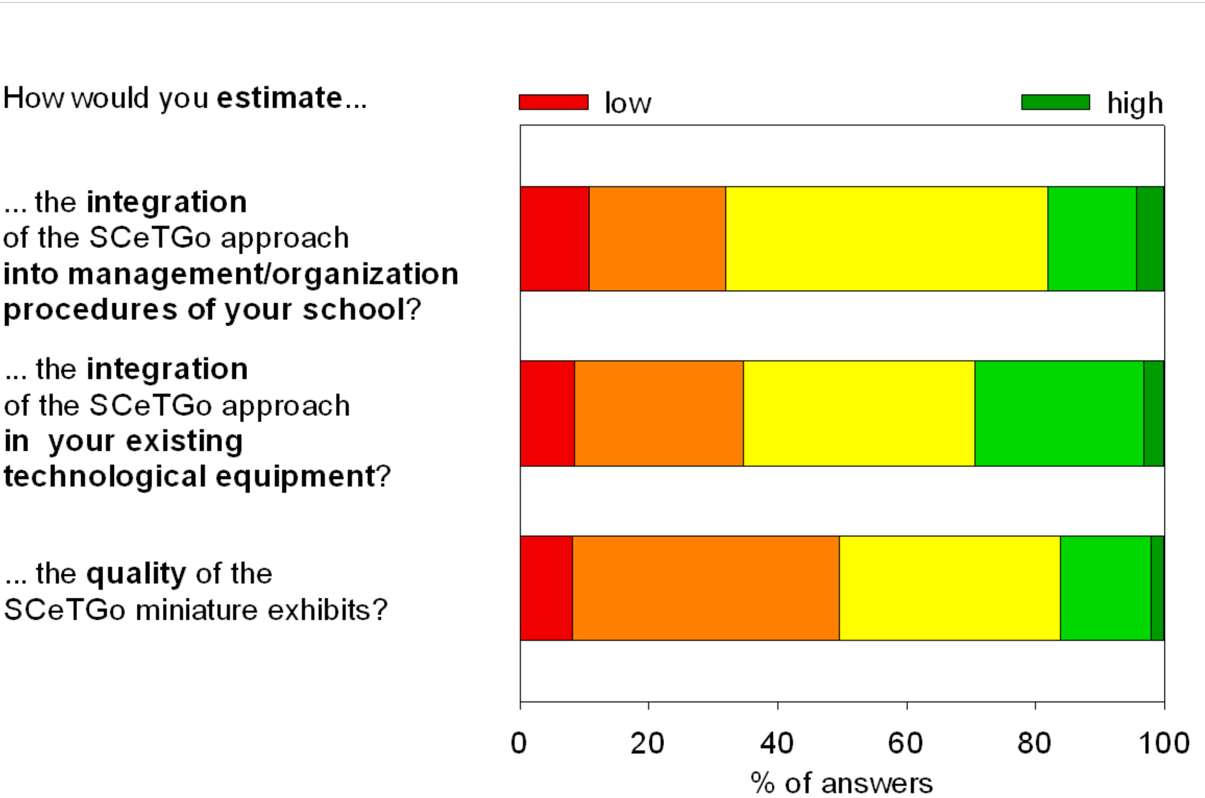

Fig. 2.1.1.3: Evaluation of Technological Aspects (VALNet)

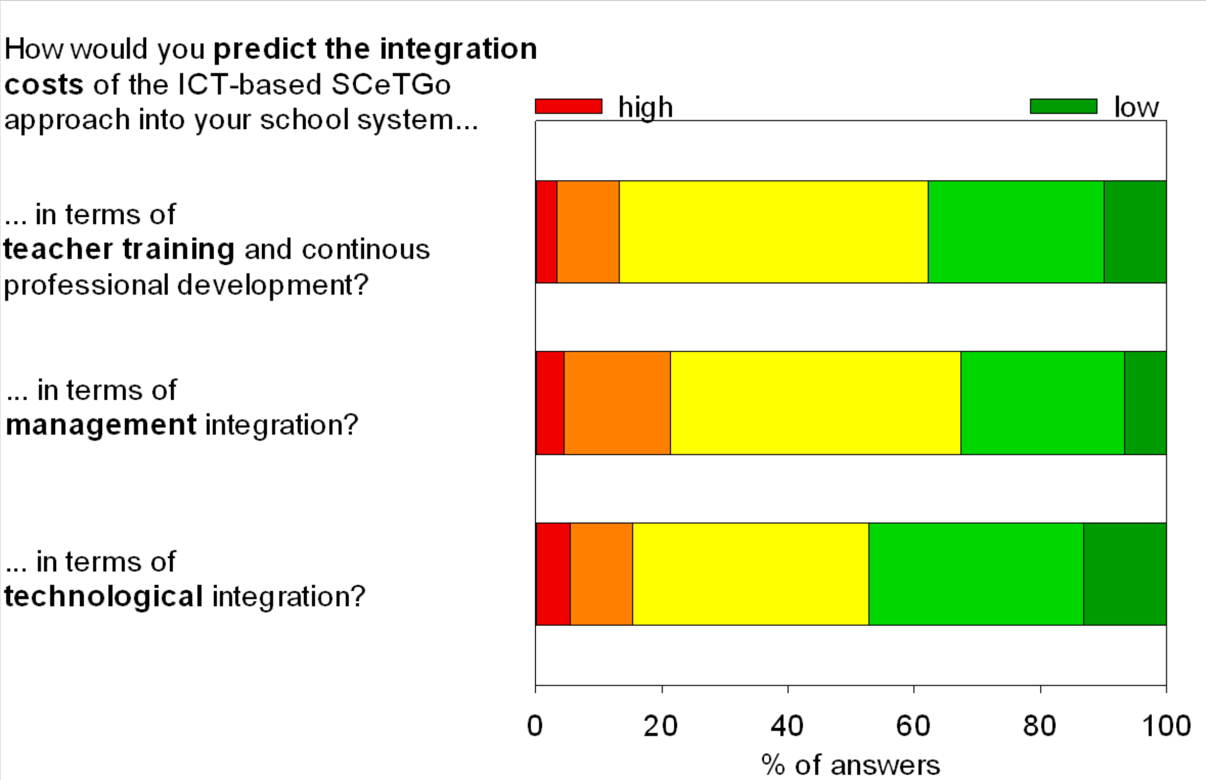

Fig. 2.1.1.4: Evaluation of Economical Aspects (VALNet) I

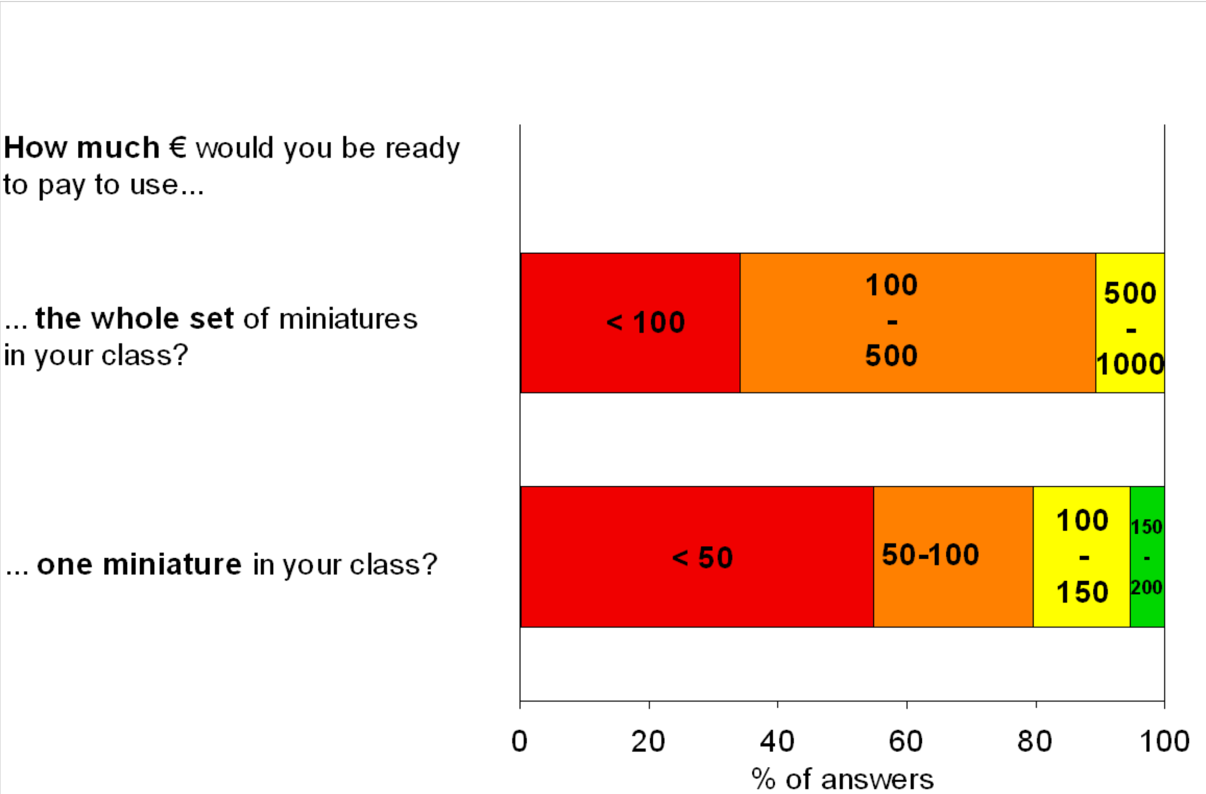

Fig. 2.1.1.5: Evaluation of Economical Aspects II

Fig. 2.1.1.6: Evaluation of Interest/Enjoyment (Intrinsic Motivation Inventory)

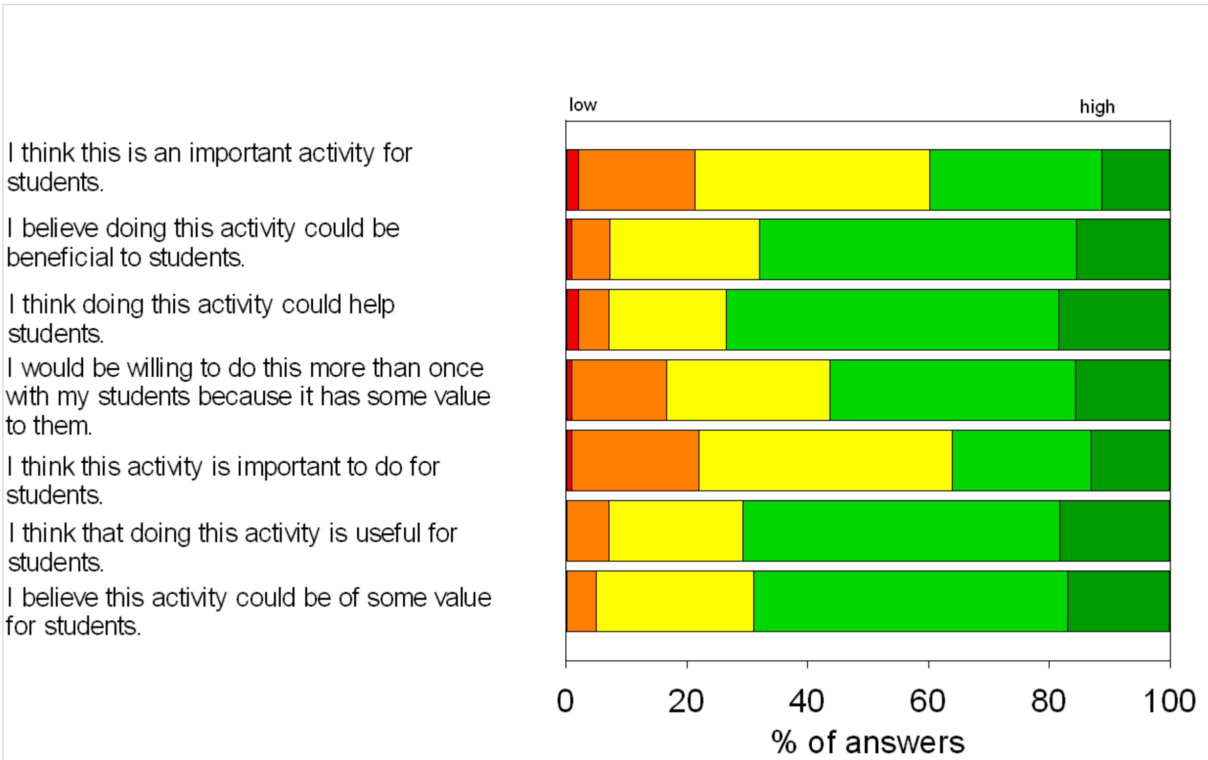

Fig. 2.1.1.7: Evaluation of Value/Usefulness (Intrinsic Motivation Inventory)

10.1.2 Survey of Students (school)

10.1.2.1 Mini-cooler & Heater (Kinetic Theory of Gases; Boltzmann)

Fig. 2.1.2.1: Evaluation of Pedagogical Aspects I (VALNet)

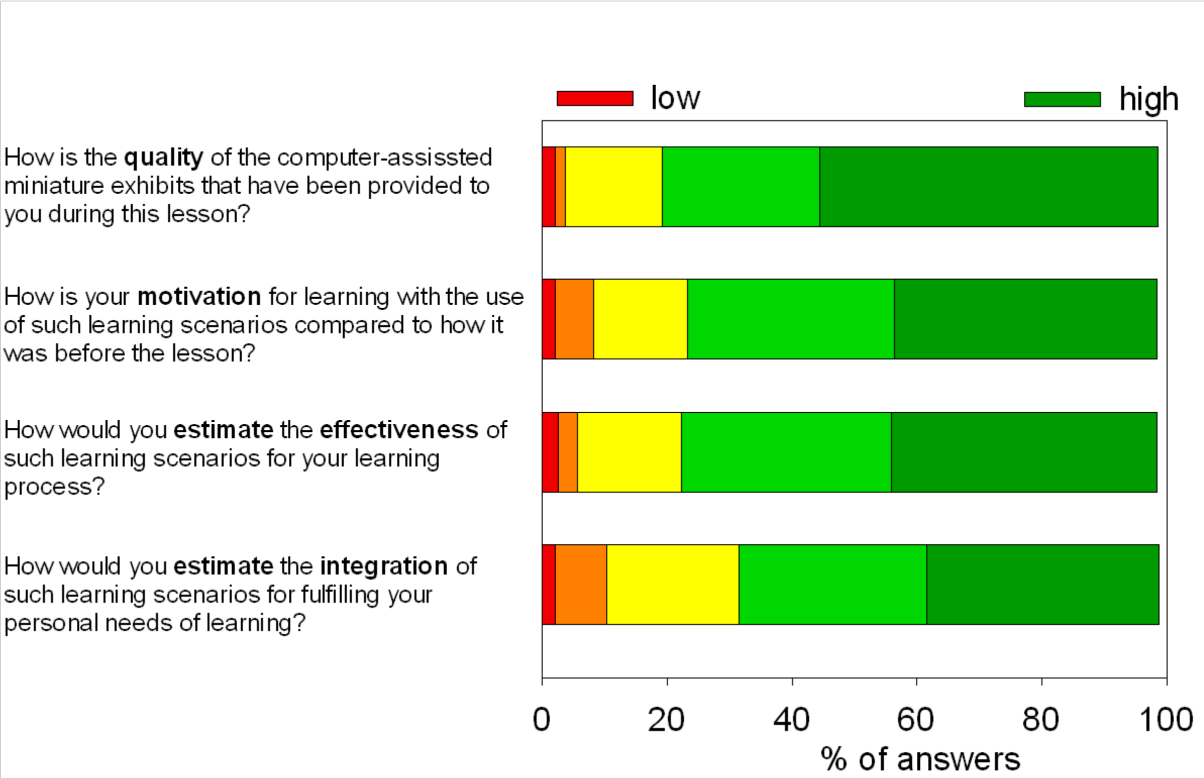

Fig. 2.1.2.2: Evaluation of Pedagogical Aspects II (VALNet)

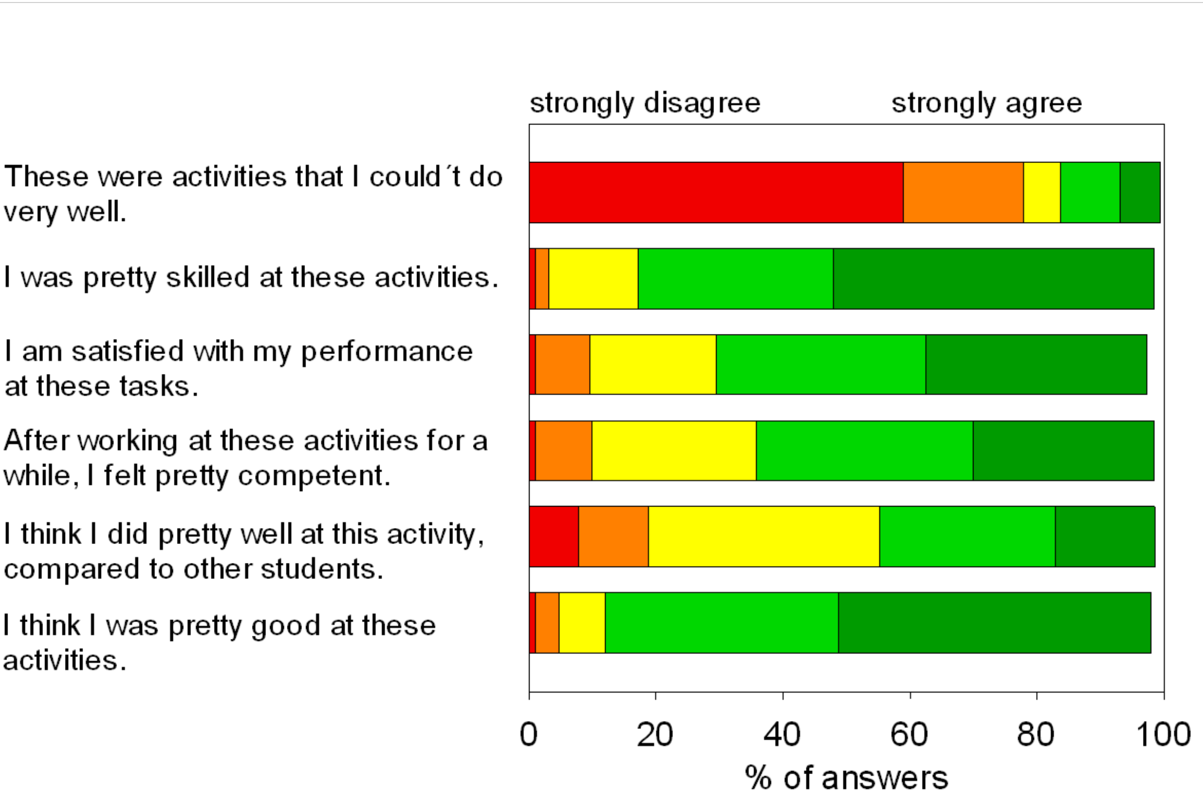

Fig. 2.1.2.3: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

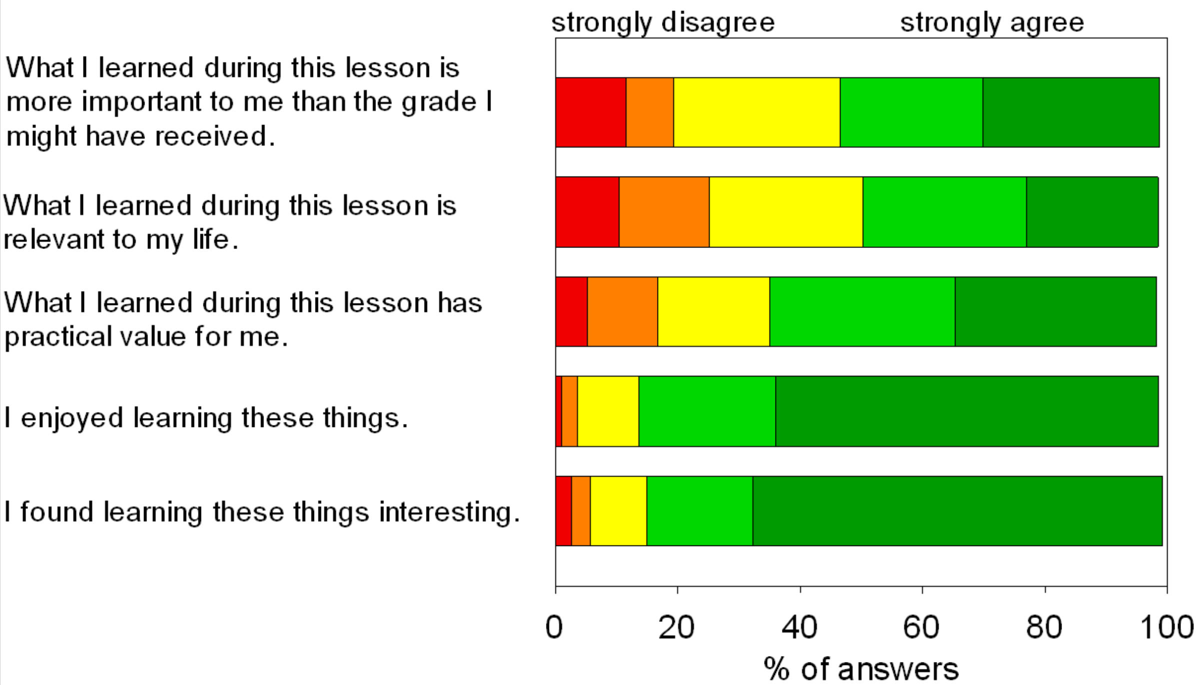

Fig. 2.1.2.4: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

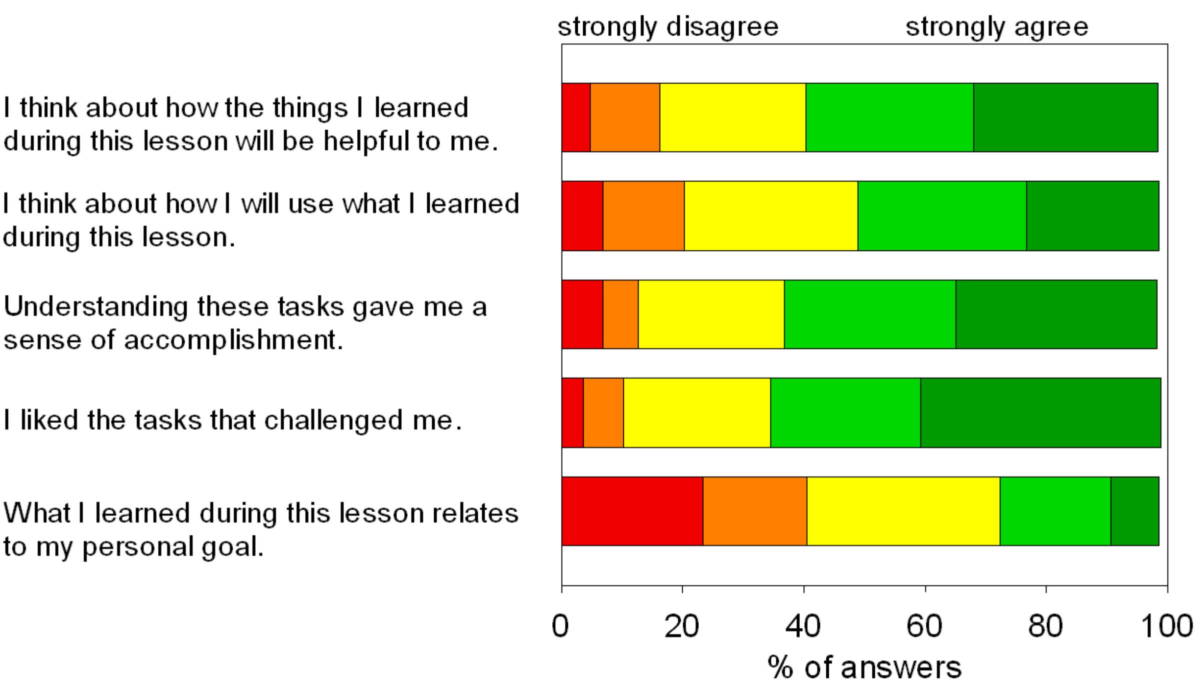

Fig. 2.1.2.5: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

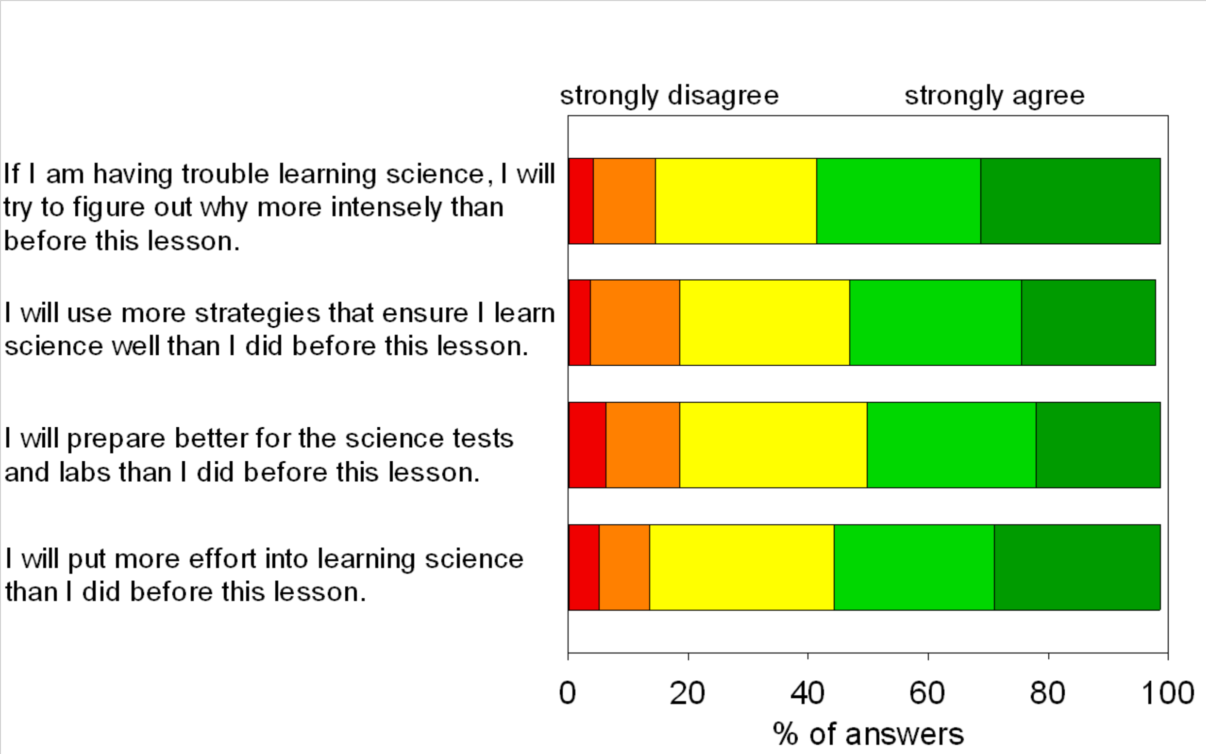

Fig. 2.1.2.6: Evaluation of Self-determination (Science Motivation Questionnaire)

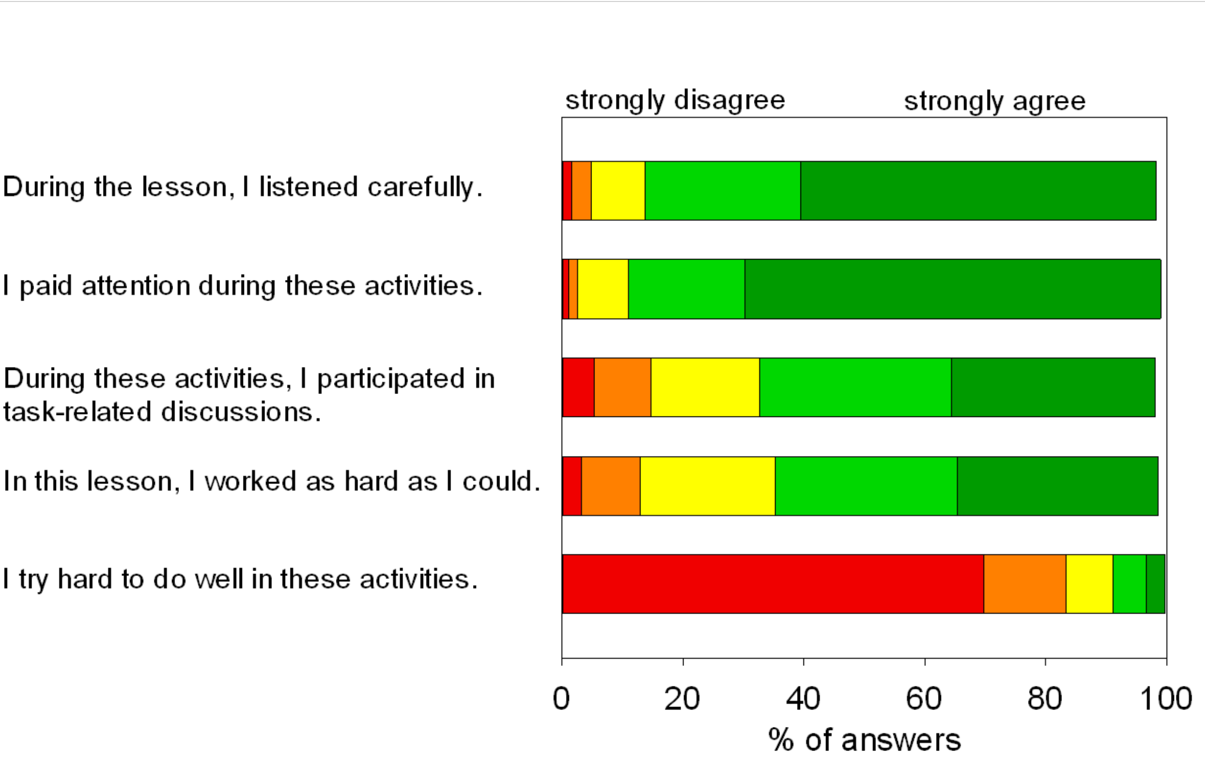

Fig. 2.1.2.7: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

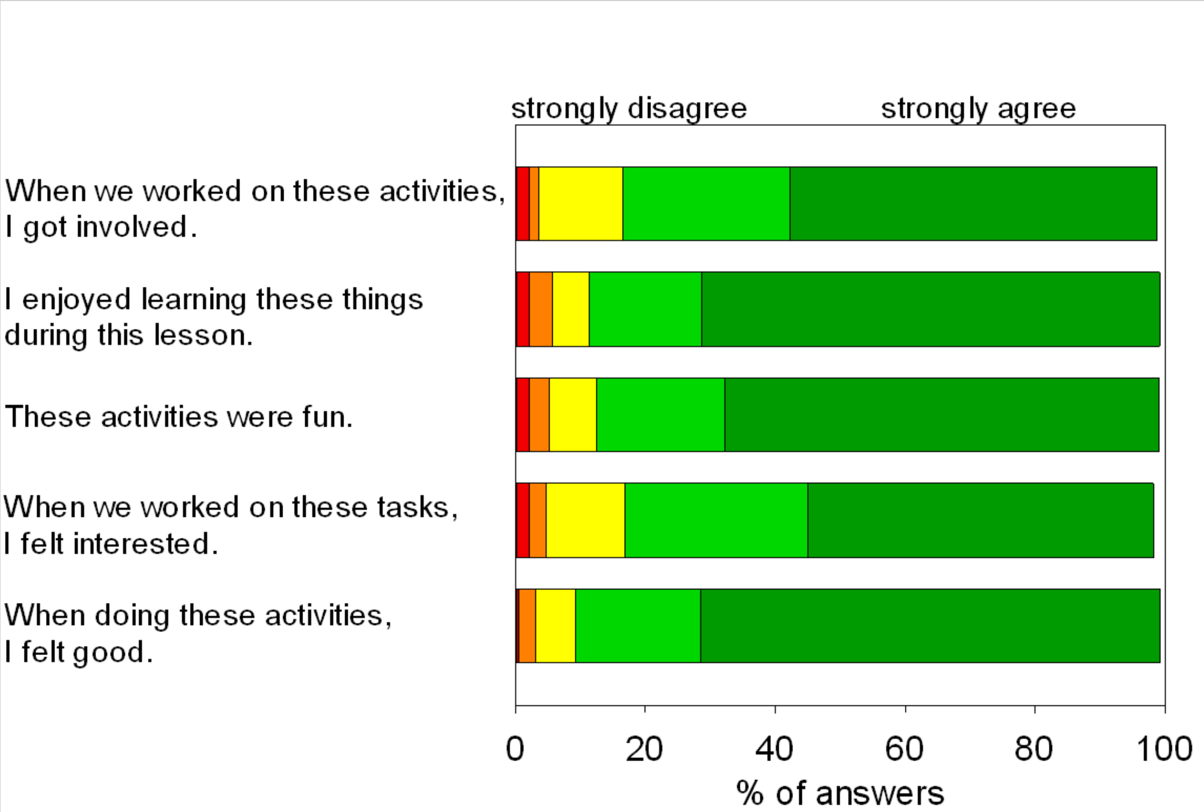

Fig. 2.1.2.8: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.1.2.2 Mini-Wing (Wing Dynamics)

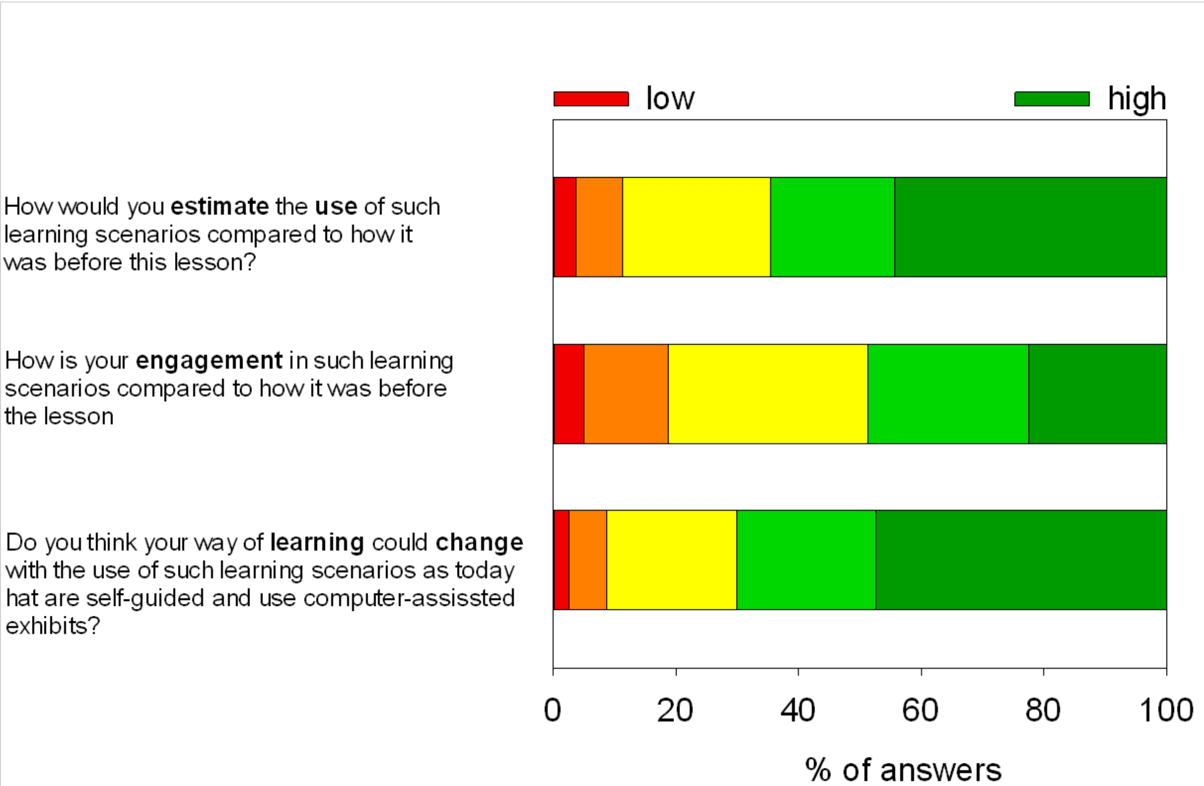

Fig. 2.1.2.9: Evaluation of Pedagogical Aspects I (VALNet)

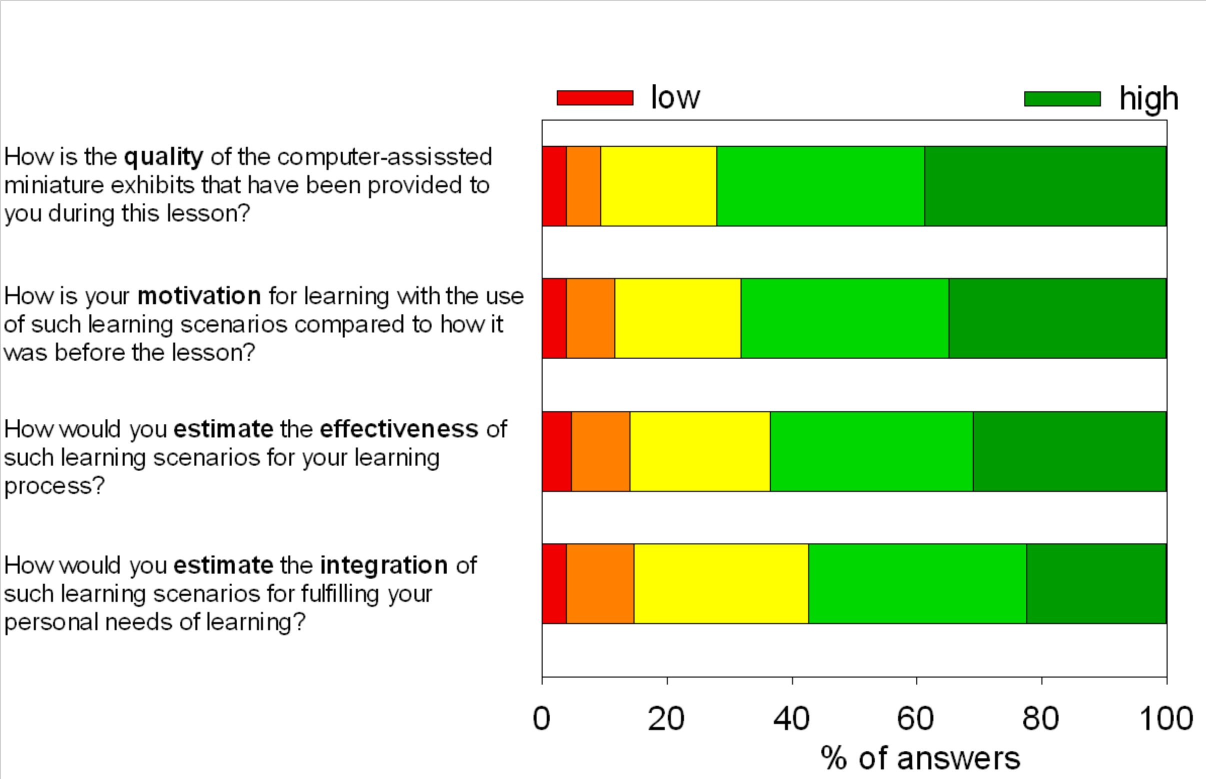

Fig. 2.1.2.10: Evaluation of Pedagogical Aspects II (VALNet)

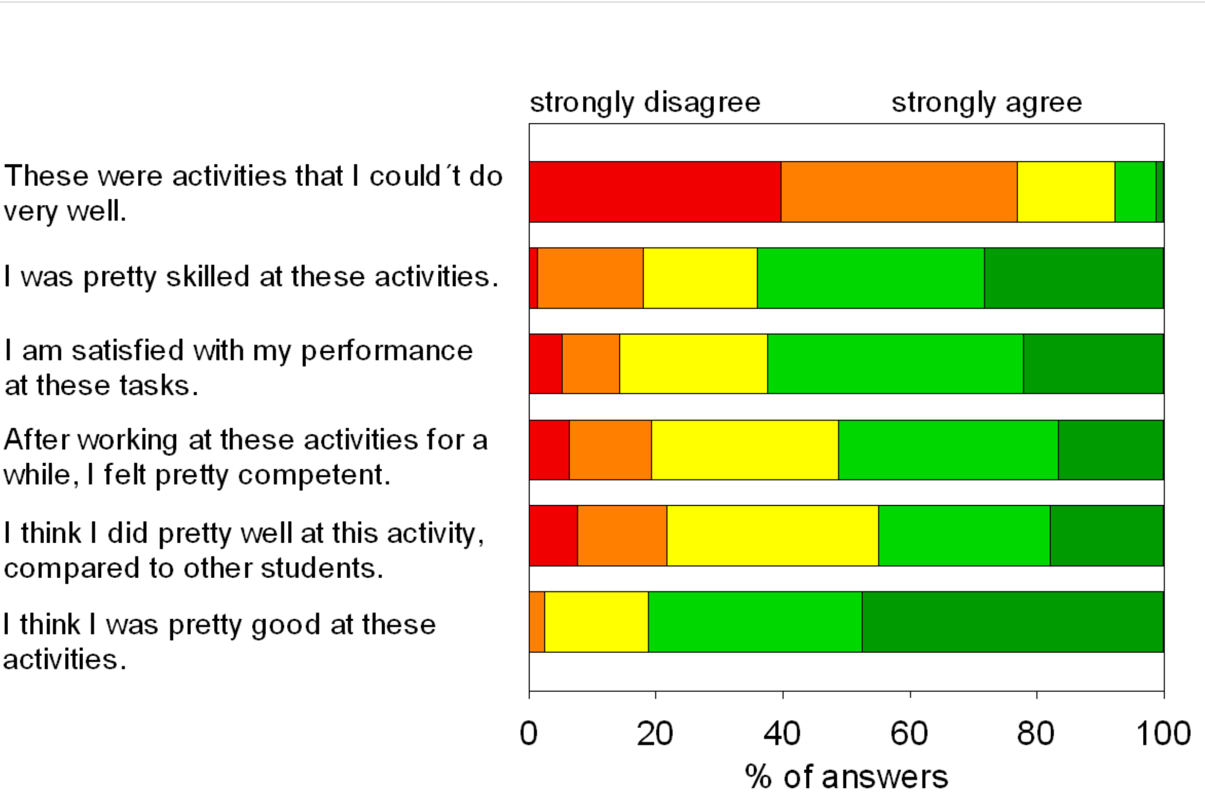

Fig. 2.1.2.11: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

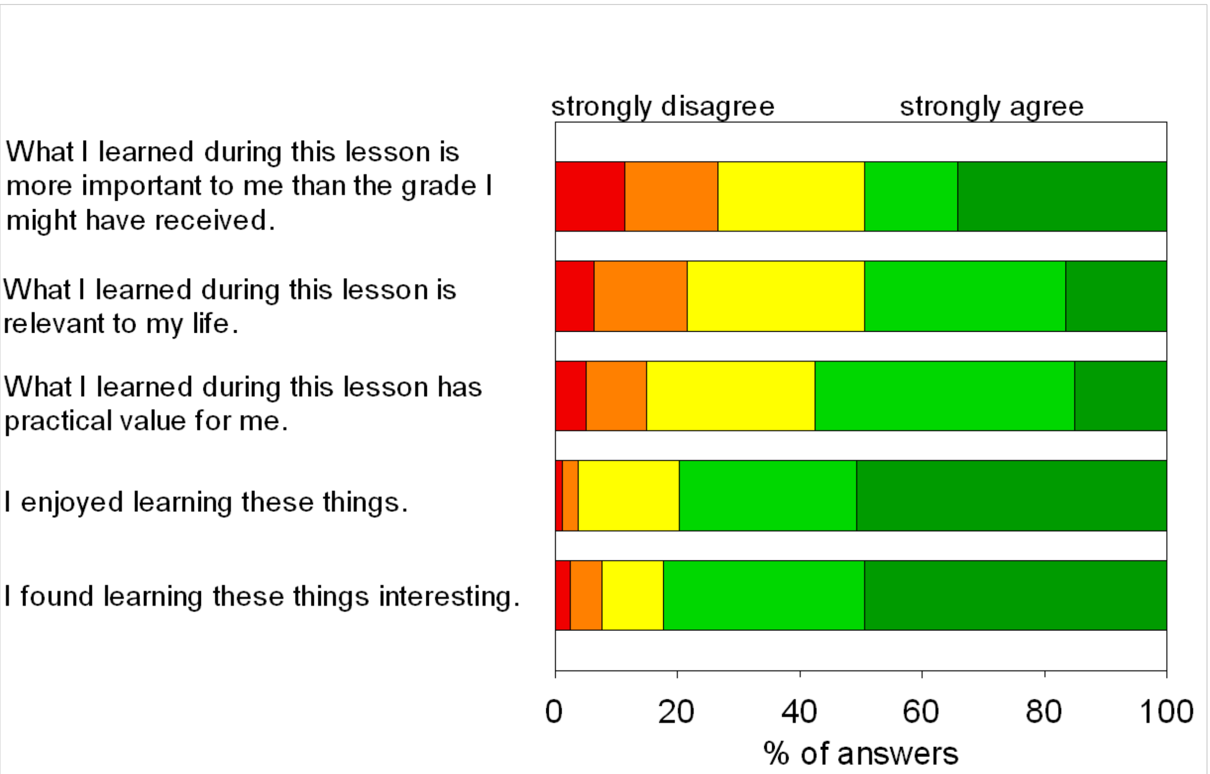

Fig. 2.1.2.12: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

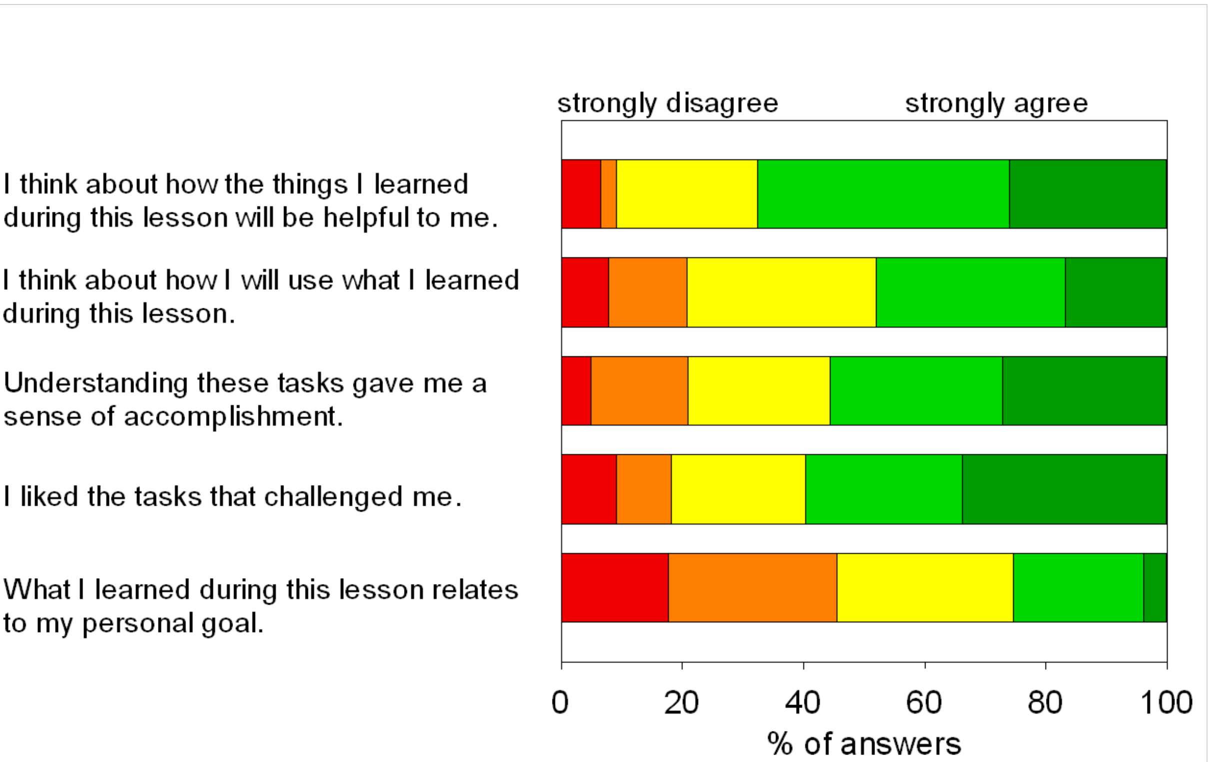

Fig. 2.1.2.13: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

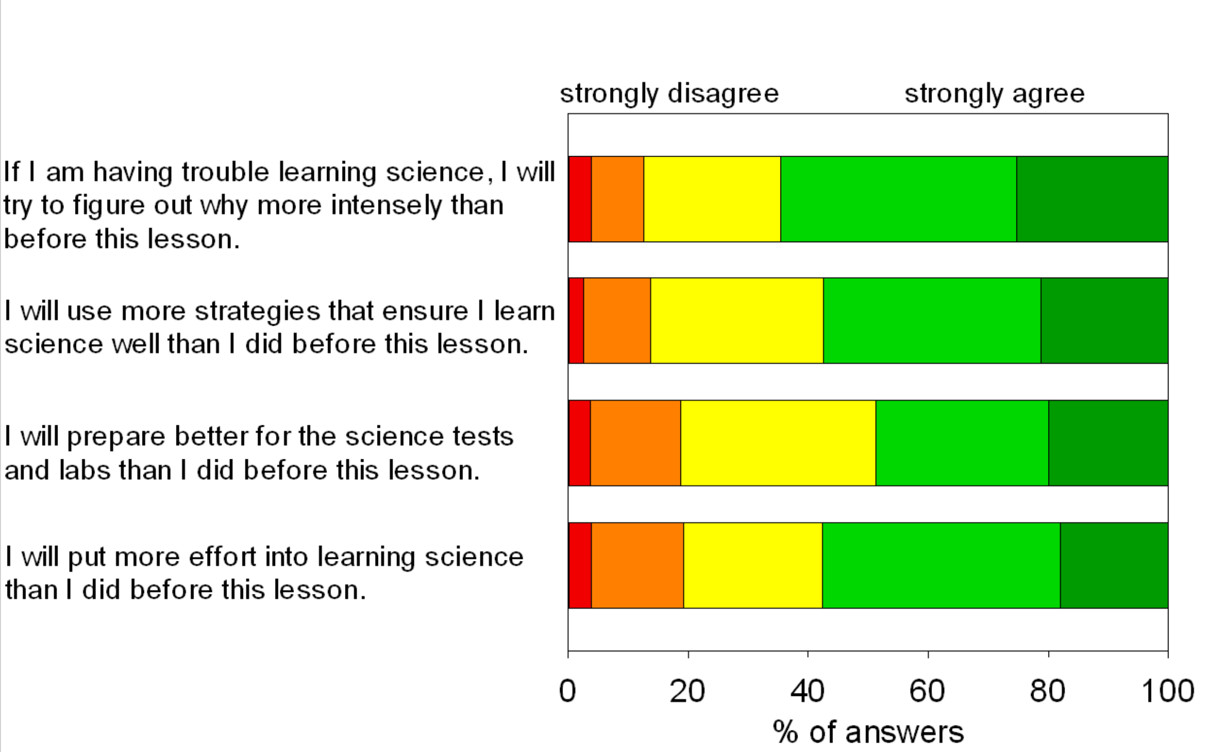

Fig. 2.1.2.14: Evaluation of Self-determination (Science Motivation Questionnaire)

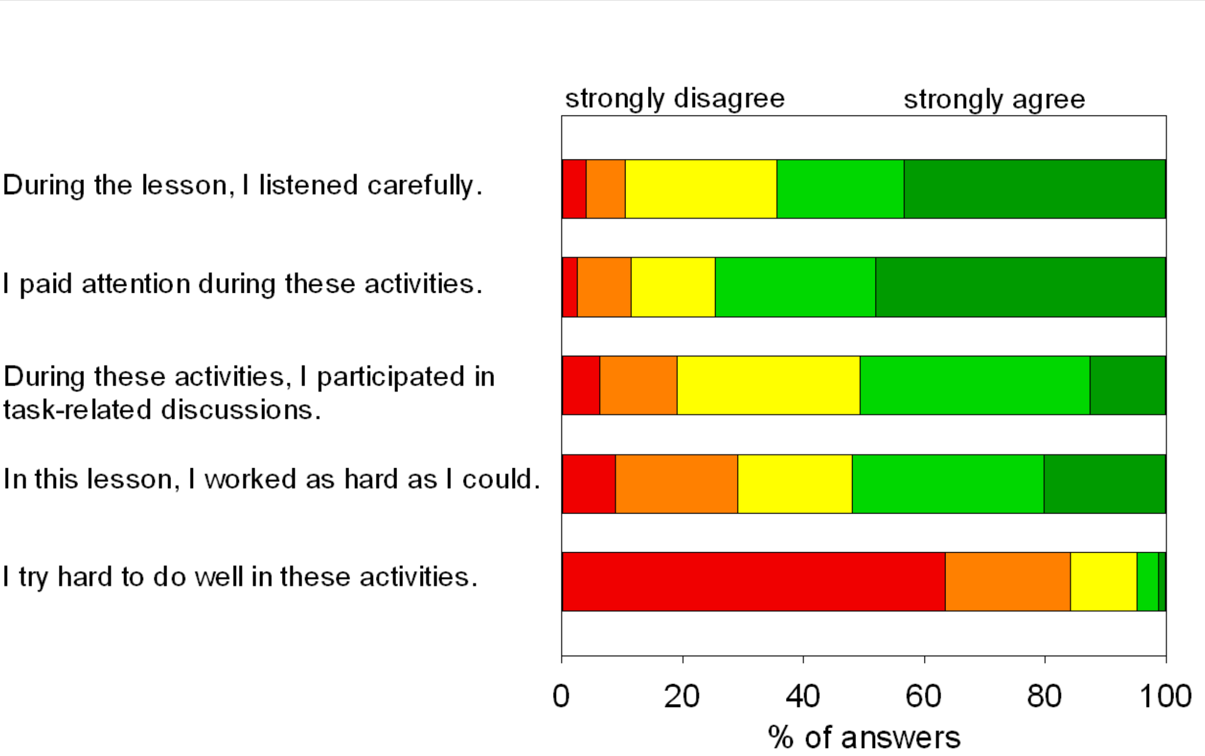

Fig. 2.1.2.15: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

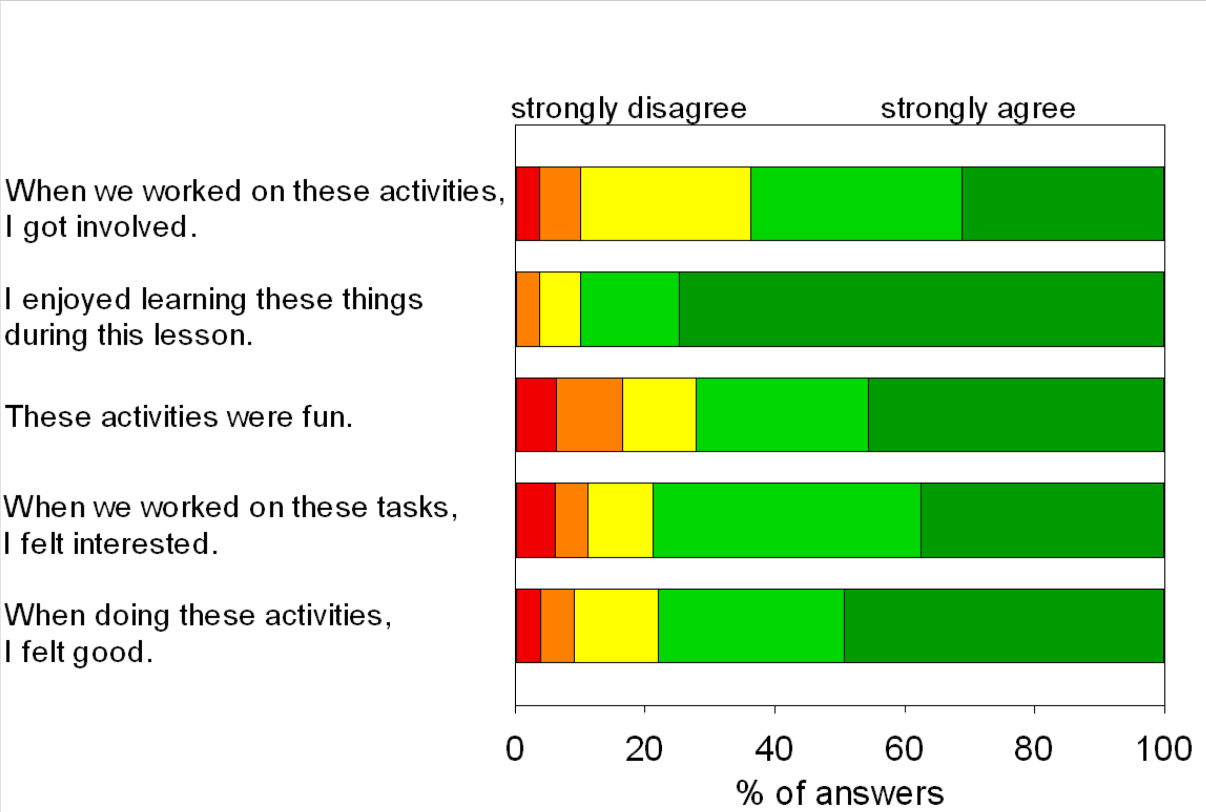

Fig. 2.1.2.16: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.1.2.3 Mini-Firetruck (Doppler Effect)

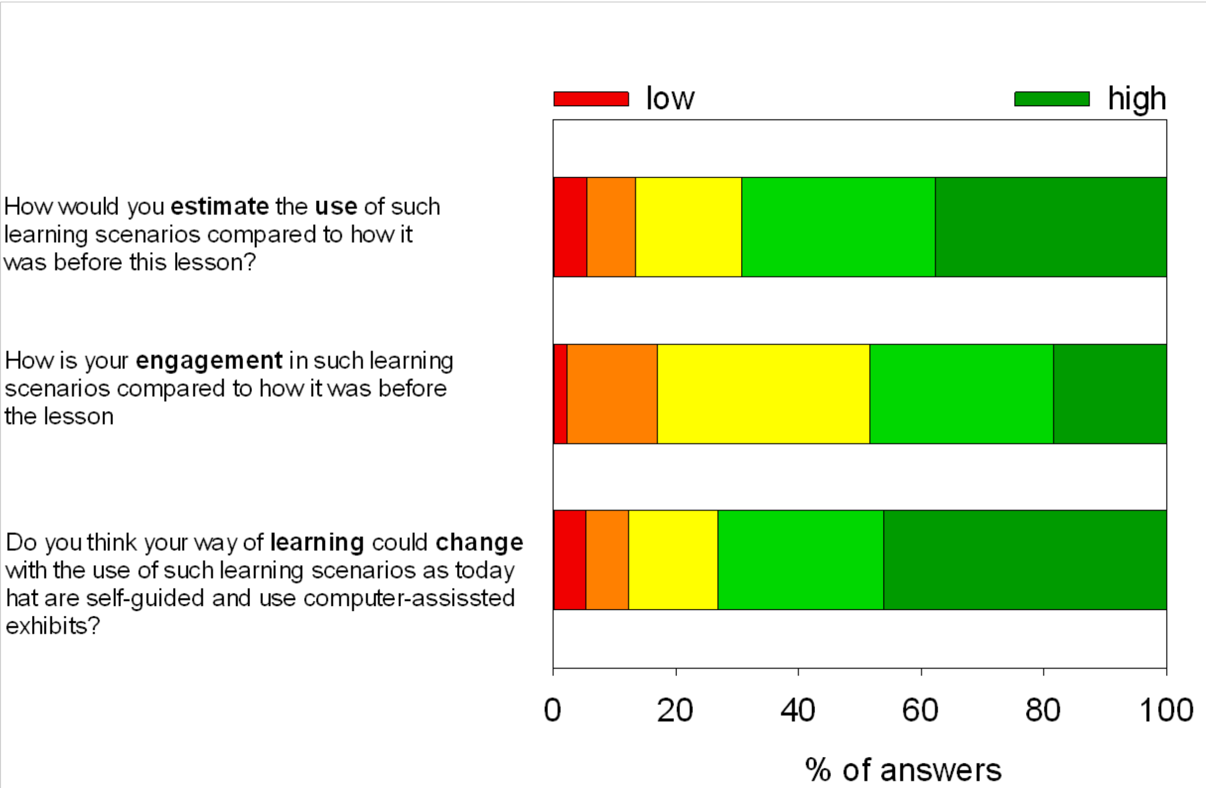

Fig. 2.1.2.17: Evaluation of Pedagogical Aspects I (VALNet)

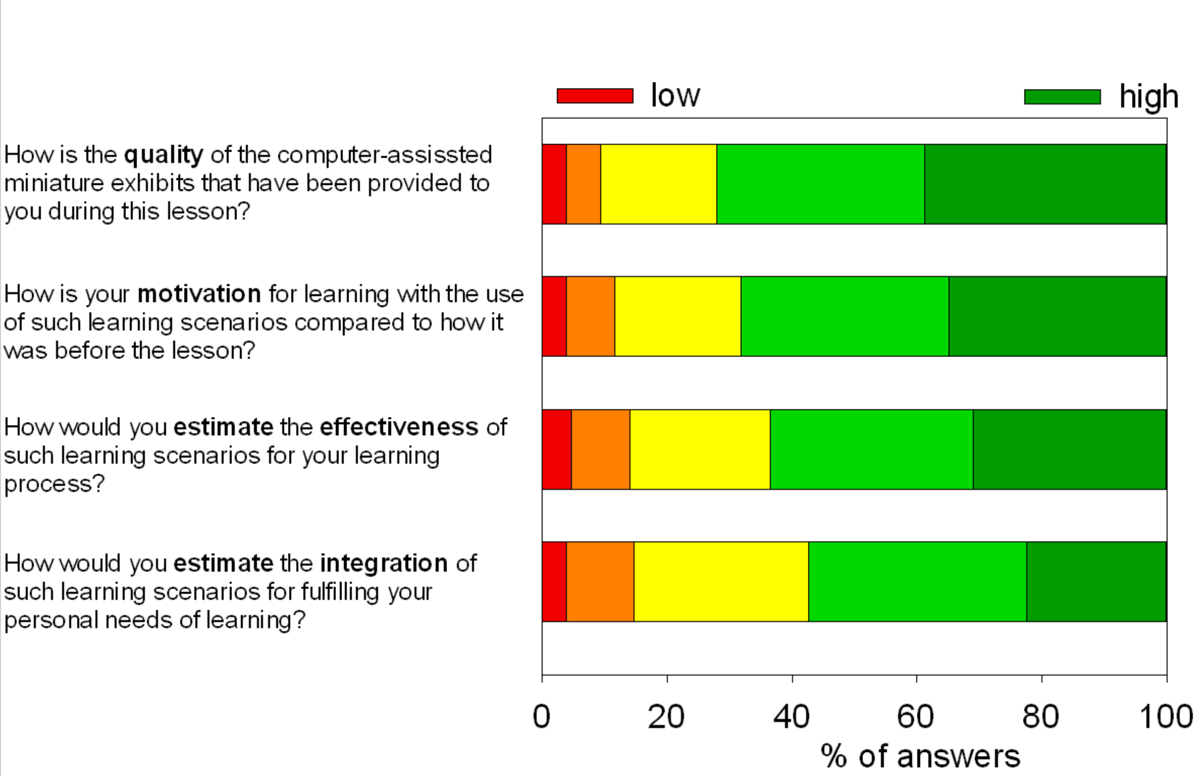

Fig. 2.1.2.18: Evaluation of Pedagogical Aspects II (VALNet)

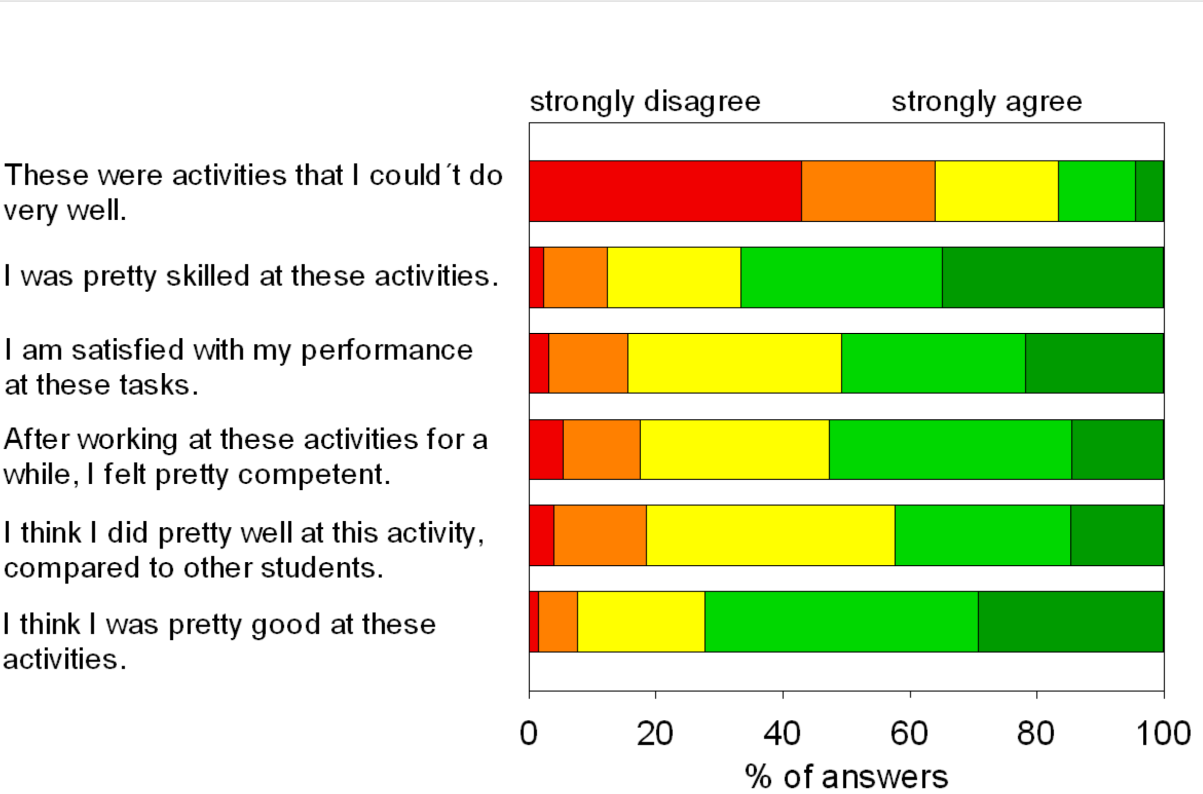

Fig. 2.1.2.19: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

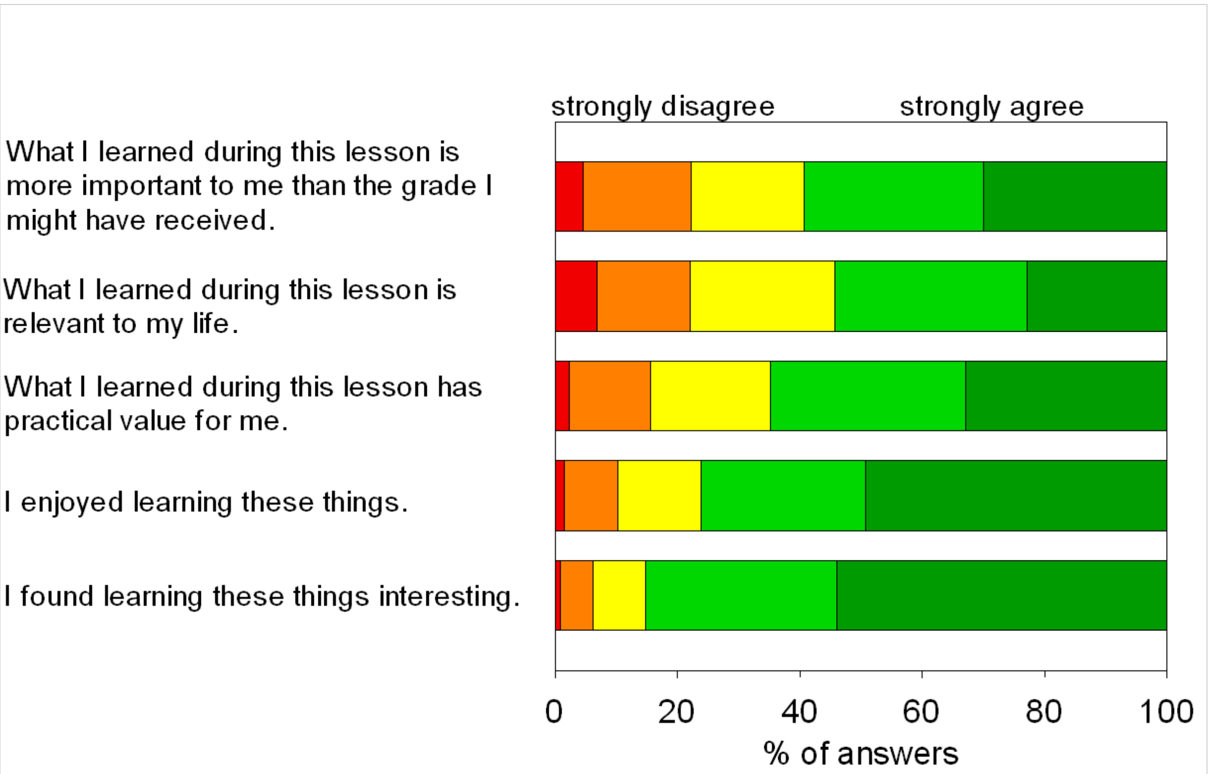

Fig. 2.1.2.20: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

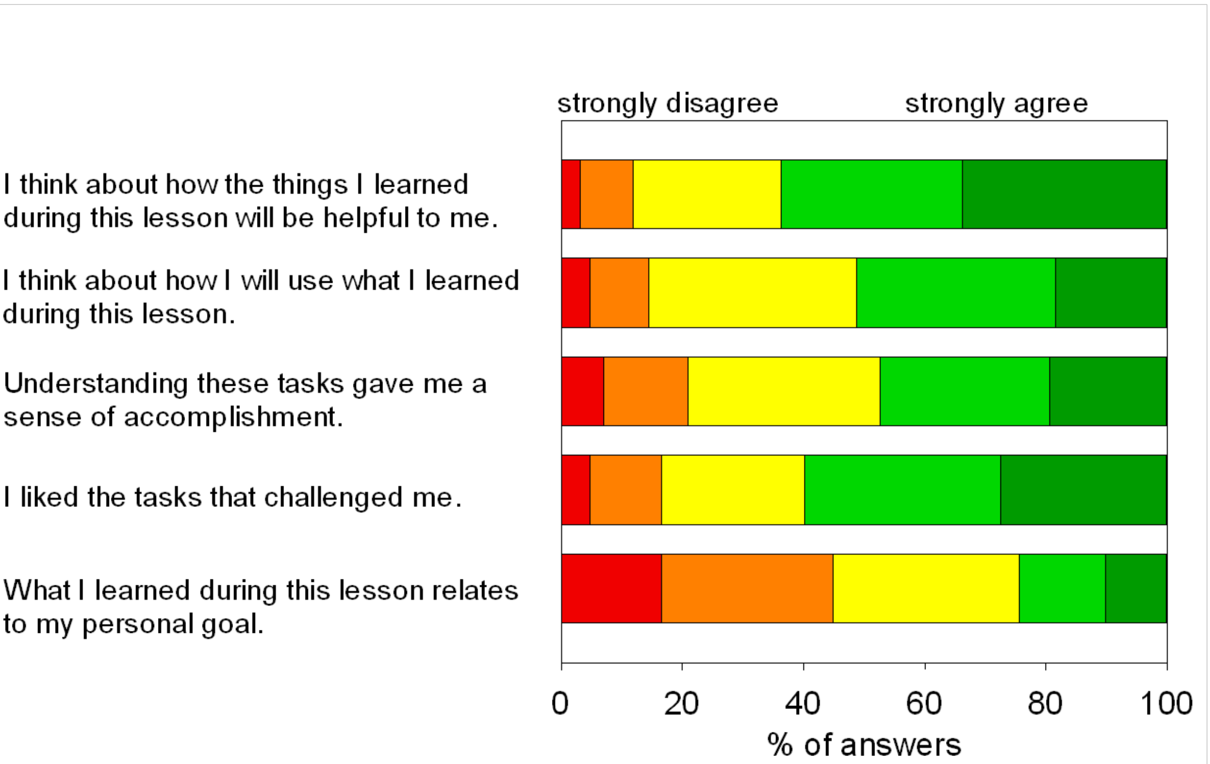

Fig. 2.1.2.21: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

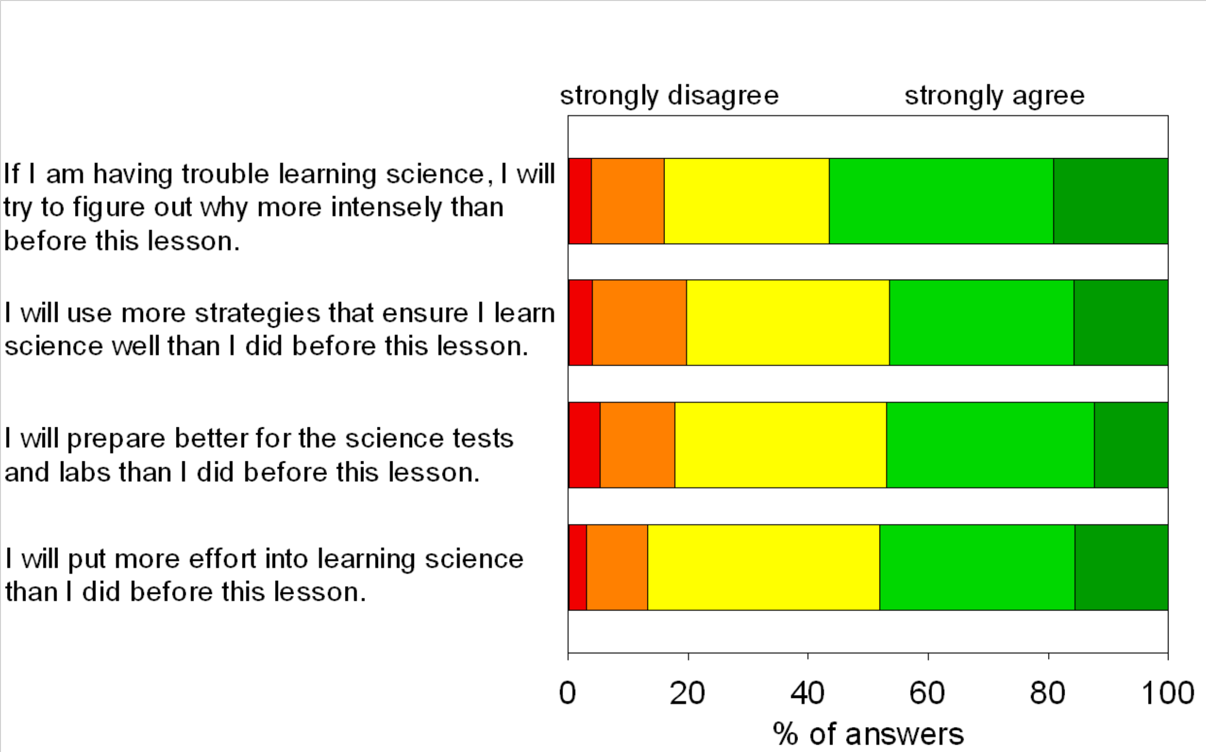

Fig. 2.1.2.22: Evaluation of Self-determination (Science Motivation Questionnaire)

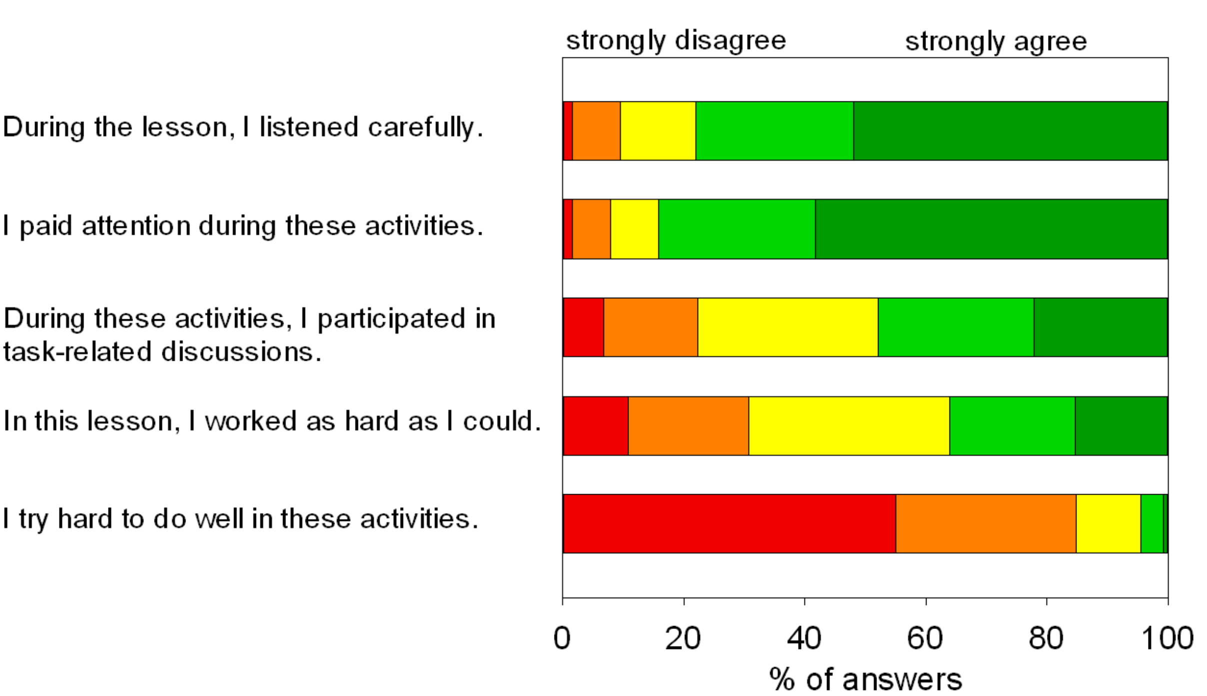

Fig. 2.1.2.23: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

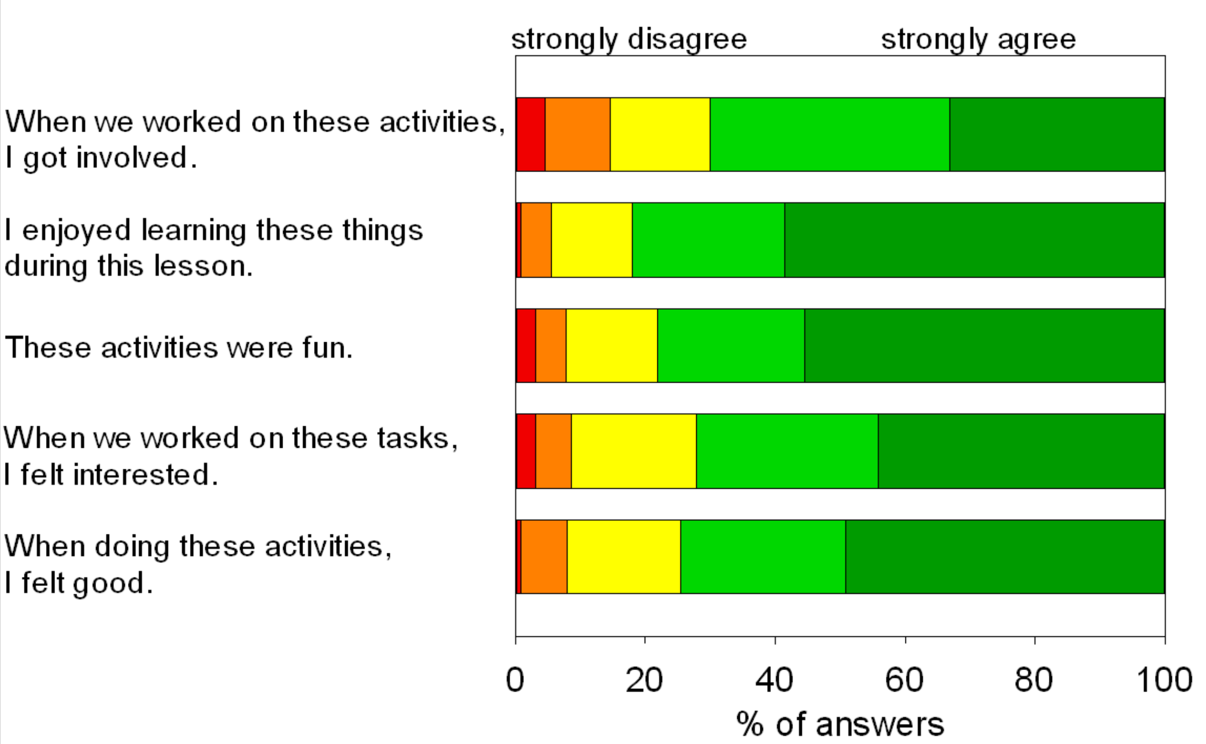

Fig. 2.1.2.24: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.1.2.4 Mini-Double Cone (Classical Mechanics)

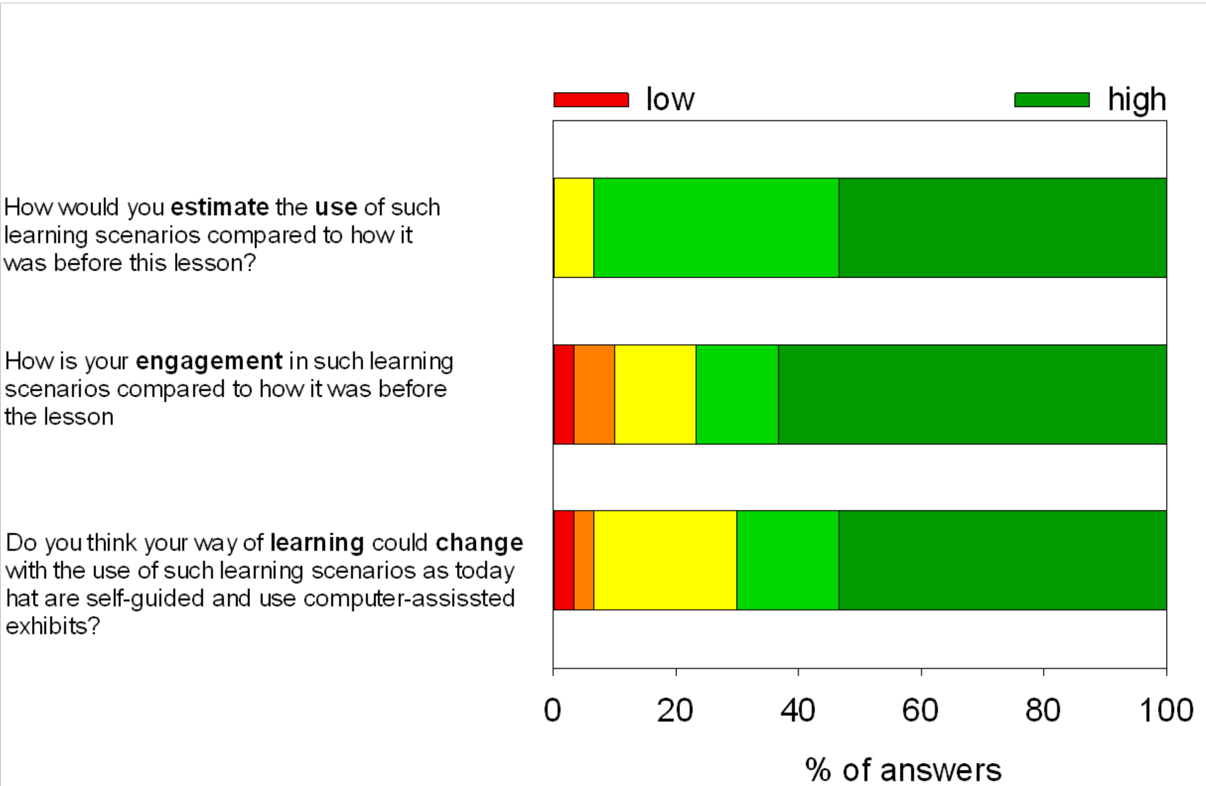

Fig. 2.1.2.25: Evaluation of Pedagogical Aspects I (VALNet)

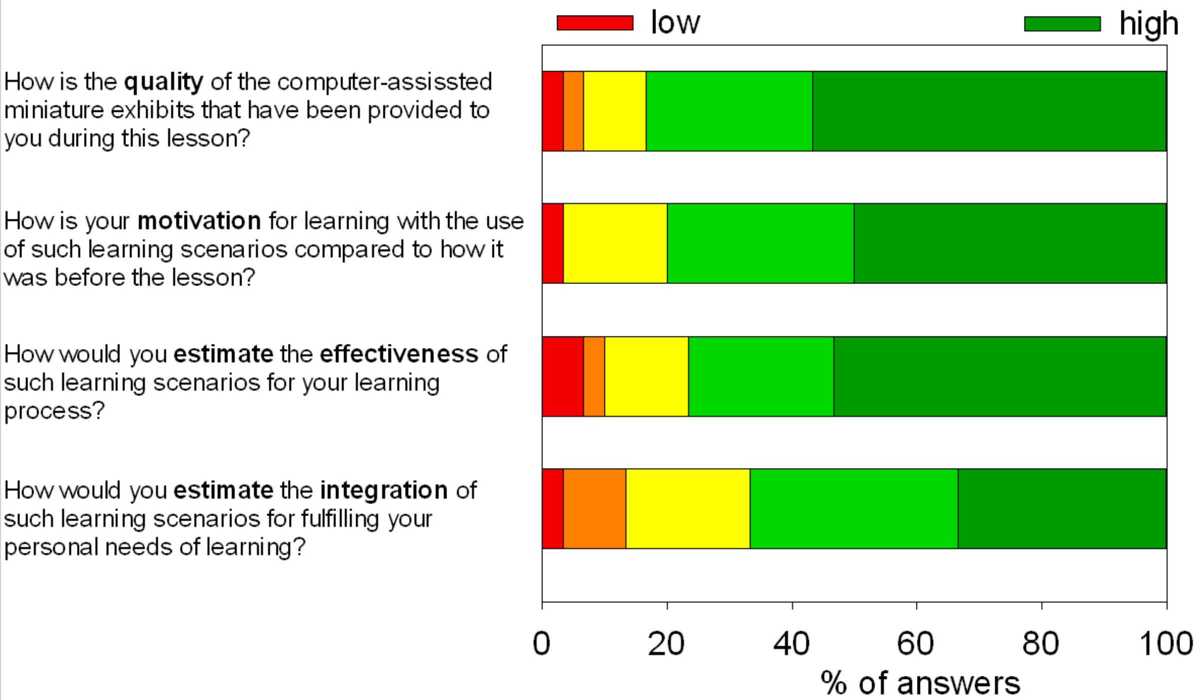

Fig. 2.1.2.26: Evaluation of Pedagogical Aspects II (VALNet)

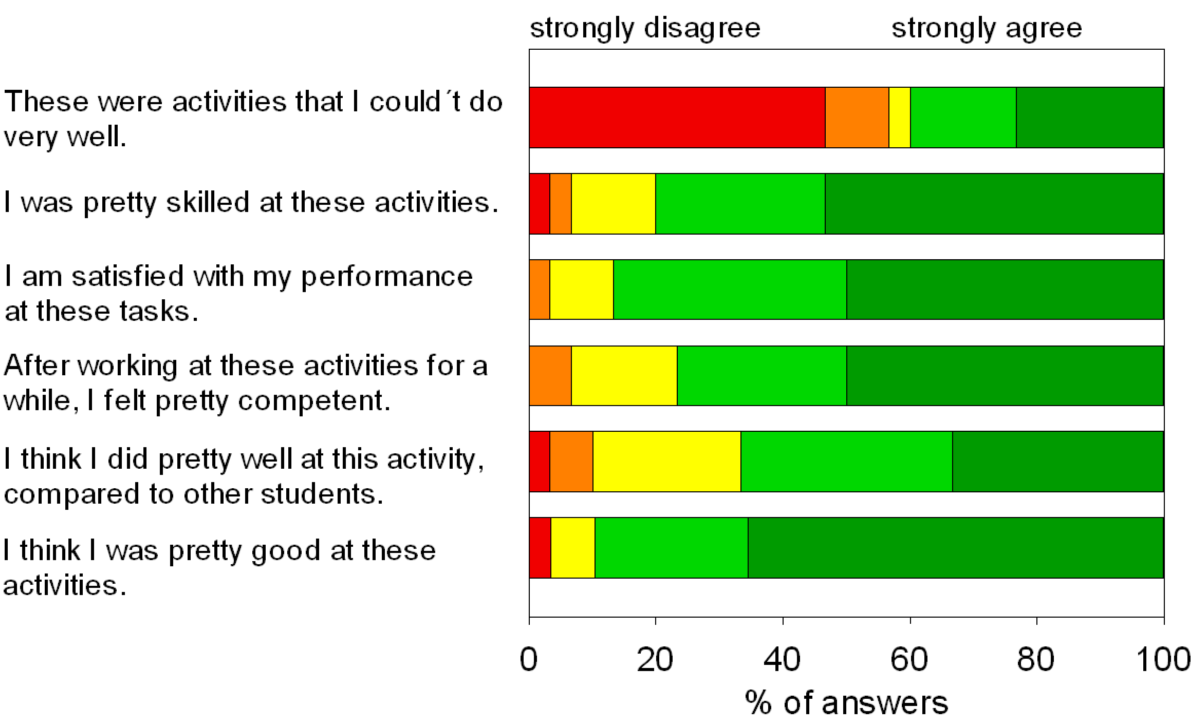

Fig. 2.1.2.27: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

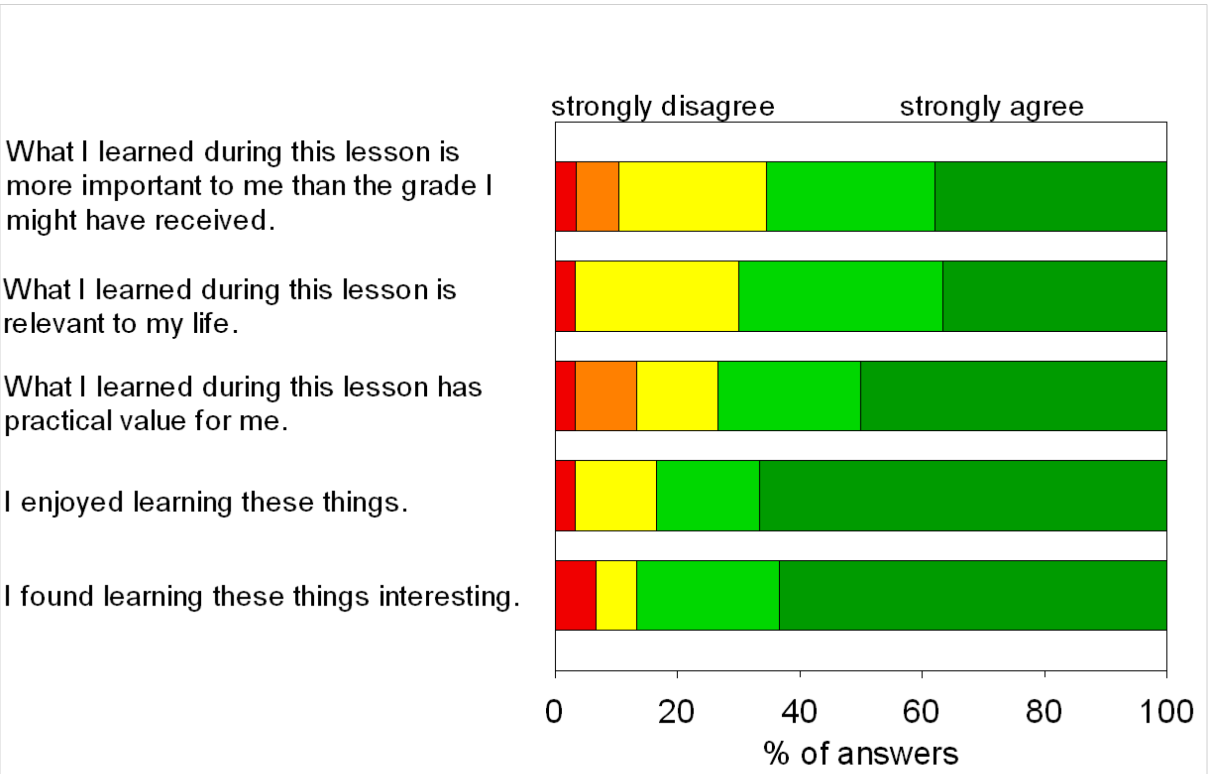

Fig. 2.1.2.28: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

Fig. 2.1.2.29: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

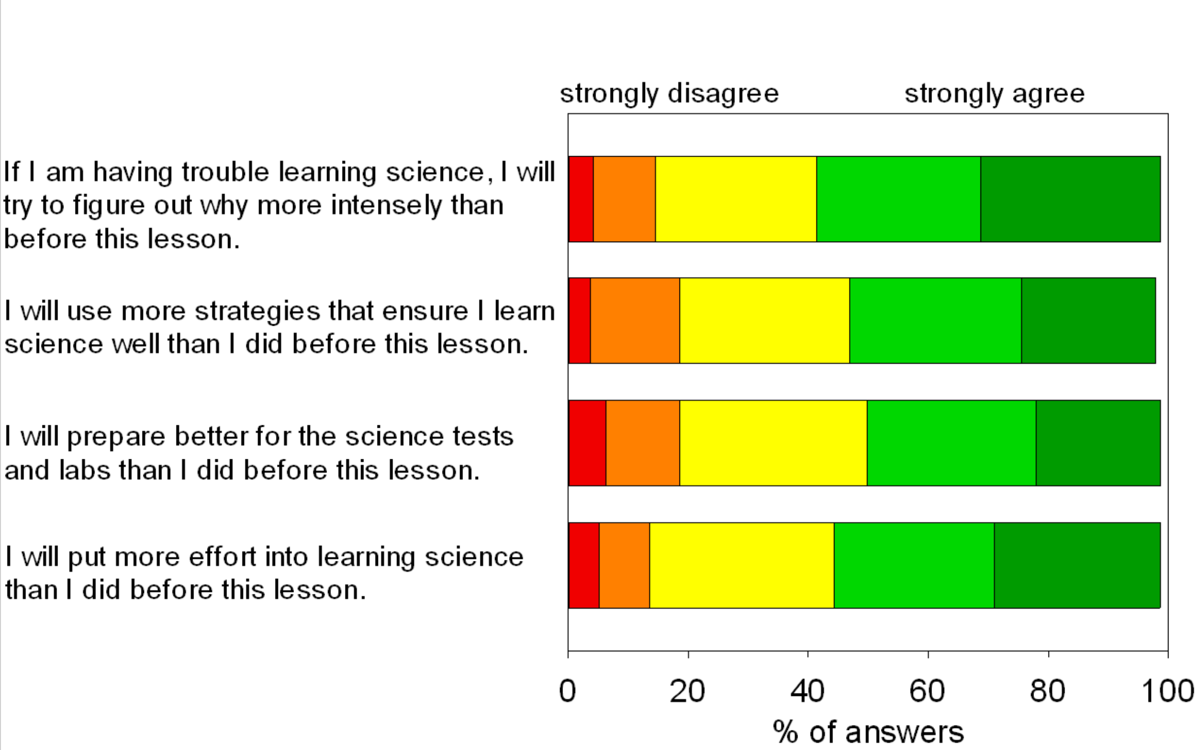

Fig. 2.1.2.30: Evaluation of Self-determination (Science Motivation Questionnaire)

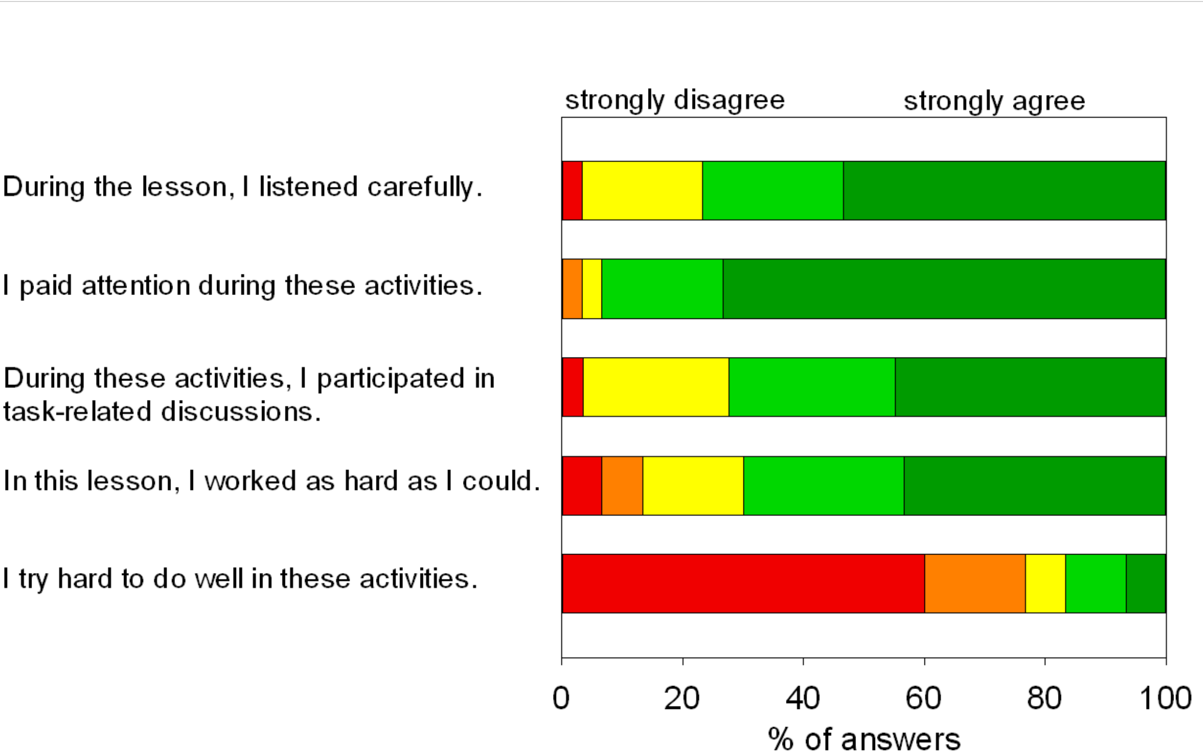

Fig. 2.1.2.31: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

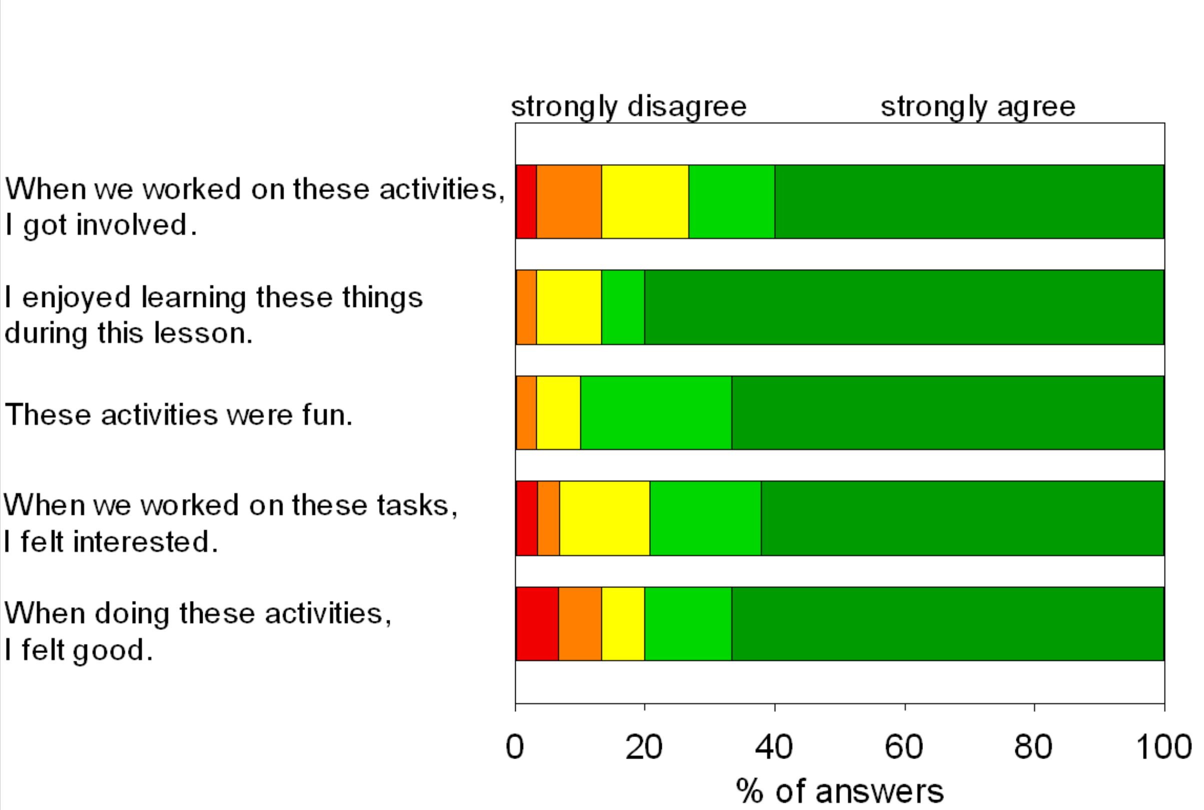

Fig. 2.1.2.32: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.1.2.5 Mini-Double Slit (Quantum Mechanics)

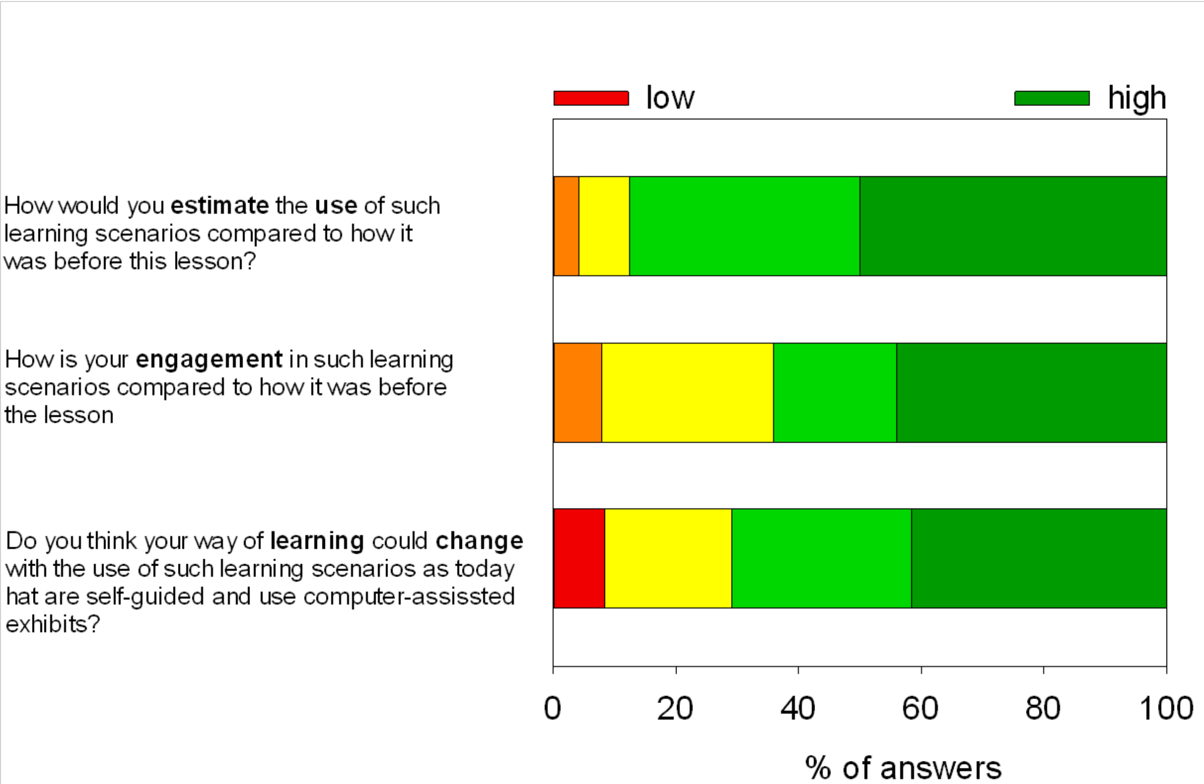

Fig. 2.1.2.33: Evaluation of Pedagogical Aspects I (VALNet)

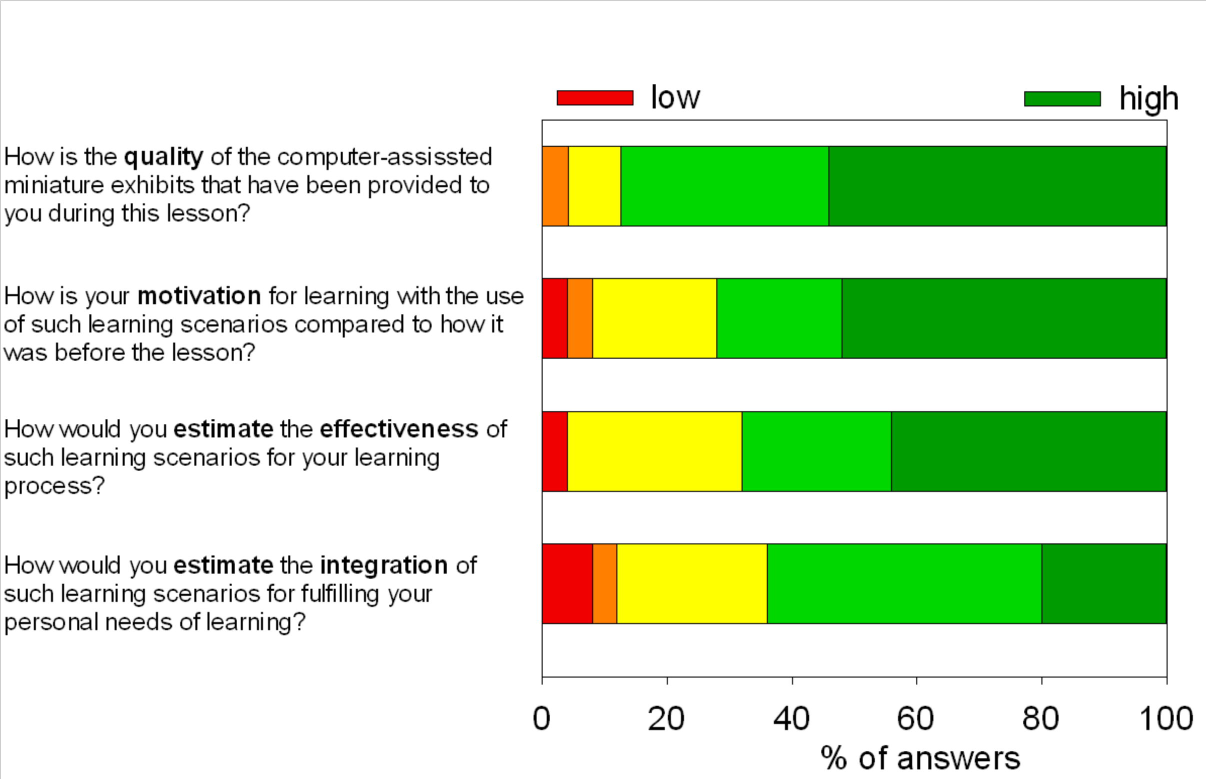

Fig. 2.1.2.34: Evaluation of Pedagogical Aspects II (VALNet)

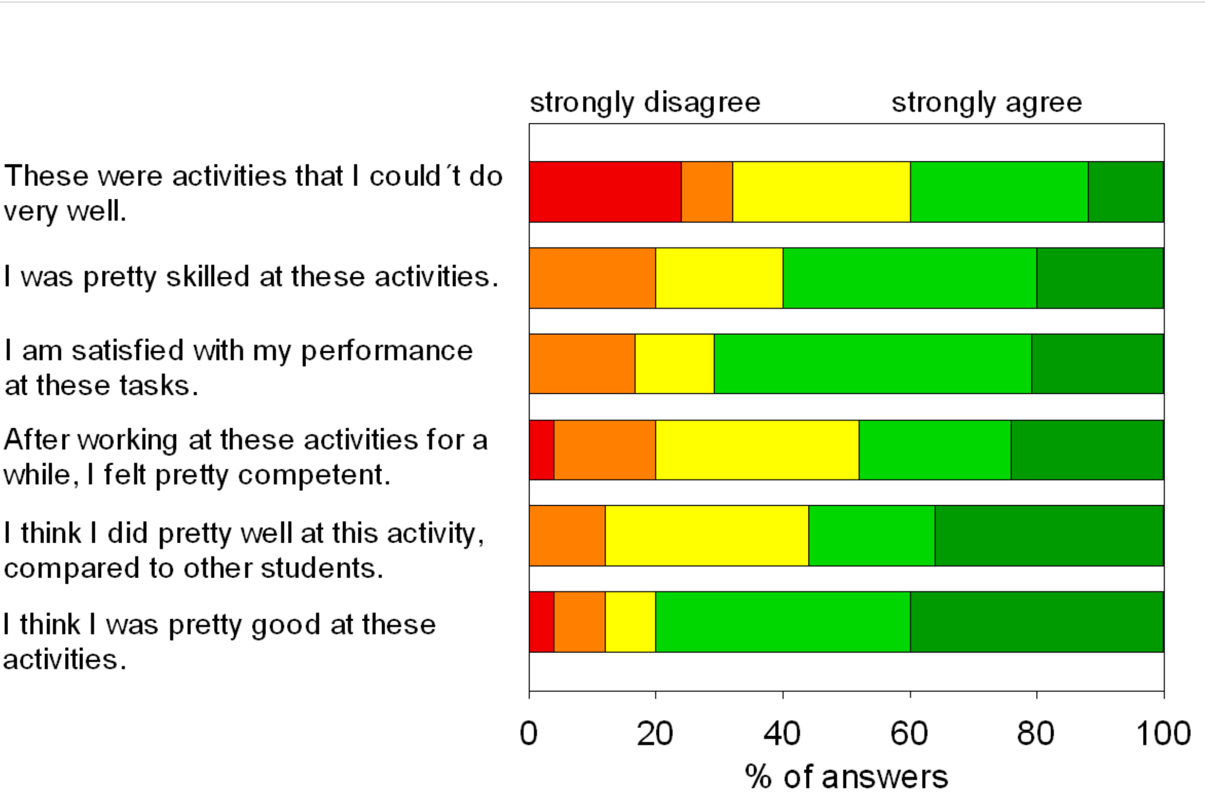

Fig. 2.1.2.35: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

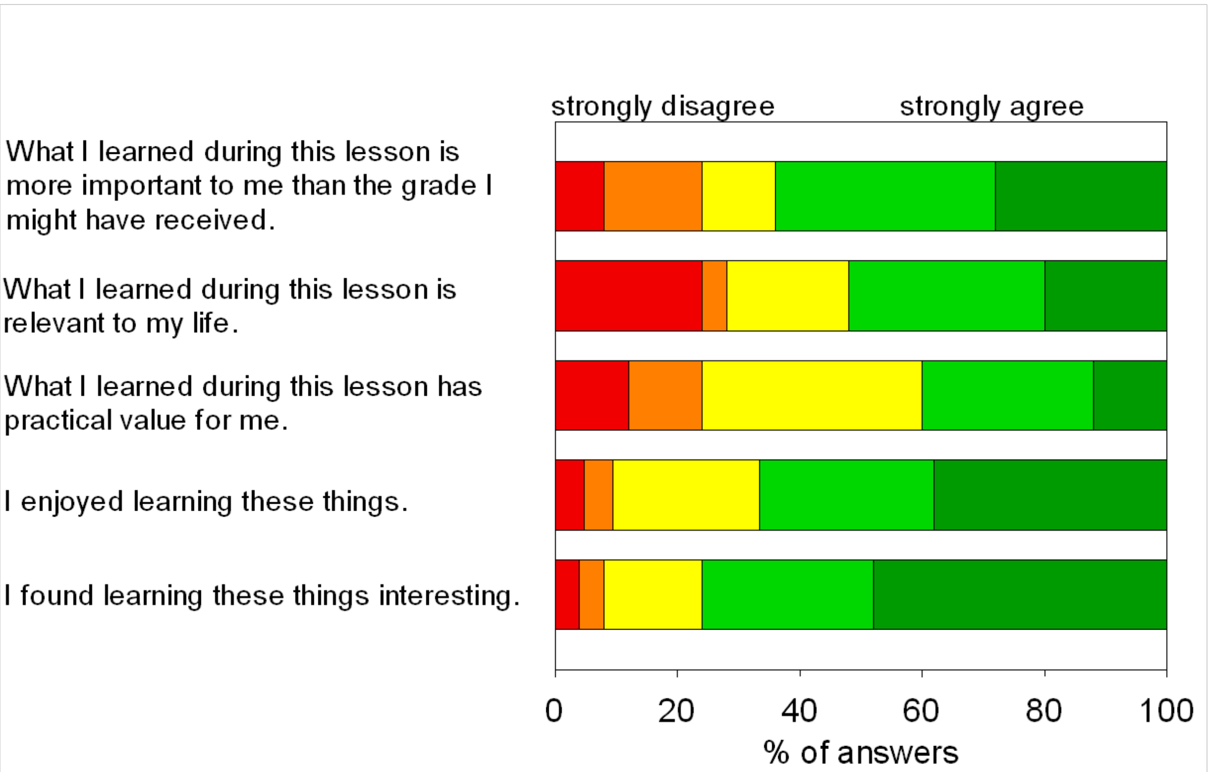

Fig. 2.1.2.36: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

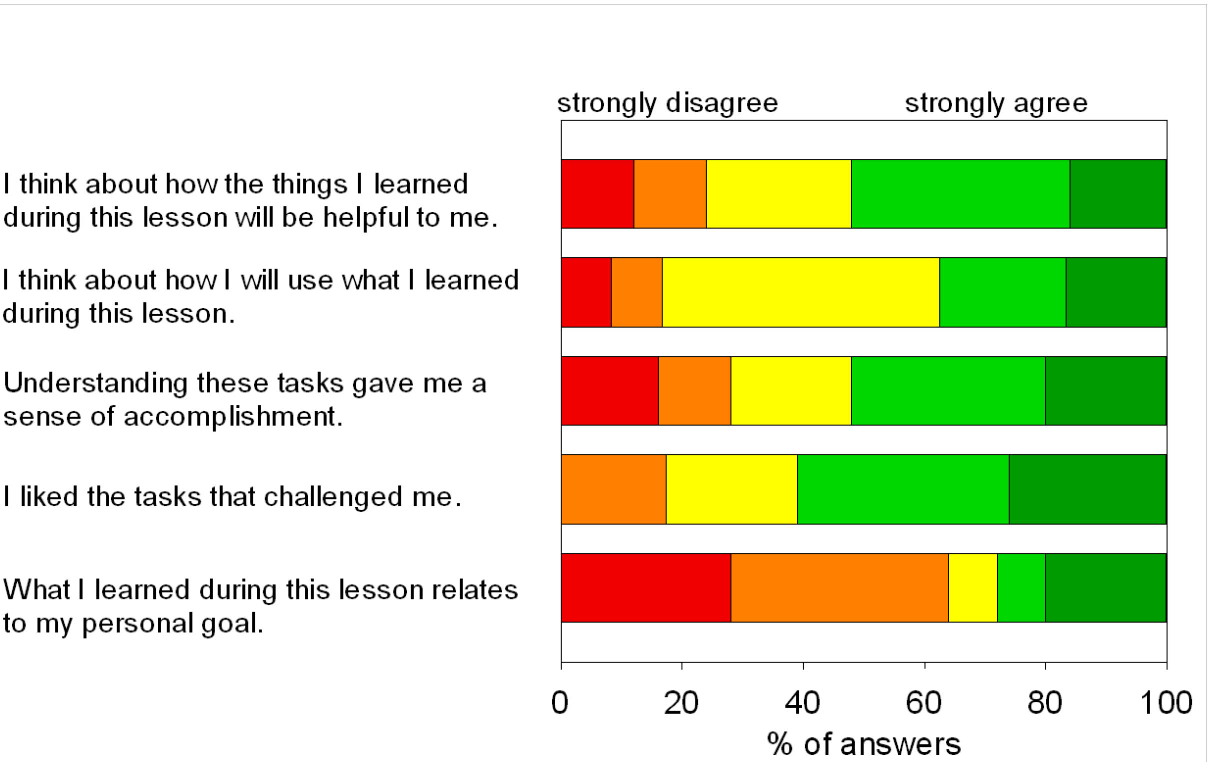

Fig. 2.1.2.37: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

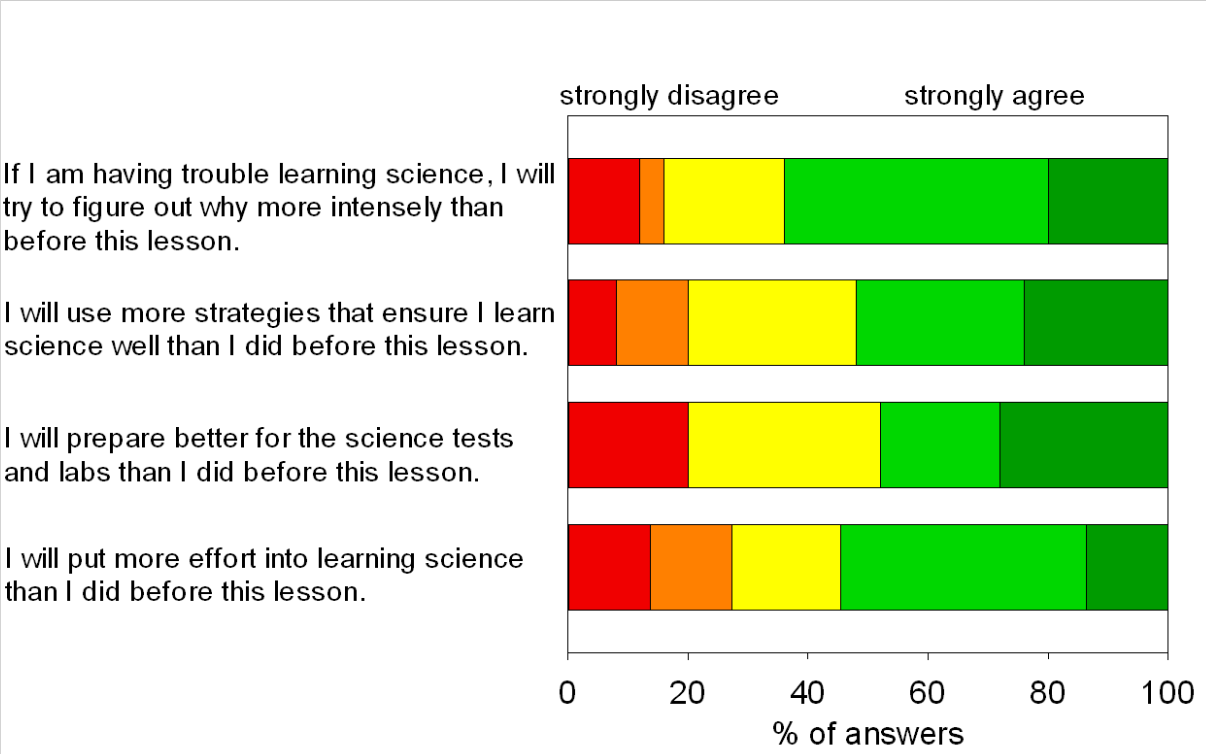

Fig. 2.1.2.38: Evaluation of Self-determination (Science Motivation Questionnaire)

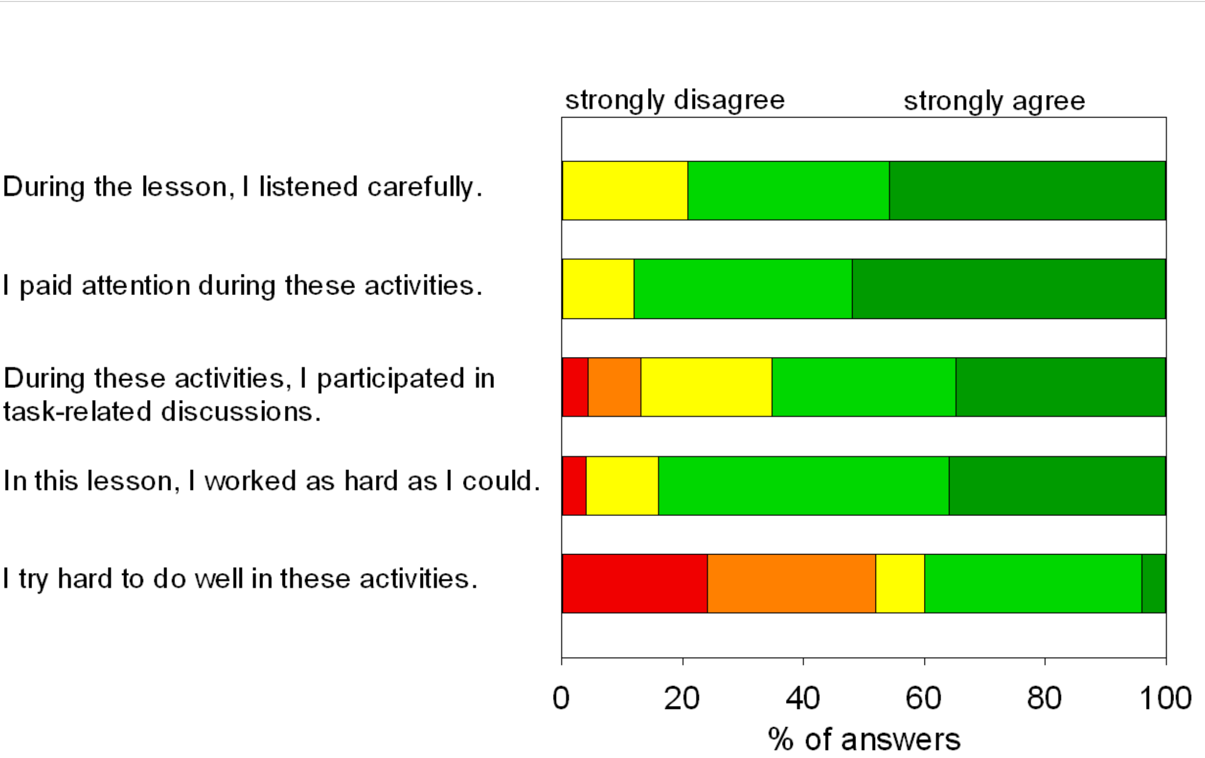

Fig. 2.1.2.39: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

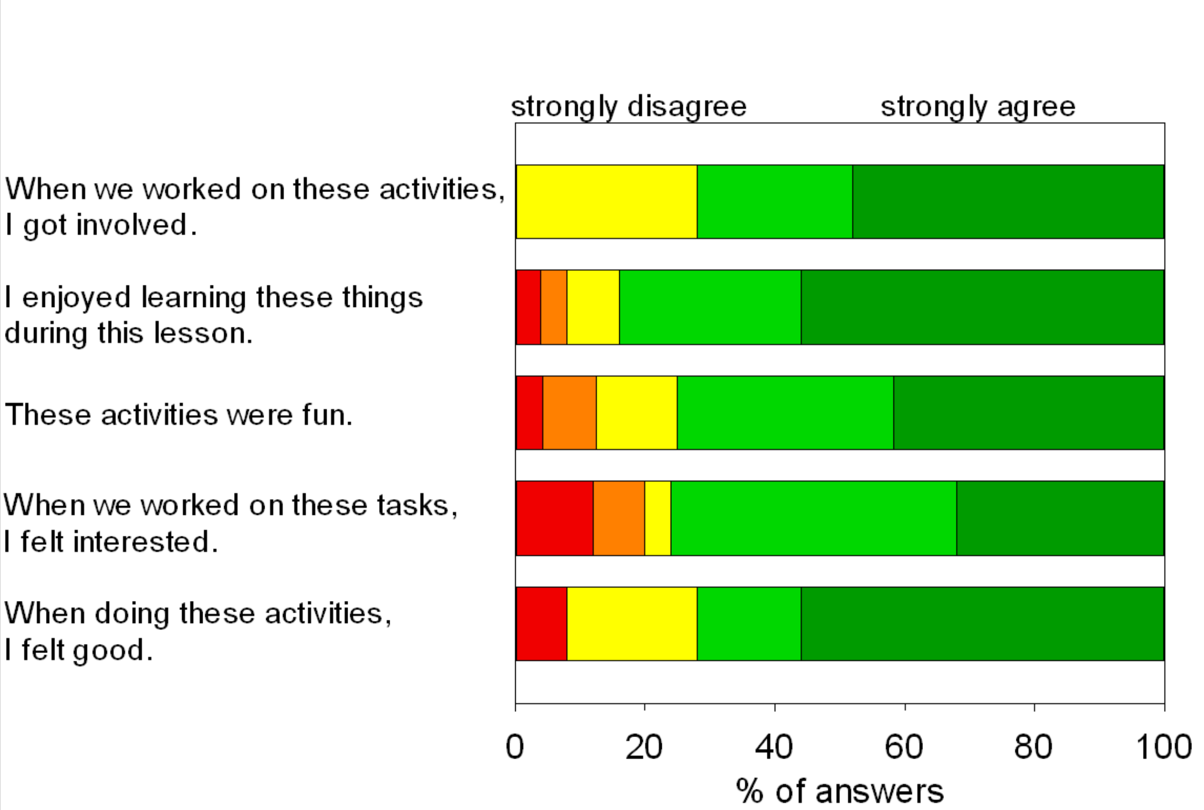

Fig. 2.1.2.40: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.2 Appendix; Phase B: Quantitative Research

10.2.1 Survey of Students (university)

2.2.1.1: Evaluation of Pedagogical Aspects I (VALNet)

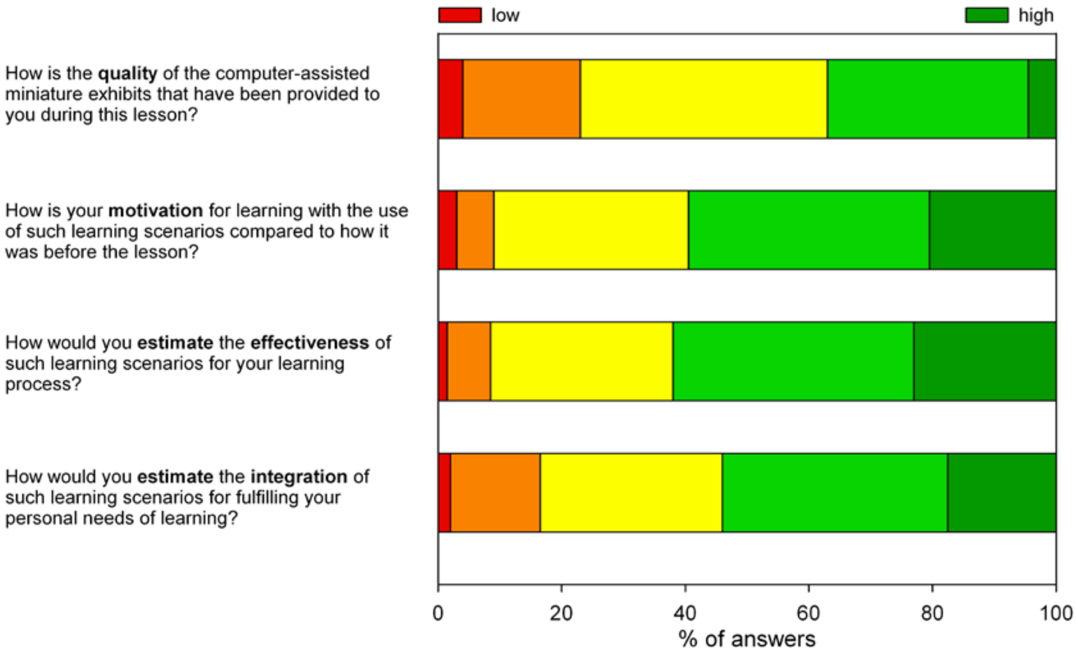

Fig. 2.2.1.2: Evaluation of Pedagogical Aspects II (VALNet)

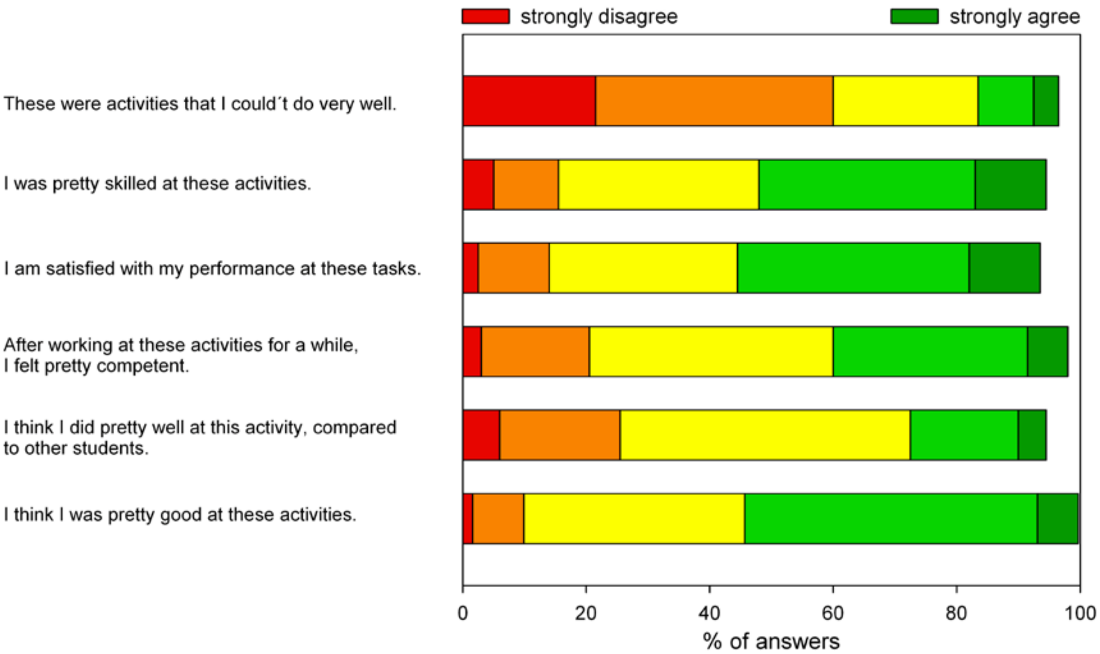

Fig. 2.2.1.3: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

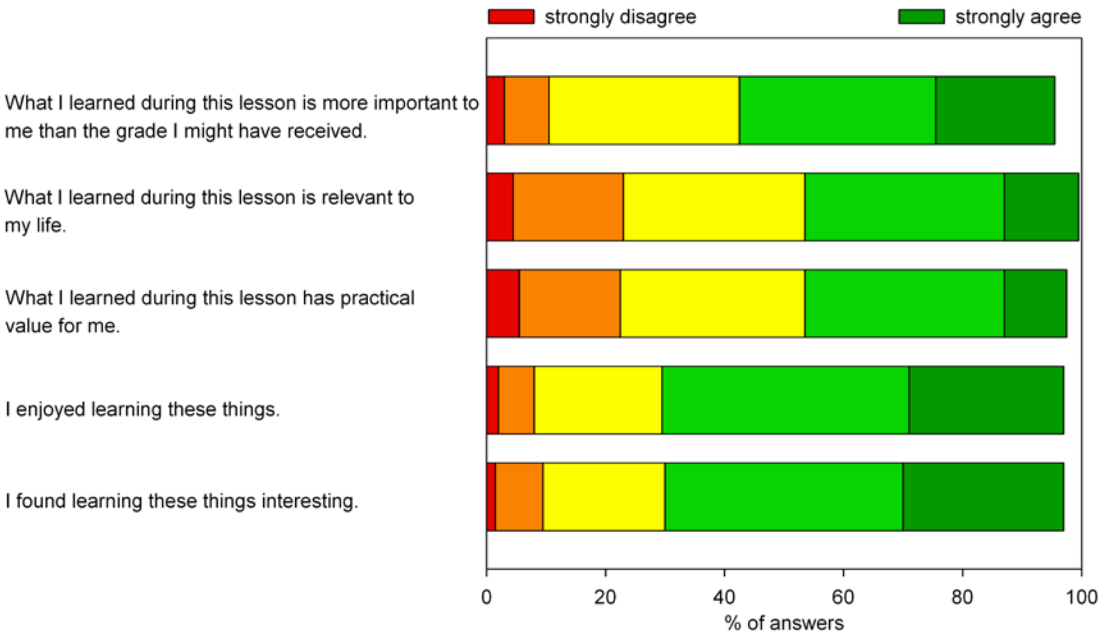

Fig. 2.2.1.4: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

Fig. 2.2.1.5: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

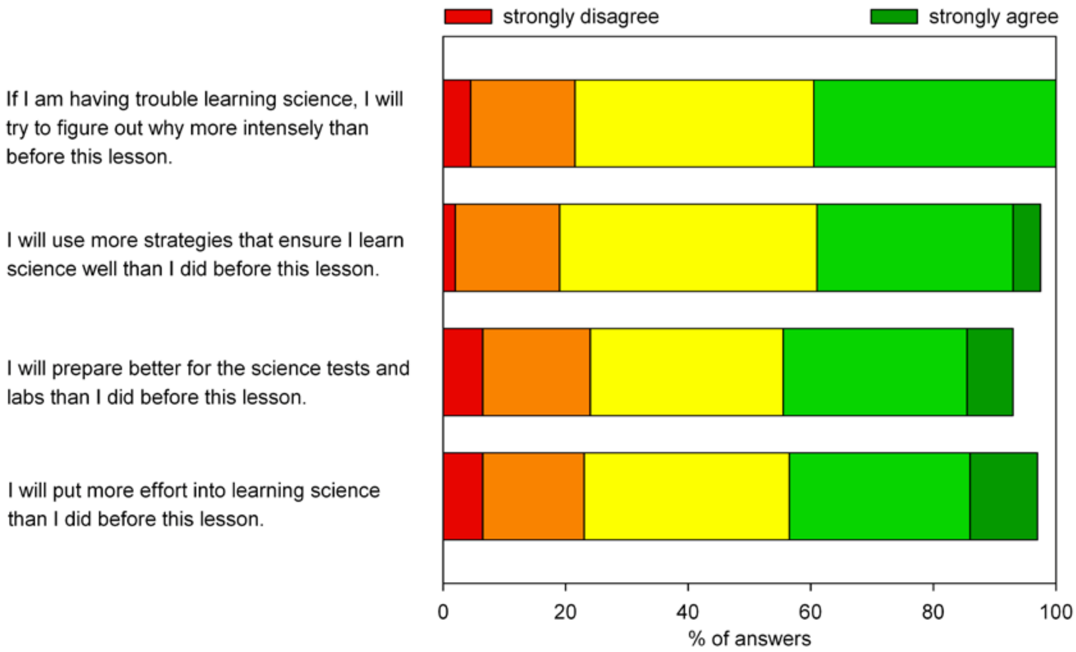

Fig. 2.2.1.6: Evaluation of Self-determination (Science Motivation Questionnaire)

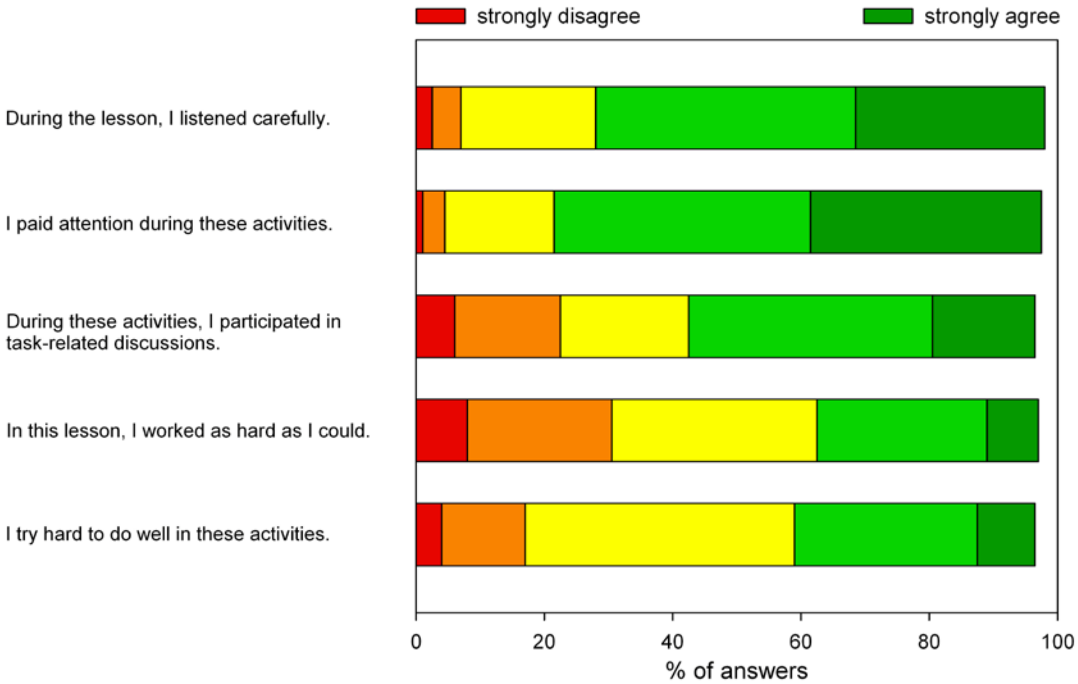

Fig. 2.2.1.7: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)

Fig. 2.2.1.8: Evaluation of Emotional Engagement (Student Engagement Questionnaire)

10.2.2 Survey of Students (school)

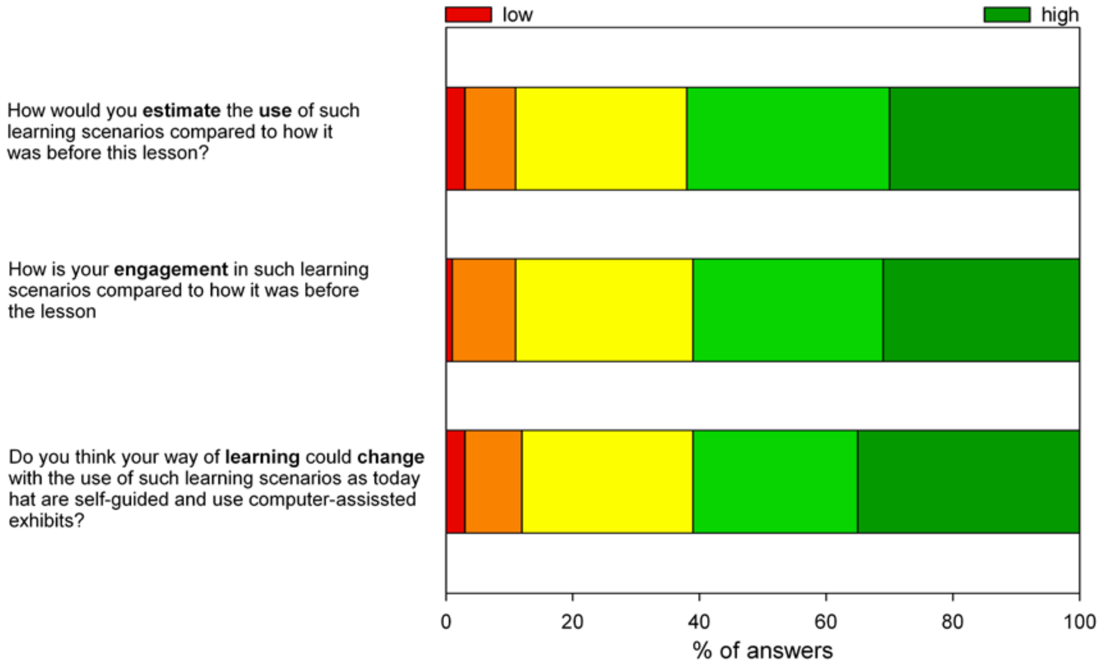

Fig. 2.2.2.1: Evaluation of Pedagogical Aspects I (VALNet)

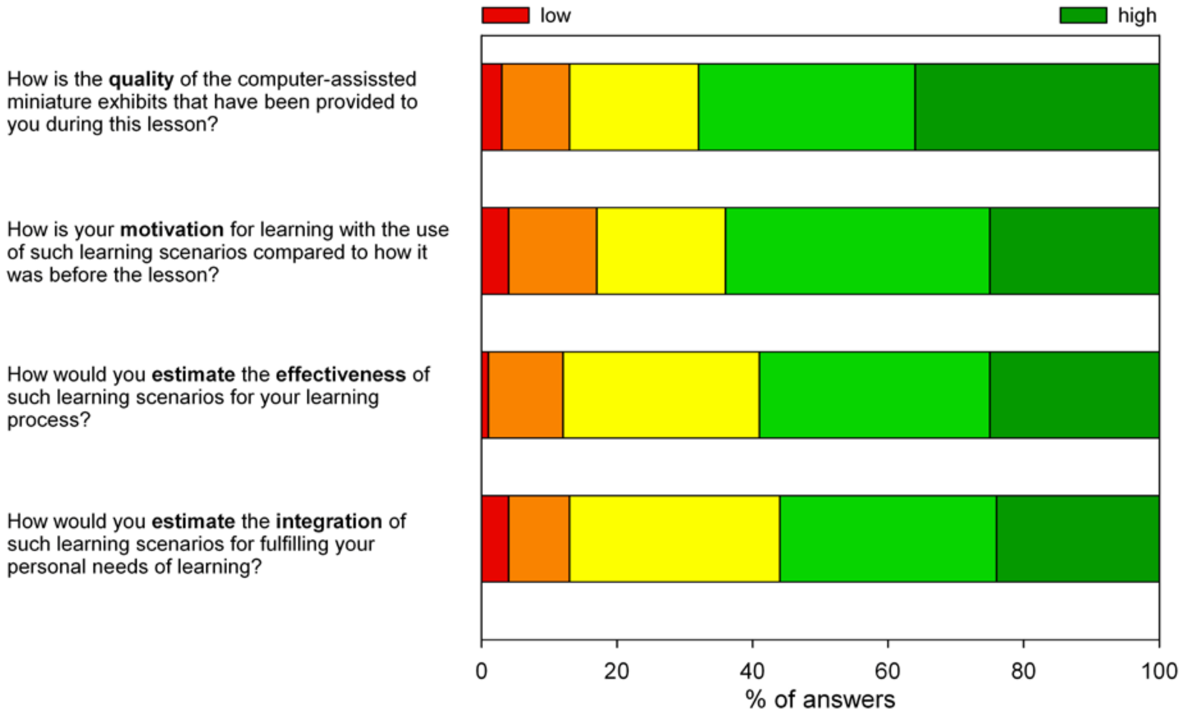

Fig. 2.2.2.2: Evaluation of Pedagogical Aspects II (VALNet)

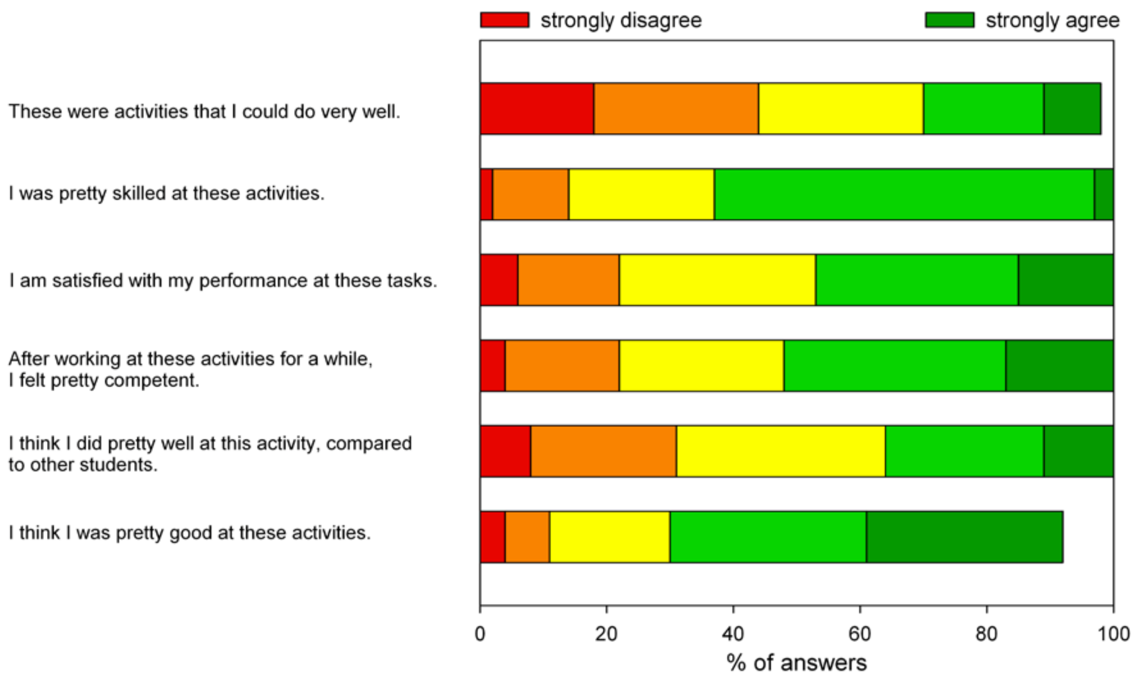

Fig. 2.2.2.3: Evaluation of Perceived Competence (Intrinsic Motivation Inventory)

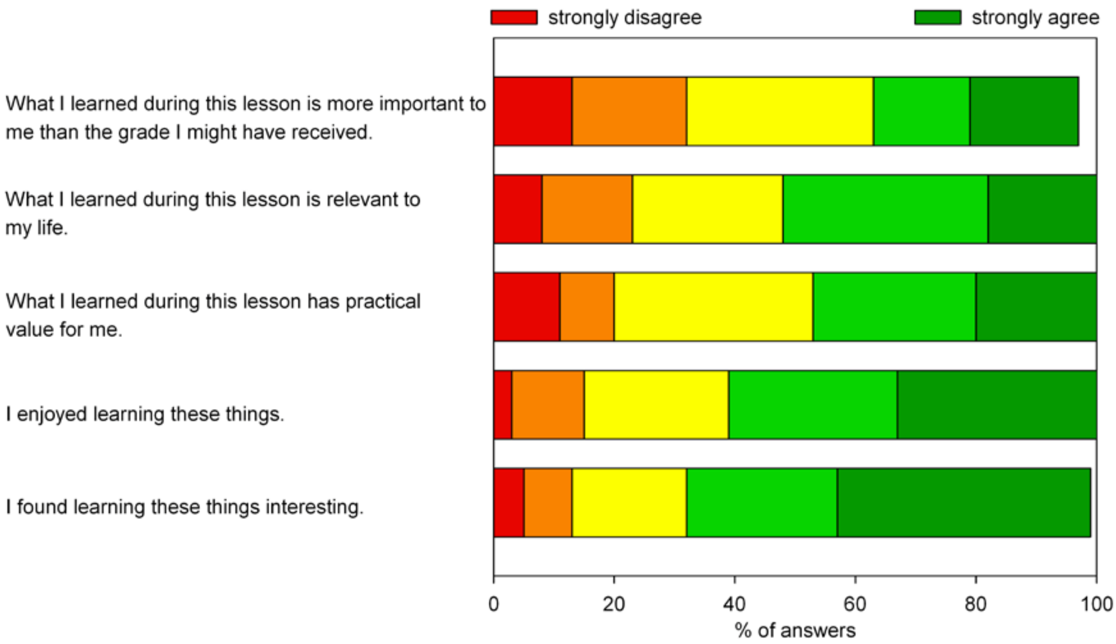

Fig. 2.2.2.4: Evaluation of Personal Relevance I (Science Motivation Questionnaire)

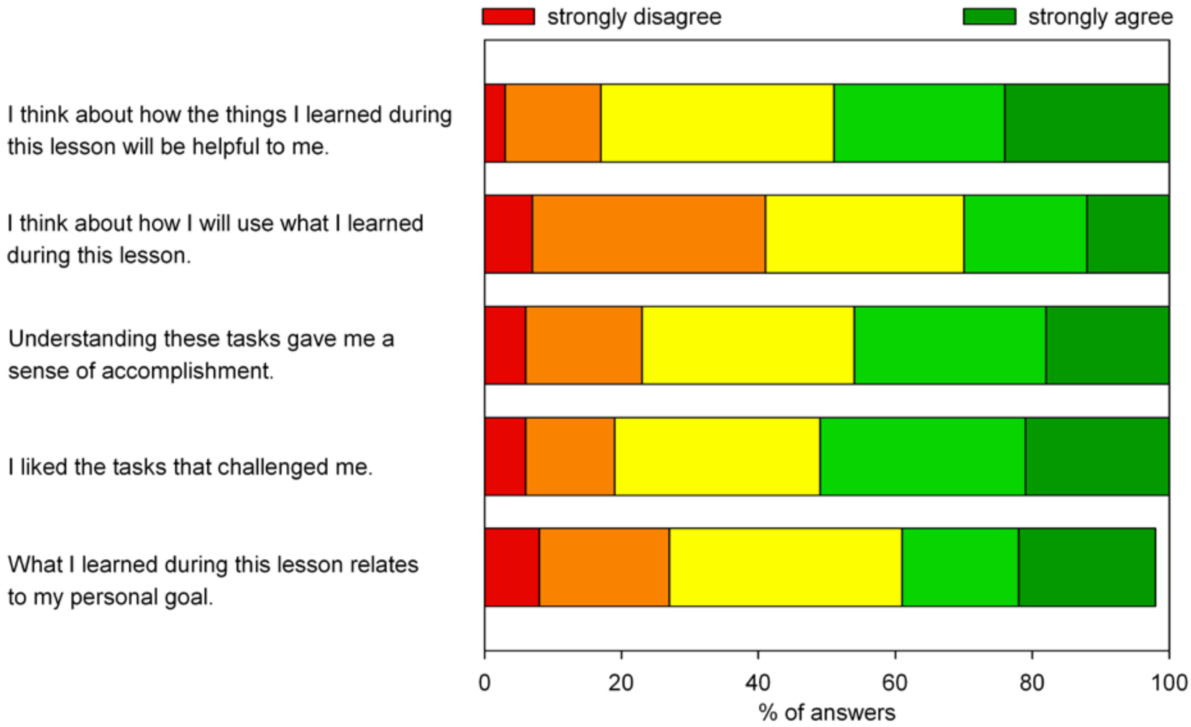

Fig. 2.2.2.5: Evaluation of Personal Relevance II (Science Motivation Questionnaire)

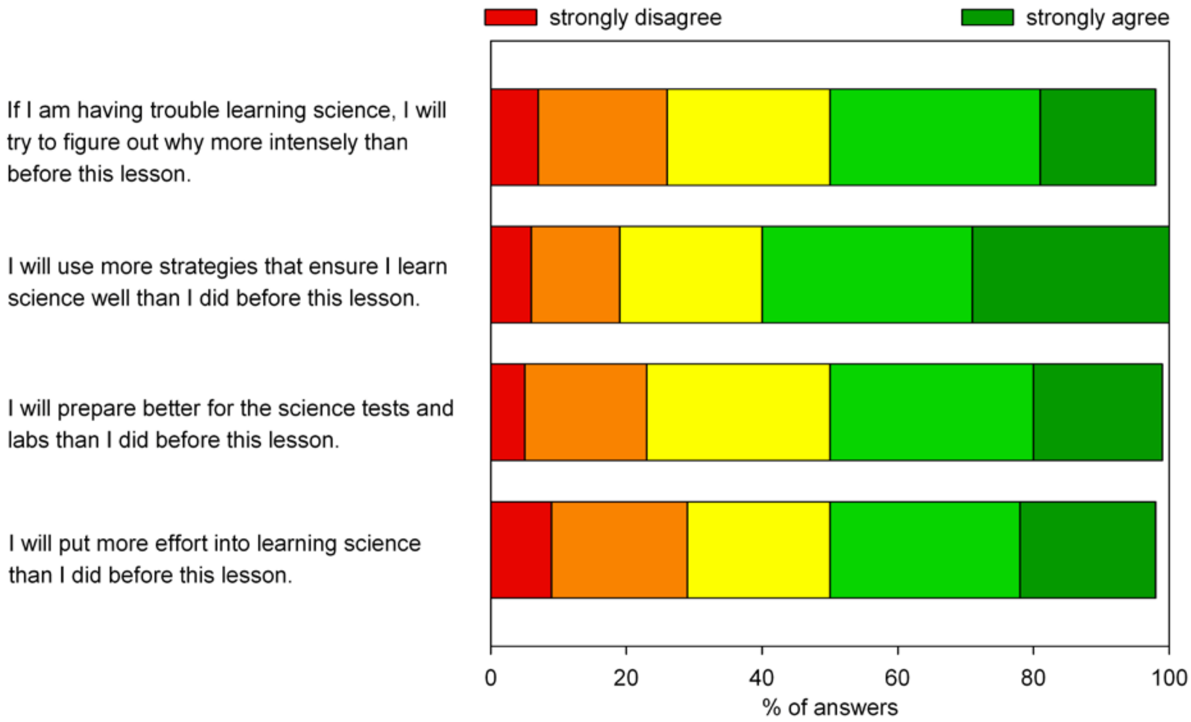

Fig. 2.2.2.6: Evaluation of Self-determination (Science Motivation Questionnaire)

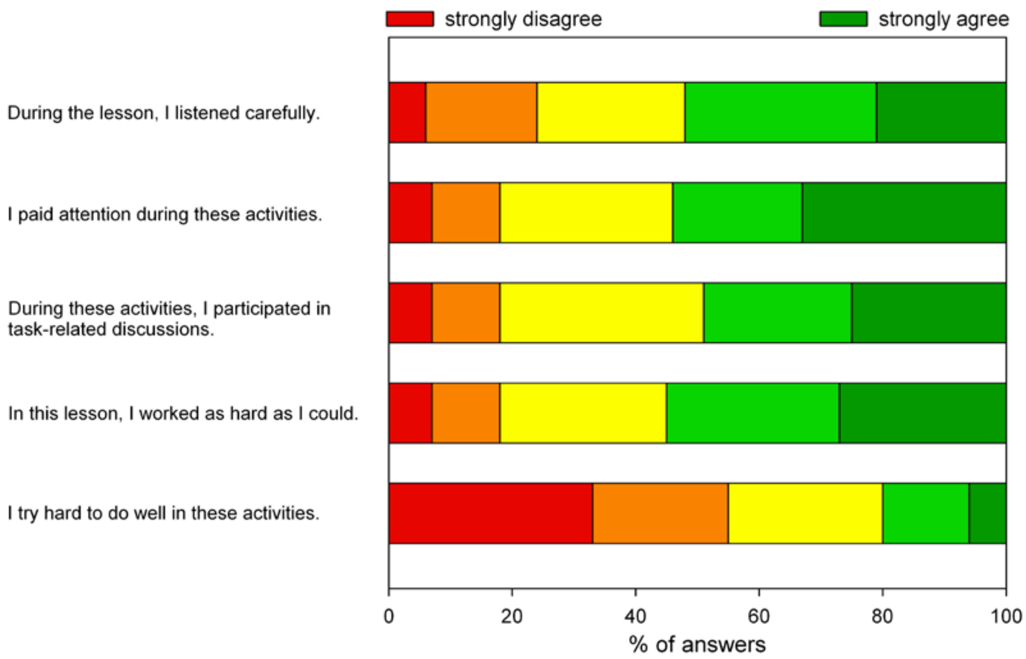

Fig. 2.2.2.7: Evaluation of Behavioral Engagement (Student Engagement Questionnaire)