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Pre-service teachers' experiences of scaffolded learning in science through a computer supported collaborative inquiry

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Abstract Scaffolding helps the novice to accomplish a task goal or solve a problem that otherwise would be beyond unassisted efforts. Scaffolding firstly aims to support the learner in accomplishing the task and secondly in learning from the task and improving future performance. This study has examined pre-service teachers' experiences of technologyenhanced/computer-supported collaborative inquiry learning when studying the anatomy of fish. The study investigated pre-service teachers' experiences of scaffolded use of a *Wiki* in structuring a dissection inquiry activity combined with scaffolded use of digital imaging to support problematizing during the sense making process. Quantitative data on the benefits experienced by the pre-service teachers in using the *Wiki* and in digital imaging were collected through responses to questions posted through an online questionnaire. Structure equation modeling was used to investigate the relationship between scaffolding with the *Wiki* and the experienced benefits of using technology. The use of structural scaffolding with the *Wiki* was not seen to be directly related to the experienced benefits. In encouraging knowledge acquisition and supporting deeper thinking on the topic, digital imaging had the strongest positive relationship to the experienced benefits of the technology, but there was no direct relationship with the use of the *Wiki*. However, scaffolding by structuring the activity with the *Wiki* had meditational, indirect, effects through visualizations and peer support to intentional and active participation and thus the scaffolds were working

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during the inquiry synergistically. For teacher education this means that pre-service teachers may recognize the benefits of using technology only through a significant experience and thus under value the role of the technology itself.

Keywords Scaffolding · Computer-supported collaborative inquiry · Collaborative learning · Learning in science · Pre-service teachers

1 Introduction

This study is concerned with a scaffolded inquiry learning project conducted by pre-service teachers; the context of the study is inquiry about the adaptation of fish to water. It examines how pre-service teachers experienced scaffolding with a pre-structured *Wiki* environment and digital imaging to support intentional and active participation during an intensive inquiry activity involving modeling. Previous research concerning inquiry learning has shown it to be an effective way to learn when properly scaffolded (Minner et al. 2010; Alfieri et al. 2011). Although there is research and development focusing on scaffolded technology-enhanced inquiry environments in science, less is known about scaffolding principles with social media tools like *Wikis* (Kali and Linn 2008; Quintana et al. 2004). Participation in such activities can help pre-service teachers develop their conceptions of both inquiry learning and teaching (Kukkonen et al. 2011) as well as their knowledge and skills in the use of social media as tools for teaching (Valtonen et al. 2011; Maeng et al. 2013).

This paper discusses first the theoretical aspects of scaffolding computer supported collaborative inquiry learning. Next, the theory is used as a basis for constructing a research model for scaffolding inquiry learning with a *Wiki*, visualizing with digital imaging and peer support. Relationships of scaffolds to experienced benefits of intentional and active participation are hypothesised. Next, data collected through an online questionnaire are analyzed by conducting a two-step structure equation modeling (SEM) starting from validating the measurement instrument through confirmatory factor analysis and continuing by analyzing the significance and strength of hypothesised relationships. Finally, the results are discussed, conclusions are drawn and further research problems suggested.

2 Theory background

In a synthesis of research from the years 1984 to 2002, Minner et al. (2010) found that inquiry-based instruction in science has a positive impact on content learning. The amount of active thinking and the emphasis on drawing conclusions from data were predictors of level of understanding in science. The amount of inquiry, especially hands-on engagement with science phenomena and students taking responsibility for their own learning, were significant predictors of better learning (Minner et al. 2010). However, "students' own responsibility" was not found to mean that inquiry learning is one form of "minimally guided instruction"− as Kirschner et al. (2006) claim. Instead, most of the previous studies report substantial scaffolding accompanying the inquiry learning approach (Bell et al. 2010; Minner et al. 2010). Hmelo-Silver et al. (2007)

argue that inquiry learning has usually been shown to be effective when it is combined with extensive scaffolding and guidance. From a meta-analysis of 164 studies, Alfieri et al. (2011) conclude that unassisted inquiry has limited benefit for the learners, whereas enhanced inquiry that takes into account the limitations of working memory benefits the learner. According to them, effective, enhanced inquiry supports learning at least by one of the following means: a) guided tasks with scaffolding, b) tasks requiring learners to explain their own ideas where feedback is provided, c) tasks that provide worked examples of how to succeed in the task (Alfieri et al. 2011).

In sociocultural terms, learning science means becoming accustomed to using the type of explanations that prevail in the discipline that have been derived from expert knowledge and expert models, i.e. the 'cultural tools' of science, and having the ability to incorporate these tools in studying and explaining natural phenomena (Tabak and Reiser 2008; Lemke 2001). Cultural tools include reasoning with representations and models that deal, for example, with structure and function (Tabak 2004). Tabak and Reiser (2008) make a case for learning technologies that present students with rich problems and engage them in scientific analysis that they might otherwise find difficult. Learning technologies can support working with rich datasets and managing the complexity of carrying out investigations utilizing the cultural tools of the discipline. The choice of cultural tools when working with representations and models needs to be carefully orchestrated and scaffolded so as to enable learners to become familiar with disciplinary ways of knowing, doing and talking (Tabak 2004). For Lemke (2001), the core sense-making processes of scientific investigation involve instrumentation and technologies, distributing cognition between individuals through the mediation of artifacts, discourses, symbolic representations and the like. Kozulin (2003) sees psychological tools as symbolic artifacts—signs, symbols, texts, formula, graphic organizers—that, after internalization, help individuals master their own psychological functions. Kozulin (2003) emphasizes that each culture has its own tools and contexts in which they are used, its 'sociocultural activities', through which learners appropriate the tools. Through these sociocultural activities, learners interact with fragments of the world, change it, and change themselves in the process (Giest and Lompscher 2003).

Turning specifically to biology, there is evidence that students experience problems in understanding key scientific models such as that of the respiratory system (Chi et al. 1994; Gadgil et al. 2011). Gadgil et al. (2011) studied change in students' mental models of the respiratory system by contrasting 'self-explanation' and 'holistic confrontation' approaches. In the holistic confrontation approach, learners were asked to make comparisons of their own diagrams (typically these are 'flawed models') with an expert model, while in the self-explanation approach, students were asked to explain the expert model. The study revealed that comparison of the models led to better learning: 90 % of the students were able to produce a correct double-loop model, whereas through self-explanation only 64 % were able to do so. Analysis showed that students produced more constructive, function-related statements in the comparison approach than they did in attempting to explain the expert model (Gadgil et al. 2011). Similar findings are reported by Schoultz et al. (2001) in their investigation of students developing their own models for comparisons during reasoning about concepts in physics.

2.1 Knowledge building in computer supported collaborative inquiry learning

The Computer Supported Intentional Learning Environment (CSILE) (e.g. Scardamalia and Bereiter 1994) has been a foundational development in the computer supported collaborative learning (CSCL) movement. According to Scardamalia and Bereiter (1994, 2006), CSILE is based on three lines of research and thought: (i) intentional learning, that is, having life goals that include personal learning agendas rather than just trying to do well in school tasks and activities; (ii) progressive expertise, "a process of reinvestment in progressive problem solving—addressing at increasing levels of complexity, the problems in a given domain"; and (iii) increasing collective knowledge by restructuring schools to become knowledge-building communities which combine social support with intentional learning and the development of progressive expertise with continued adaptation. Stahl (2006) suggests that small groups and the artifacts available to them are the engines of knowledge building. He suggests that interpersonal interaction during knowledge building becomes internalized as learning and externalized as certifiable knowledge in the communities.

Roschelle and Teasley (1995) define collaboration as "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". They propose that this kind of activity needs to occur in relation to a joint problem space, a shared knowledge structure that integrates goals, descriptions of the current state of the problem solving activity, available problem solving actions, and ways to promote shared actions towards the shared goals. Sarmiento and Stahl (2008) point out that: (i) the formation of a joint problem space arises from acts of communication aiming for shared agreement during social meaning making; and (ii) that a joint problem space is more a socially constructed activity during knowledge building than the property of any one individual. Constructing and maintaining a joint problem space is a difficult task: the creation, referencing, manipulation, assessment and re-use of knowledge artifacts serve as bridging activities between participants during collaborative knowledge building. According to White and Pea (2011), during challenging, collaborative tasks, the use of multiple representations can help learners to reappraise their roles in team activities and experiment with finding different meanings and uses for the representations (also Bell et al. 2010).

Jonassen et al. (1999) and Vahtivuori et al. (2002) argue that technology should be used in the design of learning environments that offer scaffolding for meaningful learning. Jonassen et al. (1999) characterizes meaningful learning with five attributes. Firstly, learning should be active so that learners are engaged with meaningful tasks enabling them to manipulate the environment and the objects in it (see also Sarmiento and Stahl 2008) in order to see the consequences of their activities. Secondly, learning should be constructive offering possibilities for learners to articulate and express their own conceptions and then explore the topic and reflect on it more deeply in order to develop more complex mental models. Thirdly, learning should be intentional and the learning environment should offer opportunities for learners to articulate their own goals, the decisions they make, the strategies they use, and the answers they find. Fourthly, learning should be authentic taking into account the full complexity of the topic and situated in real-life contexts to provide new possibilities for practicing skills and developing ideas. Fifthly, the learning should be collaborative and conversational; the learning environment should offer learners opportunities to negotiate common understandings about the topic and benefit from the multiple viewpoints of their peers. Larusson and Alterman (2009) investigated the use of a *Wiki* as a tool for collaborative actions and they point out the importance of offering means to help students and teachers manage coordination and communication. They claimed that when students were expected to work collectively on a shared problem task and produce a product in a tightly coupled activity, the prestructured *Wiki* scaffolded the joint problem solving and helped students gain a common focus, enabling them to jointly solve important tasks. They claim that the larger the teams the more likely are the students to use the *Wiki* for coordination and collaboration.

2.2 Scaffolding in computer supported collaborative inquiry learning

Scaffolding according to Larusson and Alterman (2009) utilizes devices and strategies to support and guide students (novices) in carrying out complex and difficult tasks that would otherwise be beyond their abilities. For example, scaffolding with a *Wiki* can offer representational structures and materials to guide student's interactions during collaboration. Also, as *Wiki* pages are automatically published to the entire community, the *Wiki* can simplify the sharing and distribution of representations among the participants (Larusson and Alterman 2009). Reiser (2004) offers two aims for scaffolding: the first is to support the learner in accomplishing the task, the second is to support learning from the task and improve future performance. These two goals imply in turn two scaffolding strategies: (i) scaffolding by structuring and (ii) scaffolding by problematizing. Reiser (2004) lists the main situations in collaborative inquiry learning where scaffolding is needed and the types of scaffolding involved: (i) unfamiliar strategies (e.g. inquiry strategies); (ii) unfamiliar interaction practices (e.g. collaborative planning, evaluation, keeping track of alternatives); (iii) unfamiliar discourse practices (e.g. expressing hypothesis, arguing on the basis of evidence, falsifying); (iv) non-reflective work (e.g. problematizing, to move students beyond the superficial aspects of work); and (v) superficial understanding (e.g. of scientific constructs and formal representations) (see also Bell et al. 2010; Kim and Hannafin 2011a, b).

Reiser (2004) points out that the scaffolding strategies for collaborative inquiry learning listed above are relevant for pre-service teachers (see also Kukkonen et al. 2011; Maeng et al. 2013). The scaffolding strategies could be used to address Windschitl's (2003, 2004) concern, that pre-service teachers conceptions of inquiry learning are too simplistic, linear and unproblematized, and that they are too loosely connected to theory or modeling (Windschitl et al. 2008; Kim and Hannafin 2011a). Pre-service teachers typically do not have the relevant skills, attitudes or knowledge about student-centered methods for using information and communication technology (ICT), social media or guided inquiry approaches (Urhahne et al. 2010; Valtonen et al. 2011; Kim and Hannafin 2011a).

Scaffolding in CSCL includes the use of symbols, numeracy, representations, and certain forms of technology (Sherin et al. 2004; Quintana et al. 2004; Urhahne et al. 2010; Kim and Hannafin 2011a). Reiser (2004) claims that tools can be a critical factor in tasks that involve accessing, manipulating, storing and reasoning about information; for example, tools for visualization can provide conceptually meaningful representations and help users form deep models of underlying systems. Quintana et al. (2004) define three central processes related to scaffolding scientific reasoning: (i) sense making as a process for testing hypotheses and interpreting data; (ii) process management for controlling the inquiry and for articulation; and (iii) reflection, for constructing and articulating what has been learned. In sense making, learners must understand how to represent what they intuitively know and what is also known with formal scientific representations (e.g. chemical structures). They must be able to modify these representations to develop an empirical test, encode new information into representations (e.g. numerical values and graphical representations) and make inferences in a disciplinary way while noting what is important about scientific situations. Science inquiry is an ill-structured problem solving process in which learners need support in managing the process. During investigations, novice learners may lack expert knowledge about relevant actions and activities such as implementing an investigation plan and keeping track of the hypothesis and results. Reflection processes are critical parts of inquiry and essential to process management and sense making. Inquiry involves constructing and articulating arguments, reviewing and reflecting on them, synthesizing explanations of results, and recognizing weaknesses and strengths in one's own thinking and within the process of investigation (Quintana et al. 2004; Bell et al. 2010; Kim and Hannafin 2011a). Wu and Pedersen (2011) found that at least in a relatively short intervention, a combination of early teacher-based metacognitive and computer-based continuous procedural scaffolding was most effective in supporting the development of science inquiry skills. However, students still needed scaffolds to support their conceptual learning.

2.3 Research model

Building on the theoretical background outlined above, in this study it was hypothesised that when pre-service teachers are making inquiries about complex science phenomena:

1. There will be *experienced benefits in:*
   a. making the topic accessible by structuring and scaffolding the activity with a pre-structured Wiki;
   b. making visualizations with digital imaging in order to make thinking visible;
   c. peer support.
2. There will be *experienced benefits of*:
   a. technology to support intentional participation;
   b. technology to support active participation in collaborative inquiry.

Furthermore, the *experienced benefits of scaffolding* in 1.a, 1.b and 1.c, above will have a positive relation on pre-service teachers *experienced benefits of technology* listed in 2a and 2.b. The criteria for positive relations are derived from Kali's and Linn's (2008) four scaffolding meta-principles for supporting technology-enhanced science inquiry learning: a) make science accessible, b) make thinking visible, c) enable students to learn from each other, and d) promote self-directed learning. These are parallel to Jonassen et al.'s (1999) principles for designing technology to support meaningful learning.

By combining Jonassen et al.'s (1999) with Kali and Linn's (2008) principles, and linking with the theoretical justifications given in the introduction, the hypotheses of positive relations from scaffolds to intentional and active participation can be elaborated as follows:

It is hypothesised that by scaffolding there should be positive relations to:

a) make science accessible by communicating the diversity of science inquiry (e.g. through disciplinary ways of communicating, Tabak and Reiser 2008; Bell et al. 2010) and the use of sociocultural tools (Giest and Lompscher 2003) using relevant examples (e.g. with a prestructured *Wiki,* Larusson and Alterman 2009) through structuring and problematizing (Reiser 2004) thus giving an authentic, contextualized activity leading to intentional and active participation. Stated as hypotheses:

   H1. Experienced benefits in scaffolding the activity with a pre-structured *Wiki* will have a positive relation to the e*xperienced benefits of* technology to support intentional participation.
   H2. Experienced benefits in scaffolding the activity with a pre-structured *Wiki* will have a positive relation to the e*xperienced benefits of* technology to support active participation in collaborative inquiry.

b) make thinking visible through visualizations (artifacts like digital imaging cf. Lemke 2001; White and Pea 2011) and templates to organize learners ideas (Kali and Linn 2008) with a *Wiki* in order to promote active learning (Jonassen et al. 1999; Bell et al. 2010; White and Pea 2011) leading to intentional and active participation. Stated as hypotheses:

   H3. Experienced benefits in scaffolding by making visualizations with digital imaging in order to make thinking visible will have a positive relation to the e*xperienced benefits of* technology to support intentional participation.
   H4. Experienced benefits in scaffolding by making visualizations with digital imaging in order to make thinking visible will have a positive relation to the e*xperienced benefits of* technology to support active participation in collaborative inquiry.

c) enable students to learn from each other (i.e. collaboratively and conversationally, Jonassen et al. 1999) through the construction of a coordinated joint social problem space (cf. Roschelle and Teasley 1995; Stahl 2006; Sarmiento and Stahl 2008; Larusson and Alterman 2009) to promote d) self-directed, intentional learning (Jonassen et al. 1999) by encouraging reflection and self-explanation (e.g. Gadgil et al. 2011). Recently, Belland (2011), based on a review of research findings, concluded that the two most extensively utilized principles for scaffolding are supporting problem reformulation through qualitative modeling, and having students work cooperatively (also Bell et al. 2010; Urhahne et al. 2010). Stated as hypotheses:

   H5. Experienced benefits in scaffolding the activity with peer support will have a positive relation to the e*xperienced benefits of* technology to support intentional participation.

> H6. Experienced benefits in scaffolding the activity with peer support will have a positive relation to the e*xperienced benefits of* technology to support active participation in collaborative inquiry.

A model of the hypothesised relations of scaffolds to experienced benefits of technology to support intentional and active participation is given in Fig. 1.

3 Method

3.1 Instructional setting

The research was conducted with 114 pre-service teachers undertaking a four phase computer supported collaborative inquiry activity investigating the adaptation of fish to water. The pre-service teachers worked in 28 groups of four or five persons. Each group had one laptop with a wireless connection, one digital camera, one fish and dissection equipment and a preconfigured *Wiki* to scaffold the activity.

In the first phase as introduced in the *Wikis*, the pre-service teachers were asked to make drawings of fish and to externalize their own conceptions by naming different parts of the fish and their functions. These drawings were shared and discussed (i.e. the inquiry was 'problematized' with visualizations). All the facts known were listed, and then photographs of the drawings were taken and uploaded into the groups' *Wikis*. The pre-service teachers' drawings and related concepts were compared with textbook examples shown in the *Wikis*.

In the second phase as introduced in the *Wikis*, the external anatomy of the fish was investigated. The pre-service teachers took photographs of a real fish. These were annotated with image processing software and the digital images uploaded to the *Wikis*. The organs and their functions were characterized and written down and comparisons were made with textbook material and other online resources.

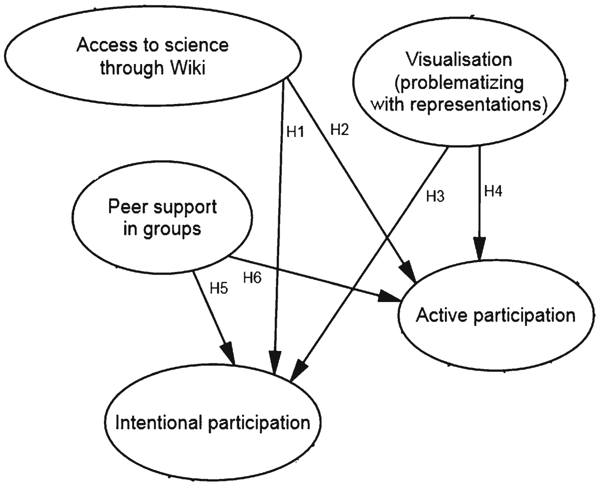

Fig. 1 Hypothesised relations of scaffolds to experienced benefits of technology to support intentional and active participation

In the third phase, pre-service teachers investigated the internal anatomy of the fish by dissecting it and taking photographs of the internal organs. The photographs were annotated and uploaded to the *Wiki*s. The organs and their functions were described in the *Wikis* and comparisons were made with textbook material and other online resources.

In the fourth phase, the pre-service teachers were asked to reflect on the following questions in their *Wikis*: How do the textbook models and digital imaging models differ from each other? Why are models used in teaching biology? What are the advantages of the modeling? What are the disadvantages of the modeling? What kind of models would you use when teaching about fish, and why? In the future, how will you use models when you are teaching about fish?

At the end of inquiry, the pre-service teachers were asked to write an essay type report: "How has the fish become adapted to water?" At least all of the following biological functions as well as their functional descriptions were requested to be included: a) the senses (sight, smell and the 'touch' sensitive lateral line system), b) the respiratory system, c) the heart and circulatory systems, d) the swim bladder, e) reproduction, f) any other structural adaptations to water.

The prestructured *Wiki* environment (cf. Larusson and Alterman 2009) had a central role in the inquiry. In all the phases, activities were structured to facilitate comparisons of pre-service teachers' models and 'expert' scientific models. The sequence of the activities was described and students had the opportunity of following and comparing their work with that of other groups: (http://ryhma2.wikispaces.com to http://ryhma30.wikispaces.com). Fig. 2 shows an example of pre-service teachers' *Wiki* pages.

3.2 Data collection

Data on pre-service teachers' *experiences* of the scaffolding offered by the computer supported collaborative inquiry activity were collected through an online questionnaire containing Likert-type statements scored on a five point scale (1=strongly disagree, 5=strongly agree). The questionnaire was modified from the instrument used by Valtonen et al. (2009) for investigating meaningful learning with high school students in online contexts. The questionnaire (detail in Appendix 1) contained 37 items concerning issues such as learning about the science content (e.g. the prestructured *Wiki* helped me understand the topic as a whole), visualization (e.g. image modeling clarified my understanding of the structure-function relation), intentionality of learning (e.g. I was able to set my own learning goals), peer support in groups (e.g. working in groups motivated me to work harder), and active participation (e.g. technology encouraged me in knowledge acquisition).

3.3 Statistical analyses

For testing the hypotheses, data were analyzed using structure equation modeling (SEM). SEM combines confirmatory factor analysis (CFA) with regression analysis. CFA is used to establish if measures of a construct are consistent with a researcher's understanding of the nature of the construct. Here 'construct' means a cluster of items from the questionnaire which relate to a distinct and coherent theme. For example, the 'visualization' construct contains the questionnaire items 'image modeling clarified my

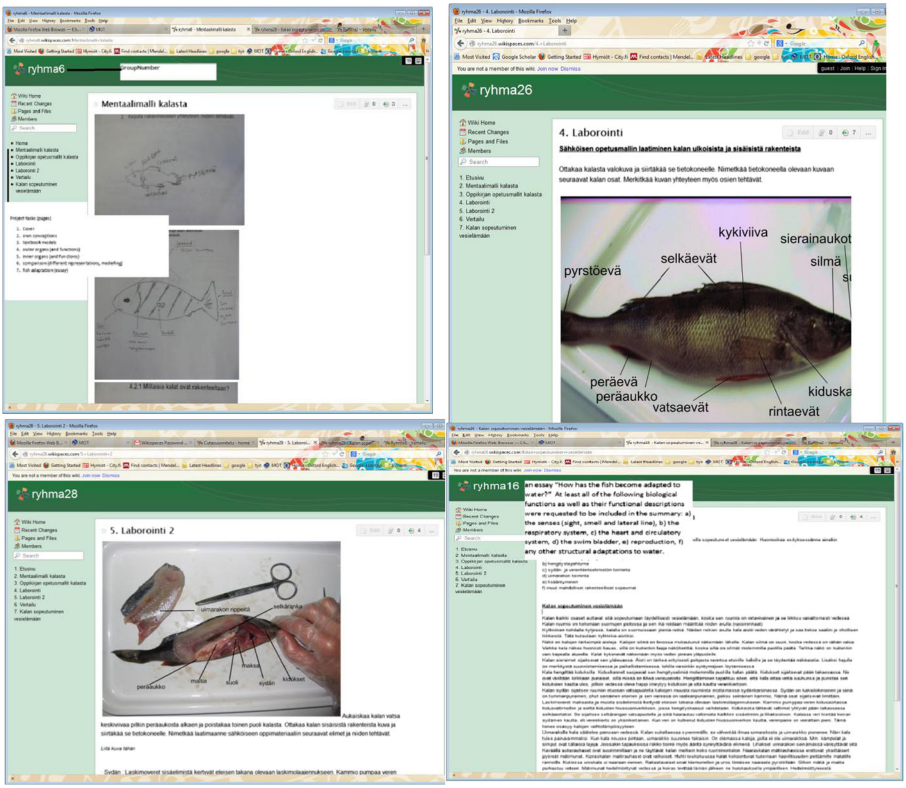

Fig. 2 An example of pre-service teachers' *Wiki* pages

understanding of the structure-function relation', 'image modeling helped me focus on the most relevant things', and 'cameras and laptops helped me understand the topic'. When combined with regression analysis, CFA allows estimation and statistical testing of interrelationships among constructs and also an evaluation of the extent to which the construct model fits the data (Reisinger and Mavondo 2007). In this study, data were analyzed by conducting two-step modeling (Anderson and Gerbing 1988). First through CFA a measurement model (Appendix 2) was developed and evaluated, then through SEM a path model with five constructs was developed with Amos 21.0 and SPSS software (Fig. 3).

4 Results

4.1 Demographics

Research data were collected through the online questionnaire which was used as a reflective assignment at the end of the course so all the participating pre-service teachers filled in the questionnaire. Of the 114 pre-service teachers, 85 (75 %) were female and 29 (25 %) male; this is a typical gender distribution in primary level pre-

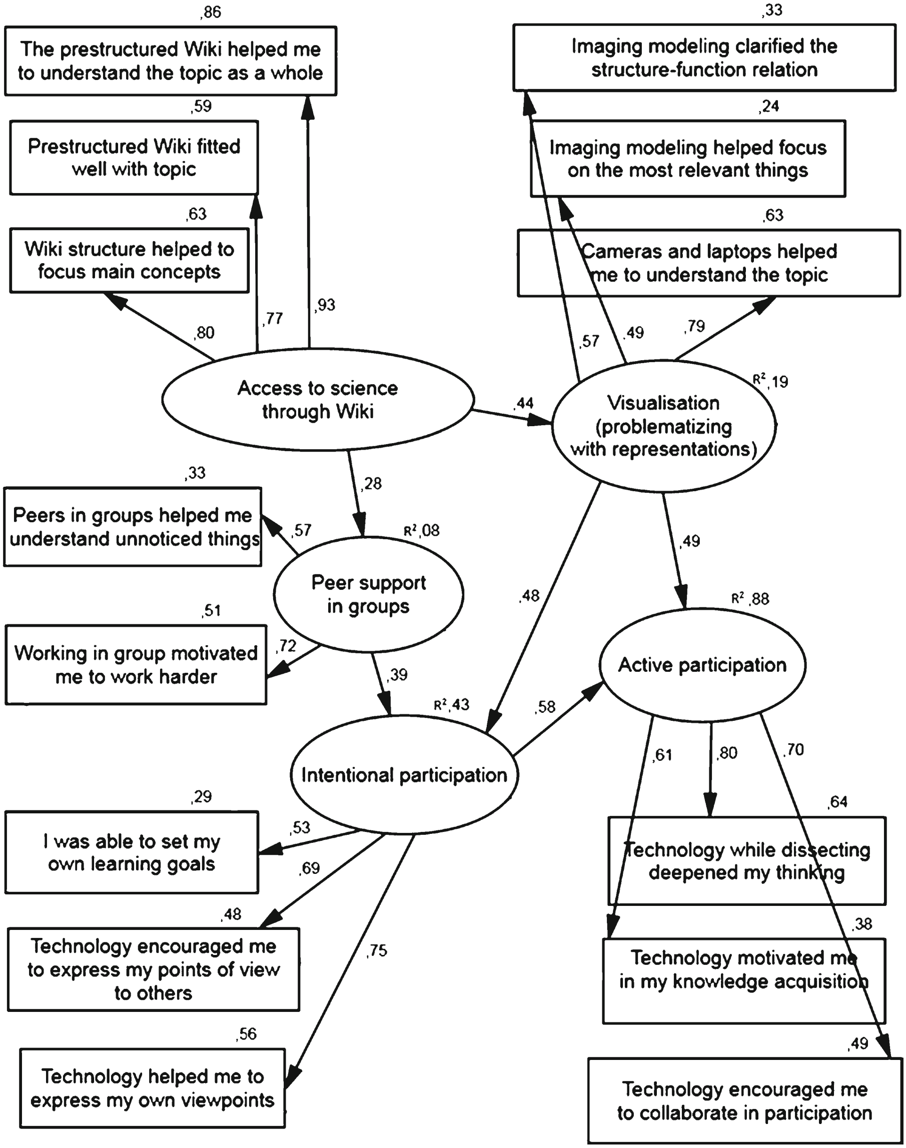

Fig. 3 Relations of scaffolds to experienced benefits after dissection inquiry (standardized estimates)

service teacher education in Finland. 73 % were first year students, 14 % second year students and the remaining 13 % had been studying for 3 years or more.

4.2 Instrument validation

The number of participants was only 114 and therefore in the SEM-analysis the number of indicator variables has to be considered. Fabrigar et al. (2010) point out that for accurate parameter estimates a sample size of 100 may be adequate when variances are low and each latent construct is represented with 3 or 4 measured variables, yet the size of the data limits the model to include at most 15 variables so that the number of covariances is smaller than the number of respondents (Hair et al. 1998, p.604).

The development of the measurement model (CFA) was based on a preliminary principal component analysis of the data (Vesisenaho et al. 2010) which was used to systematically transform the original questionnaire items into condensed constructs (Afifi and Clark 1996) so that of the original 40 items in the questionnaire only those with significant loadings to the constructs were selected for building the model (taking into account the results of the exploratory factor analysis as the starting point for the development of the CFA model as suggested by Gerbing and Anderson 1988).

In order to examine the goodness-of-fit of the measurement model (Appendix II) several indicators of fit were used (Table 1). Nowadays the chi-square statistic is considered to be inappropriate as a sole indicator of the goodness-of-fit of the model due to its limitations (Byrne 2001). The normal fit index (NFI=0,872) was somewhat lower than the 0,95 which Hu and Bentler (1999) recommend as the lower limit. However, Byrne (2001) points out that the NFI has been shown to underestimate the fit with small samples. According to Byrne (2001), it has been suggested that the comparative fit index CFI and Tucker-Lewis Index TLI should be indices of choice in the case of smaller samples. These goodness-of-fit indices were CFI=0,979 and TLI=0,972, above the suggested lower limit 0,95 (Hu and Bentler 1999; Byrne 2001). Also the root mean square error of approximation RMSEA=0,038 is below the recommended upper limit of 0,05 indicating also a good fit (Byrne 2001). The standardized root mean square residual SRMR (0,0594) was below the recommended 0,08 (Hu and Bentler 1999). Based on these considerations, we conclude that the SEM-model had a reasonably good fit (Table 1) and, with estimated significant loadings, provides evidence of convergent validity and unidimensionality of the constructs (Gerbing and Anderson 1988).

The discriminant validity of the constructs was checked by two means: firstly, by making pairwise tests for constructs (Anderson and Gerbing 1988). In this test of discriminant validity the constructs are tested by comparing a model where the correlation between pairs of constructs is freely estimated against a model where correlation of the pairs of constructs is constrained to be 1. A statistically significantly lower value for $\chi 2$ to the unconstrained model indicates discriminant validity of the constructs. Table 2 shows that the results of the pairwise comparisons support the discriminate validity of the constructs in the measurement model (Anderson and Gerbing 1988; Segars and Grover 1998).

Table 1 The measurement model's goodness of fit (n=114)

	Chi-square (df)	P	CMIN/DF	NFI	CFI	TLI	RMSEA [conf90]	SRMR
Estimate	77,734 (67)	0,174	1,160	0,872	0,979	0,972	0,038[0,000;0,070]	0,0594

NFI normed fit index; *CFI* comparative fit index; *TLI* Tucker-Lewis Index; *RMSE* root mean square error of approximation [with 90 % confidence interval]; *SRMR* standardized root mean square residual

Table 2 Results of pairwise χ2 discriminant validity tests of the constructs

Test	With	ML correlation estimate	Constrained Model Chi	Unconstrained Model Chi	chi difference
Access to science through *Wiki*	Visualization	0,437	75,331(9)	12,158(8)	63,173***
	Peer support	0,274	48,982(5)	0,787(4)	48,195***
	Intentional participation	0,377	70,398(9)	9,927(8)	60,471***
	Active participation	0,457	46,631(9)	8,13(8)	38,502***
Visualization	Peer support	0,391	66,578(5)	0,751(4)	65,827***
	Intentional participation	0,553	82,749(9)	5,696(8)	77,053***
	Active participation	0,772	59,770(9)	5,097(8)	54,673***
Peer support	Intentional participation	0,482	42,638(5)	1,012(4)	41,626***
	Active participation	0,444	38,267(5)	5,313(4)	32,954***
Intentional participation	Active participation	0,873	43,810(9)	12,536(8)	31,274***

***Significant at $p<0,001$

Secondly the discriminant validity was checked by comparing the average variance extracted against the squared construct correlations (Fornell and Larcker 1981). As shown in Table 3, the squared correlations between scaffolding constructs (‘access to science through *Wiki*’, ‘visualization’, and ‘peer support’), were smaller than the corresponding average variance extracted estimates, indicating that these latent constructs were discrete (Table 3). However, the constructs: ‘visualization’, ‘active participation’ and ‘intentional learning’ correlated strongly and were not discrete (but Segars and Grover (1998) note that the Fornell and Larcker (1981) heuristics of accessing the discriminant validity may be overly restrictive).

In the five construct model some of the measured variables were retained due to their explanatory value even though their loadings were just above the recommended lower limit (0.4) but less than the recommended (0.7) for a good fit (Hair et al. 2011).

Table 3 Discriminant validity of the constructs

Construct	CR	AVE	Access to science through *Wiki*	Visualization	Peer support	Active participation	Intentional participation
Access to science through *Wiki*	0,871	0,694	**0,694**				
Visualization	0,663	0,408	0,146	**0,408**			
Peer support	0,587	0,416	0,077	0,124	**0,416**		
Active participation	0,754	0,509	0,215	0,624	0,195	**0,509**	
Intentional participation	0,709	0,453	0,118	0,307	0,243	0,709	**0,453**

CR construct reliability, *AVE* average variance extracted, Diagonals (in bold) represent the average variance extracted, and under diagonals entries represent the squared construct correlations

However, accepting lower loadings for measured variables implies that for some of the constructs in the model the average variance extracted (Table 3) was somewhat less that the recommended 0,50 (as shown in the diagonals in Table 3). These loadings affected also the construct reliabilities, which ranged from 0,587 to 0,871; for exploratory analysis these should be 0.60 to 0.70 (Hair et al. 2011) yet Fornell and Larcker (1981) considered construct reliability above 0,58 as acceptable. Altogether the instrument was evaluated to be (with precautions) acceptable for firstly measuring and reporting pre-service teacher's experiences and secondly further developing the path model for evaluating the relations between constructs.

4.3 Experienced benefits of scaffolding

Table 4 shows the descriptive statistics for the constructs concerned with scaffolding through collaborative learning. On the 1–5 scale measuring the extent to which the pre-service teachers agreed with given statements, the three items for 'visualization' gave the highest level of agreement with a mean of 3,99 (SD=0,615), indicating the importance of the pre-service students' modeling with images and then comparing their own models with expert models in order to better understand the structure of the fish. The second most agreed scale was 'peer support', with a mean of 3,9 (SD=0.759) indicating the importance of peer support in motivating work and drawing attention to detail that would otherwise have gone unnoticed by some individuals. An almost similar agreement concerned 'access to science through *Wiki*' with a mean of 3,76 (SD=0,79) indicated the role of the *Wiki* in scaffolding to help the pre-service teachers focus on the central concepts and understand the phenomena as a whole (e.g. the structure-function relation and the adaptation of the fish to water). Taken together these results confirm the prediction that pre-service teachers would report experienced benefits from the scaffolding by 'visualization', 'peer support' and 'access to science through *Wiki*'.

Table 4 Descriptive statistics for collaborative learning scaffolding (scales from 1 not true at all to 5 completely true)

Construct items	Mean	Standard Deviation
Visualization (3 items)	3,99	0,615
Imaging modeling clarified the structure-function relation: 4,27(0,71) mean(SD) Imaging modeling helped focus on the most relevant things: 3,95 (0,69) mean(SD) Cameras and laptops helped me to understand the topic: 3,79 (0,98) mean(SD)		
Peer support	3,91	0,759
Peers in groups helped me understand unnoticed things: 4,12 (0,78) mean(SD) Working in group motivated me to work harder: 3,70 (1,02) mean(SD)		
Access to science through *Wiki*	3,76	0,769
The prestructured *Wiki* helped me to understand the topic as a whole: 3,82(0,88) mean(SD) Prestructured Wiki fitted well with topic: 3,78 (0,85) mean(SD) Wiki structure helped to focus main concepts: 3,69 (0,86) mean(SD)		

4.4 Experienced benefits to intentional learning and active participation

Table 5 shows the descriptive statistics for the constructs concerned with the experienced benefits of active participation and intentional participation (hypotheses 2.a and 2.b). The pre-service teachers recorded only a little benefit for 'active participation' with a mean of 3,36 (SD=0,819). The item 'technology while dissecting deepened my thinking' with a mean of 3,52 (SD=1.02) suggests that the setting supported slightly more directly individual participation than participation through collaboration (the item 'technology encouraged me to collaborate in participation' had a mean of 3,20 (SD=0,91)). The benefits associated with 'intentional participation' were almost neutral with a mean of 3,03 (SD=0,731). There were small benefits associated with 'I was able to set my own learning goals' (mean 3,12) while the technology was evaluated as neutral for encouraging (mean 3,00) and helping (mean 2,99) pre-service teachers express their own viewpoints.

4.5 Analysis of the hypothesised positive relations

The goodness-of-fit indices (Table 6.) for the structure equation (path) model were very similar to those of the measurement model indicating an acceptable fit for the structure equation (path) model.

Figure 4 shows relationships between the three constructs concerned with the experienced benefits of scaffolding and the constructs 'active participation' and 'intentional participation'. Table 7 summarizes the direct effects (regression estimates) in the relationships. The predicted direct positive relations from the construct 'access to science through *Wiki*' in the hypotheses H1 and H2 could not be established with statistical significance. Neither the relation from 'access to science through *Wiki*' to 'intentional participation' nor the relation from 'access to science through *Wiki*' to 'active participation' was statistically significant. The predicted positive relationships in the hypothesis H3 from 'visualization' to 'intentional participation' (β=0,48; p=0,005) and hypothesis H4 from 'visualization' to 'active participation' (β=0,49; p=0,004) could be established with statistical significance. The predicted positive relationship in

Table 5 Descriptive statistics of the experienced studying benefits, constructs in the model (from 1=completely untrue to 5=completely true)

Scales and items (with their means and standard deviations)	Mean	Standard deviation
Active participation	3.36	0,819
Technology while dissecting deepened my thinking: 3,52 (1,02) mean(SD) Technology motivated me in my knowledge acquisition: 3,36(1,09) mean(SD) Technology encouraged me to collaborate in participation: 3,20 (0,91) mean(SD)		
Intentional participation	3,03	0,731
I was able to set my own learning goals: 3,12(0,84) mean(SD) Technology encouraged me to express my points of view to others: 3,00(0,93) mean(SD) Technology helped me to express my own viewpoints: 2,99(0,97) mean(SD)		

Table 6 The structure model's goodness of fit (n=114)

	Chi-square (df)	P	CMIN/DF	NFI	CFI	TLI	RMSEA [conf90]	SRMR
Estimate	82,850 (71)	0,159	1,167	0,864	0,977	0,971	0,038[0,000;0,069]	0,0664

NFI normed fit index; *CFI* comparative fit index; *TLI* Tucker-Lewis Index; *RMSE* root mean square error of approximation [with 90 % confidence interval]; *SRMR* standardized root mean square residual

the hypothesis H5 from 'peer support' to 'intentional participation' (β=0,39; p=0,021) could be established , whereas the direct relation (hypothesis H6) from 'peer support' to 'active participation' could not be established. There were positive relationships between the construct 'access to science through *Wiki*' and the construct 'visualization' (β=0,44; p=0,003) and between 'access to science through *Wiki*' and 'peer support' (β=0,28; p=0,025). Interestingly the strongest direct relationship was between 'intentional participation' and 'active participation' (β=0,58; p=0,001).

Instead of the *direct* relationship from constructs 'access to science through *Wiki*' and from 'peer support' in the hypotheses (H1, H2 and H6) there *were indirect, mediated*, positive relationships between the predicted constructs. In order to acquire the confidence intervals and significance estimates for the parameters in Table 8, a bootstrapping with Amos software (i.e. re-sampling the original data and transforming it to 250 bootstrap sub-samples, see Byrne 2001) was carried out. Table 8 summarizes the standardized total effects (direct and indirect) with bias-corrected to 90 % confidence intervals and significance estimates. Instead of the *direct* relationship in the hypotheses H1 and H2, there was an *indirect* positive relationship between the construct 'access to science through *Wiki*' and the construct 'intentional participation' (β=0,32; p=0,002) and also an *indirect* positive relationship between the construct 'access to science through *Wiki*' and the construct 'active participation' (β=0,400; p=0,003). For the hypothesised relationships from construct 'peer support' there was in addition to the direct relationship also an *indirect* positive relationship (H6) between the

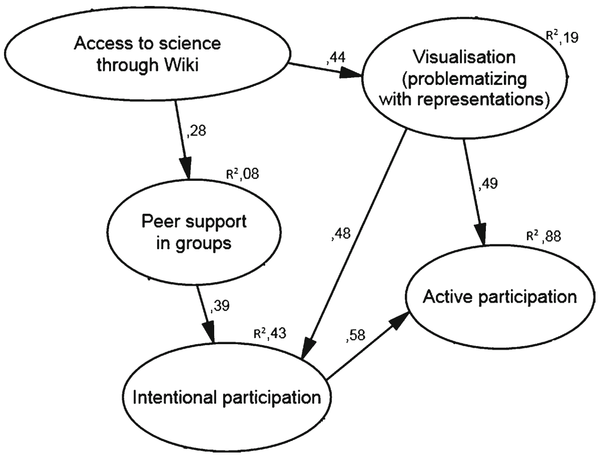

Fig. 4 Relationship of constructs: experienced benefits of scaffolding to experienced benefits of active participation and intentional participation (standardized estimates)

Table 7 Regression weights (direct effects) of the relations between constructs

Relation (between constructs)			Standardized estimate (β)	Nonstandard estimate	S.E.	ρ	R^2
Visualization	←	Access to science through *Wiki*	0,438	0,215	0,072	0,003	0,191
Peer support	←	Access to science through *Wiki*	0,282	0,300	0,134	0,025	0,080
Intentional participation	←	Visualization	0,480	0,638	0,227	0,005	
Intentional participation	←	Peer support	0,393	0,241	0,104	0,021	0,431a
Active participation	←	Visualization	0,490	0,967	0,331	0,004	
Active participation	←	Intentional participation	0,579	0,860	0,265	0,001	0,875b

a. together peer support and visualization explains intentional participation

ether visualization and intentional participation explains active participation

construct 'peer support' and the construct 'active participation' (β=0,228; *p*=0,008). Interestingly, the construct 'visualization' had the strongest total effect (direct + indirect) in the model to the construct 'active participation' (β=0,768; *p*=0,008).

5 Discussion

The high (mean) evaluation of the use of digital imaging for visualization along with use of the *Wiki* which enabled the pre-service teachers to compare models

Table 8 Standardized total effects (direct and indirect) with bootstrapped bias-corrected 90 % confidence intervals and two-tailed significance estimates

Relation (between constructs)			Standardized total effect estimate (β)	90 % confidence lower bound	90 % confidence upper bound	ρ
Visualization	←	Access to science through *Wiki*	0,438	0,283	0,660	0,002
Peer support	←	Access to science through *Wiki*	0,282	0,029	0,542	0,041
Intentional participation	←	**Access to science through *Wiki***	**0,321**	0,193	0,538	0,002
Active participation	←	**Access to science through *Wiki***	**0,400**	0,241	0,580	0,003
Intentional participation	←	Visualization	0,480	0,278	0,691	0,010
Active participation	←	Visualization	0,768	0,586	0,904	0,008
Intentional participation	←	Peer support	0,393	0,201	0,684	0,007
Active participation	←	**Peer support**	**0,228**	0,095	0,483	0,008
Active participation	←	Intentional participation	0,579	0,305	0,799	0,015

was positively related to the self-evaluated benefits to intentional and active participation. This supports the findings of Gadgil et al. (2011) on model comparisons as an effective means to support understanding of concepts in biology such the respiratory system. These findings also corroborate Tabak's (2004) point about support for reasoning with culturally acceptable patterns of use of representations and tools (also cf. Bell et al. 2010; Kim and Hannafin 2011a, b) in a disciplinary way. Even though there was no direct relationship with the use of the *Wiki* as would be suggested by the findings of Larusson and Alterman (2009), the *Wiki* was indeed the place in which the pre-service teachers produced and used multiple representations during challenging, collaborative tasks to help their peers reappraise their roles in team activities (cf. White and Pea 2011; Bell et al. 2010; Urhahne et al. 2010). Similarly, as Sarmiento and Stahl (2008) suggest, the scaffolds seem to have enabled the students to use the artifacts produced, modified and embedded by the group in the *Wiki* to build up, construct and maintain a cognitive and social joint problem space.

As indicated by the positive relationship in the SEM model in this study, peer support in groups was evaluated to be influential in the inquiry especially in helping the pre-service teachers notice things they would otherwise have missed. Peer support also had a moderate positive relationship with intentional participation which mediated a positive indirect relationship with active participation. Scaffolding with the pre-structured *Wiki* facilitated the pre-service teachers' inquiry by making the science accessible (Kali and Linn 2008; Bell et al. 2010) as it was influential in the visualization and also in peer support in the groups. The path model (Fig. 3) suggests that scaffolding by structuring the activity with the *Wiki* had meditational, indirect, effects through visualizations and peer support to intentional and active participation and thus there is reason to assume that the scaffolds were working during the inquiry activity as synergistic, enmeshed, intertwined, scaffolds (cf. Tabak 2004).

During the inquiry activity, the combined scaffolded use of a) the *Wiki* in structuring and problematizing the activity, and b) the scaffolded comparisons of models with digital imaging, supported the sense making process and advanced the pre-service teachers' inquiry learning. This study endorses the design of an instructional setting for pre-service teachers to experience and reflect on inquiry learning and teaching in line with the conclusions of Minner et al. (2010), that inquiry learning is effective when it includes an active process of drawing conclusions based on data, when it is connected with hands-on engagement of science phenomena, and when it emphasizes students' responsibilities. This is important especially for alerting pre-service teachers (see also Urhahne et al. 2010) that their conceptions of inquiry learning are too loosely connected to theory or modeling (Windschitl et al. 2008). The four scaffolding meta-principles suggested by Kali and Linn (2008), combined with Jonassen et al's. (1999) principles for using technology for meaningful learning, seem to be appropriate for designing technology-enhanced learning environments for science inquiry e.g. as guidelines for the design of pre-structured *Wikis* and perhaps for other social media tools.

6 Conclusions

This study investigated how technology, especially a prestructured *Wiki*, could be used as an effective addition to collaboration between pre-service teachers in co-constructing synergistic scaffolds to inquiry learning in science education. Small groups were equipped with a laptop with a wireless connection, digital cameras, and a prestructured *Wiki* to scaffold the activity by structuring and problematizing. They used digital imaging to make comparisons (scaffolded with the use of the *Wiki*) while conducting structure-function reasoning during an inquiry into the adaptation of fish to life in water.

The use of digital imaging for visualizations to make model comparisons was evaluated most highly by the pre-service teachers. Also peer support in small groups supported intentional participation in the inquiry and thus enhanced the development of the pre-service teachers' self-evaluated understanding of the topic. Even though scaffolding the inquiry with the prestructured *Wiki* was designed to facilitate the activity, it was the visualizations, which by problematizing challenged the pre-service teachers to make comparisons through the digital imaging that most strongly contributed to the self-evaluated benefits of active and intentional participation in the inquiry. This kind of active engagement with collaborative inquiry is beneficial for pre-service teachers, not only for learning content knowledge and adopting disciplinary ways of working in the subject of biology, but also for the general advancement of teacher knowledge about effective ways of educating young learners and utilizing technology meaningfully.

In this study the use of the pre-structured *Wiki* and digital imaging served as critical parts of a joint social problem space by allowing the pre-service teachers to make model comparisons collaboratively and to learn from each other. The model comparisons with digital imaging and the *Wiki* were found to be effective both in making science accessible with examples of expert and peer produced models, and in promoting self-directed learning by encouraging reflection and explanation while comparing different models in collaboration with peers. A pre-structured *Wiki* proved to be a suitable tool for offering 'individual' scaffolding for small groups; in this study 28 *Wikis* where used. The pre-service teachers clearly noticed the benefit of using the visualizations with digital imaging, but the use of the *Wiki* was somewhat unnoticed by the participants. For teacher education this unfortunately means that pre-service teachers may recognize the benefits of using technology only from a significant experience (the visualization in this study) and thus under value the role of the technology itself. The deeper structure and benefits of the technology-enhanced inquiry learning environment (the *Wiki* in this study) may remain unnoticed (Maeng et al. 2013). It would be a matter for further study to investigate if the pre-service teacher students are able to recognize the features of the design (e.g. scaffolding with *Wiki*), when directly required to reflect continuously on the design of the scaffolding offered during the inquiry activity.

Appendixes

Appendix 1

Table 9 Questionnaire items

In my opinion netbooks (laptops) are suitable as a part of university teaching
The use of netbooks was felt an 'unnecessary extra' for this topic
Netbooks and similar devices are used too infrequently in university teaching
In my opinion other fellow students were positive about experimenting with netbooks and technology
Cameras and laptops helped me to understand the topic
Imaging modeling clarified the structure-function relation
Cameras and laptops disrupted my concentration on the topic
Wiki structure helped to focus on the main concepts
Conducting the dissection alone would not have given so clear a conception about the topic under investigation
The prestructured *Wiki* limited my own activity during the course
Imaging modeling helped focus on the most relevant things
Th prestructured *Wiki* fitted well with topic
The prestructured *Wiki* helped me to understand the topic as a whole
Technology helped me to express my own viewpoints
The use of technology enhanced collaboration in my group
Technology encouraged me to collaborate in participation
During the activity I received feedback from other students
Interaction between teacher and students was alive
Working in the group motivated me to work harder
Peers in groups helped me understand unnoticed things
Technology while dissecting deepened my thinking
Technology motivated me in my knowledge acquisition
I was able to set my own learning goals
I could influence the way of my studying
During the activity we noticed new questions/problems to be solved
Technology encouraged me to express my points of view to others
Studying with the technology was fun
Studying with the technology was motivating
Studying with the technology suited well to my own style of studying
Studying with the technology was meaningful
Studying with the technology was frustrating
The software that was used (*Wiki* and Image processing) suited well in studying the topic
The software used were clear and easy to use
The netbooks/laptops used in the experiment fitted well with the studying
There was a suitable number of students working with one laptop
In my opinion each student should have been working with their own computer
There was enough technical assistance available

Appendix 2

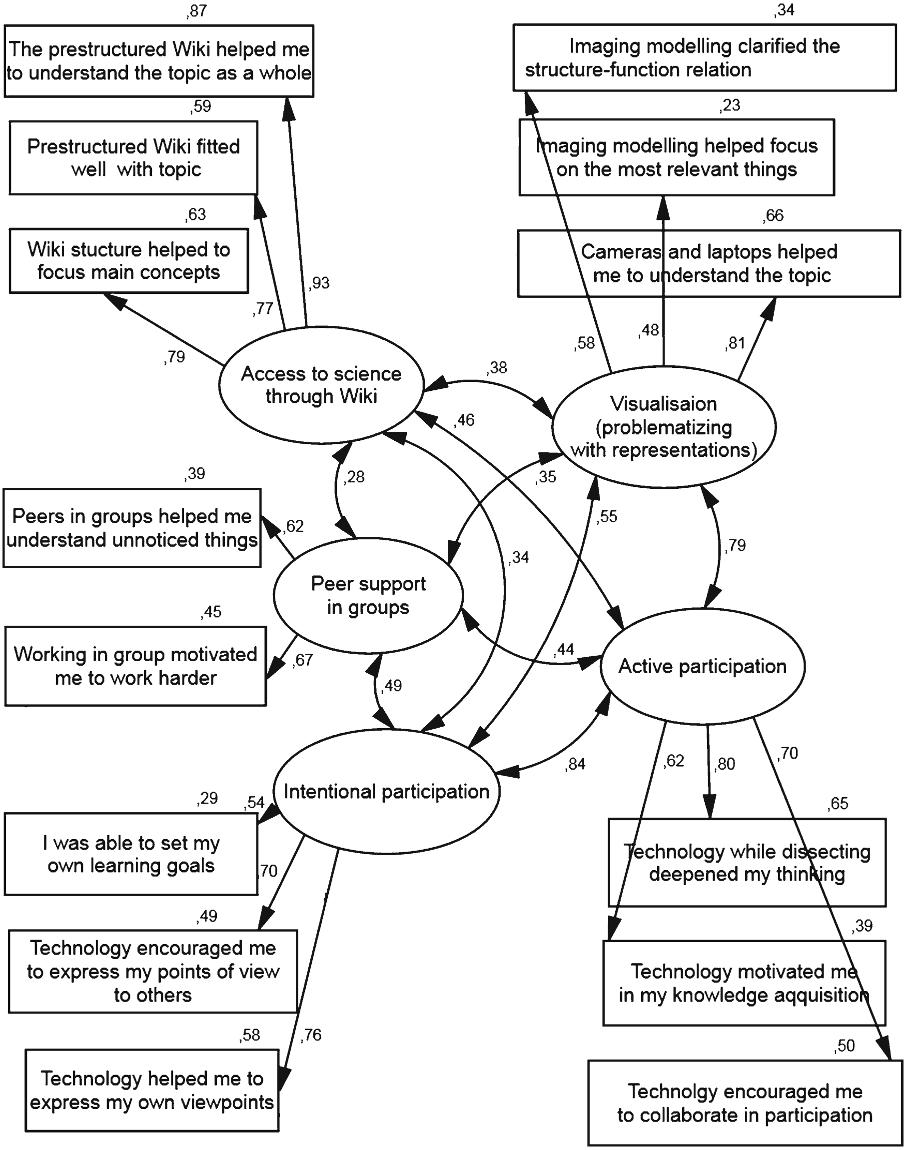

Fig. 5 Measurement model of scaffolds (CFA-model) and experienced benefits after dissection inquiry (standardized estimates, error terms omitted)

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