TEACHING IN VIRTUAL REALITY - CONCEPTS AND EVALUATION

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Abstract

Studierstube is a Virtual Environment whose unique and distinctive features of collaboration, augmentation, and customized views seem particularly appropriate for applications in the field of education. As an innovative teaching tool Studierstube is considered to support learning processes by enhancing the students' understanding of contents to be visualized three-dimensionally such as spatial relationships, complex three-dimensional structures, dynamic models or simulations of physical processes. The implementation of Virtual Environments for educational purposes needs to be evaluated not only to obtain directions for further improvements but also to document the effectiveness of Studierstube as a teaching method. The development and discussion of a formative evaluation design concludes this paper.

1. System Description of Our Virtual Environment

Real-time 3D display, highly interactive setting, and sophisticated 3D interaction are characteristic properties of *virtual environments* (VE). Studierstube, our implementation of a collaborative VE, extends these features by introduction of individual views and viewpoints, personal interfaces, and collaboration techniques. We apply *Augmented Reality* (AR), the less obtrusive cousin of Virtual Reality that enables computer generated images to be overlaid over reality using semi-transparent *head-mounted displays* (HMDs). This does not only allow direct social user interaction without mediating layers of software but also the possibility of including objects of the real environment – tables, mirrors, architectural models etc. – into the interaction concept. A basic interaction device is the *Personal Interaction Panel* (PIP, Figure 1), a black board overlaid by computer-generated interaction elements [15].

As a user interface, Studierstube allows multiple concurrent users to interact with each other and with the application via the shared space provided by augmented reality. A typical setup is

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illustrated in Figure 2. Two users collaborating on a scientific visualization are using *augmented props* – simple black plastic boards overlaid with computer generated interaction elements – to control the simulation. They can see each other through the HMDs and additionally perceive the virtual imagery stereoscopically displayed between them.

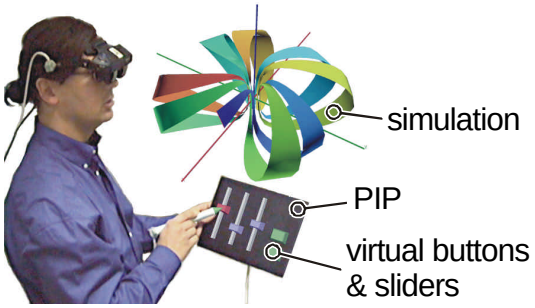

Figure 1: the Personal Interaction Panel, an augmented prop

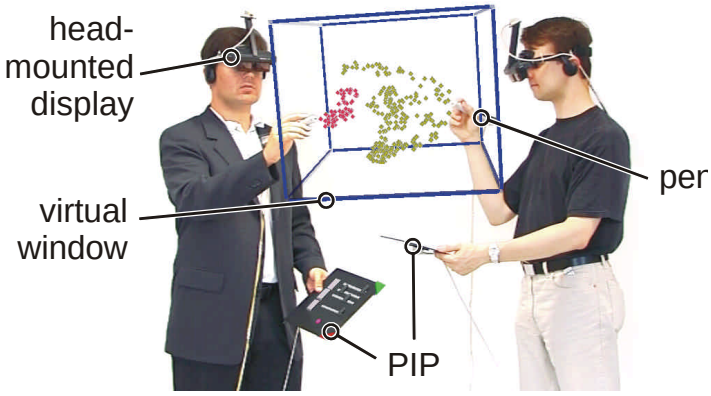

Figure 2: two users interacting in virtual reality

Studierstube is intended to be a collaborative AR user interface in which a variety of tasks can be performed. Such a user-interface is opposed to a dedicated application that is designed for only a single purpose, a concept dominant in today's VR installations.

2. Educational Application of Studierstube

From the very beginning of the development of Studierstube it has been considered not only an environment for scientific use but also an appropriate setting for applications in the field of education [15]. Many distinctive features of Studierstube's hardware setup and underlying software concepts support teaching processes:

- Collaboration
  Studierstube supports *local collaboration*, multiple users may interact with any number of applications and with each other during a session. *Remote collaboration* of multiple groups of users via Internet connections will support distance education situations.
- Augmentation
  Since we display the computer generated images as *augmentation* of reality, participants can still use conventional teaching aides, like books and black- or whiteboards. In a local setup, where all users are in the same room, there is no need for the introduction of *avatars*, representations of the users` bodies in the virtual environment, since the users are able to see each other directly through the HMDs.

- Customized Views
  As described above, each user wears an individual HMD, which displays images rendered only for this user's viewpoint. Since the images have to be generated „customized" for each user, it presented no major problem to integrate this „customization" into the semantics of the system: each user is provided with a particular view of a virtual world according to his/her status in the situation. For example students may see the teacher's presentation, but not the teacher's notes, or a teacher may switch off certain aspects of the students` display, like political borders or country names on a virtual globe. An important aspect is privacy for students during a test: the teacher may see the students` work, but the students to may not see each other's work.
- General Framework
  Studierstube does not represent a specialized application of virtual reality interaction techniques, but a *framework* in which many different applications may perform concurrently or exclusively [6]. The *content* of Studierstube depends on the different applications, only the *interaction paradigms* (PIP/pen, 3D windows, augmentation) implicit in Studierstube's underlying software and hardware structure remains the same. This mirrors modern graphical user interfaces: What an application does is independent of the interface similarities (mouse, windows, menus).

3. Applicability of Studierstube to the Field of Education

The unique properties of virtual environments render them very suitable for a variety of different application areas one of which is the field of education: Three-dimensional input and output, real-time animation, simulation, and visualization are useful features for many but not all teaching goals and efforts. Studierstube promises to be a highly effective teaching method for all subjects whose content of learning includes spatial relationships, complex three-dimensional structures, dynamic models or simulations of physical processes [5]. In these cases students can acquire and apply knowledge in a more realistic way than they could have done with any other method or media. Studierstube's collaborative aspects can enhance cooperative work such as creative problem solving processes.

This does not imply that VEs should replace all other teaching methods or media, but it is considered to further contribute to the students` understanding and learning. By letting the students directly manipulate and experiment within the virtual world, a higher level of elaboration is reached than just by reading a book or listening to the teacher. Today's technology has not yet reached the point where all teaching processes may take place in a virtual environment, but considering the experiences that we have made so far with the development and use of Studierstube we have no doubts that virtual reality's enormous potential to foster learning and understanding will finally – as technology progresses – lead to a widespread use for educational purposes.

The following table proposes appropriate application examples to illustrate Studierstube's applicability to different teaching subjects.

Subjects	**Examples**	**Applicability**
Geography	Virtual globe, geological visualizations, satellite data	good
Physics	simulation of relativistic effects, kinematics, dynamics	
Astronomy	planetary motions, virtual planetarium	
Biology	medical visualization, virtual microscope, virtual dissection	
Chemistry	molecular simulations	
History	visualization of ancient cities, games and simulations	
Geometry	3D constructions	
Analysis	Visualization of functions	
Architecture	Virtual models, walkthroughs, construction and planning	
Economics	Simulation of economic systems by collaborative games	mediocre
Languages		poor
Symbolic math		
Literature		

Table 1: examples for the educational application of Studierstube

As the table shows, natural sciences dominate the spectrum of applicable topics. These are subjects which naturally lend themselves to demonstrations and experiments, and have traditionally been supported by such. Studierstube only extends the possibilities by simulating settings which otherwise would be dangerous, too expensive or even physically impossible to implement. Even conventionally three-dimensional implementable props – orreries, molecular construction kits, globes – can be more conveniently implemented in VR and thereby freed from physical limitations.

Most of these applications are self-evident, but some topics need more elaboration. Teaching and learning historical and prehistorical matters can be enhanced and supported by virtual reconstructions of artifacts and buildings. As to the field of economics, Studierstube enables students to directly manipulate parameters of economic models or to cooperate in simulations in which each student adopts the perspective of a particular economic entity like consumers, state, businesses or a whole country. Here the advantage of an VE opposed to conventional methods –

books, presentations, discussions – would be high, since complex interdependencies can be experienced directly, but a similar concept could probably be implemented using a network of desktop computers. Studierstube would in this case only provide convenient ways to visualize economic variables and interact with other students.

Topics which do not directly benefit from the advantages of a VE have the common factor of symbolic manipulation: teaching languages, abstract mathematical operations or literature can not easily benefit from 3D interactions or simulations. While of course applications can be found, most of them can be implemented using conventional media like video or CD-ROMs.

4. Evaluation of Instructional Quality

Almost simultaneously with the introduction and application of educational innovations, researchers usually begin to discuss what students learn from these forms of instruction [13]. Therefore, the usefulness of newly developed teaching methods such as the application of the Studierstube approach for educational purposes has to be supported by the results of evaluation research. A comprehensive educational evaluation study of the instructional quality of teaching methods has to consider not only the quality of the process but also the quality of the outcomes of educational efforts. The most important outcomes are the students' achievement, their motivation for learning and their satisfaction with the course they took. The evaluation of the process usually comprises quality of interaction of teachers with students as well as of students with each other, clarity and structure of instruction. The different facets of students' outcomes imply different lines of educational evaluations of instructional quality: On the one hand, the students' approval of the teaching method can be evaluated, on the other hand, their learning outcomes can be determined as an indicator of effectiveness. An evaluation research study can either concentrate on just one or on both of these main facets of student outcome.

The level of the students' motivation and satisfaction reveals their approval of the teaching method. The results of evaluations of innovations in teaching methods very often underline that students are highly motivated to work and learn with new forms of instruction. This effect of novelty (or „Hawthorne"-effect) has been described many times in the discussion on teaching methods [13] p. 19, [14] p. 270. It follows that all kinds of instruction for students of all ages at all levels of instruction should use a variety of teaching methods, media and educational settings to avoid monotony and to maintain the students' interest and motivation.

Student achievement remains one of the most important student outcomes of teaching. Hence, an abundance of research has been carried out over the past decades to determine the most effective teaching method, i.e. the method that most effectively enhances student learning. The findings of a

multitude of studies are highly inconsistent – in many cases due to methodological differences - and the debate is still controversial. It seems that besides the quality of the teaching method the main factor of learning is the teacher, his or her teaching behavior, and pedagogical adroitness. As this important factors are hard or even impossible to be kept constant in an experiment the comparison of effectiveness of two different methods is due to be methodologically flawed. However, an analysis of a number of evaluation studies has led to the conclusion that no method is consistently the most effective one and therefore superior to other forms of instruction. Rather should every teacher as a „reflective practitioner" strive to „implement the best that is known about how to foster learning" [17] p. 2, and this also pertains to applying appropriate new teaching methods in their classes [9] p. 159. Evaluation research answers the crucial question of their appropriateness.

5. Evaluation Design for Studierstube

To evaluate the application of Studierstube for educational purposes, we would suggest a comprehensive survey of the teaching process and of the outcomes. The evaluation design has to consider the following circumstances: The application of VEs represents an educational innovation, so very little is known about these settings as an educational tool. Just like any implementation of a new teaching method it primarily affects teachers and students, so different evaluands have to be taken into account. Their attitudes and experiences cannot be anticipated easily. These conditions suggest to employ qualitative methods of social research which are themselves controversial [10], [12]. The following paragraphs introduce an evaluation design that follows the principles of qualitative social research and additionally facilitates the transformation of qualitative into quantitative data. It has already been employed successfully to evaluate the implementation of Practice Enterprises that also are innovations in the Austrian Educational system [8]. Furthermore, this evaluation design particularly considers the multi-faceted nature of VR as a teaching method and the different perspectives of the evaluands by combining triangulation of perspectives and methodological triangulation.

5.1. The Concept of Triangulation

A survey as "a system of collecting information to describe, compare, or explain knowledge, attitudes and behavior" [3] p. 1 often concentrates on revealing only one single perspective of the research object and therefore fails to get the whole picture of the object which can solely be gained by regarding all or at least some of the relevant perspectives of the evaluand. "It is conventionally assumed that triangulation is the use of multiple methods in the study of the same object" [2] p. 236, but it represents even more: Triangulation comprises the combination of different methodologies, different investigators, different data sources and theories as well as different

settings of time and place [4]. The basic idea of triangulation consists in revealing the whole diversified complexity of a research object seen from as many perspectives as possible. The evaluation design will illustrate that these perspectives can be gained by combining different data sources and different methodologies.

5.2. Triangulation of Perspectives

This kind of triangulation consists in combining different empirical sources in order to gain as many different perspectives of a research object as possible. The major objective of triangulation of perspectives is not primarily to improve the study's objectivity but to reveal the complexity of research objects to get the whole picture instead of a single view. "We should combine theories and methods carefully and purposefully with the intention of adding breadth or depth to our analysis" [2] p. 246.

The evaluation study of the application of the Studierstube approach should determine the perspectives of students and teachers working with this system as well as of researchers that support the implementation of Studierstube. Additionally, as a fourth perspective completing the design of the evaluation study, observation data could be gained from participant observations in the classrooms.

5.3. Methodological Triangulation

"Each method implies a different line of action toward reality - and hence each will reveal different aspects of it, much as a kaleidoscope, depending on the angle at which it is held, will reveal different colors and configurations of objects to the viewer" [2] p. 235. Each method of social research has its own characteristics, its strengths and weaknesses, its potential for gaining information and its limitations. Each method generates a special kind of data. By applying one single method the researcher cannot overcome the method's weaknesses. Only by combining different methods can the deficiencies of one method be counterbalanced by the strengths of another and vice versa. This is because "methods are like the kaleidoscope: Depending on how they are approached, held and acted toward, different observations will be revealed. This is not to imply that reality has the shifting qualities of the colored prism, but that it too is an object that moves and that will not permit one interpretation to be stamped upon it" [2] p. 235. By combining several methods the information gained about the research object will be more complete. In the case of the evaluation study of Studierstube interviews and different kinds of questionnaires could be combined

with participant observation. The transformation of qualitative into quantitative data can be achieved by applying the Delphi method.

5.4. The Delphi Method: Combining Qualitative and Quantitative Research Methods

Linstone and Turoff provided a definition of the Delphi Method when this method was still in its infancy in the early seventies: “Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” [11] p. 3. The basic idea of the Delphi Method – named after the oracle at Delphi in ancient Greek – is the combination of a group discussion with the study of each single person’s point of view. So the respondents can as a group achieve consensus in the solution of a problem but they need not necessarily be brought together for the discussion and their anonymity can be assured. Besides, this method avoids problems like „the influence of dominant individuals on group decisions, the loss of time and energy on irrelevant or biased discussions, the distortion of individual judgment by group pressure, the inclination to reject novel ideas, and the tendency to defend a previous position“ [16] p. 81. A conventional paper-and-pencil-version of a Delphi study consists of several rounds of inquiry of the same target group. As an iterative process, each round of the Delphi summarizes the results of the preceding round and at the same time poses new questions to the respondents based on the results gained in the preceding round. So they have the opportunity to get to know the groups’ overall attitudes, to reevaluate their own original answers, and to answer new questions. Eventually, it should be possible to identify a more or less homogeneous or diverse group opinion which might also be the best solution to a problem. Although the Delphi Method is mainly considered to be a forecasting procedure or a kind of inquiry among experts, “there is a surprising variety of other application areas” [11] p.4, one of which is the field of formative evaluation [1] p. 239, [7] p. 240).

The basic principle of the Delphi method can be of advantage for gaining qualitative and quantitative data for the evaluation research of Studierstube. As very little is known about Studierstube as an educational tool in practice, the Delphi method could be used to start evaluation research with questionnaires and/or interviews based on rather general and open-ended questions. The results of the content analysis of these qualitative data will serve as a basis for the development of more detailed (still open-ended or even closed) questions of a questionnaire or an interview. Again the results of the data analysis will be used to formulate a further series of questions which will most likely be closed ones. Eventually, these data can be analyzed statistically [8]. To complete the picture, researchers should observe the teaching units in which Studierstube is used and administer achievement tests to the students covering what they should have learnt and understood in the preceding teaching units.

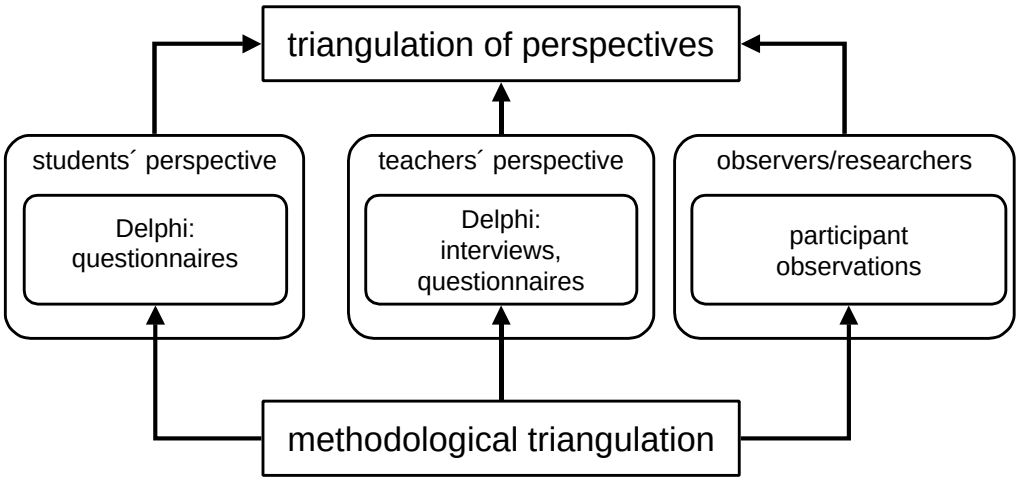

Figure 4: evaluation design for Studierstube

Figure 4 illustrates the different perspectives of the application of Studierstube that are to be examined to provide a complete picture of the research object. In fact, it not only illustrates the theoretical triangulation of perspectives, but also the methodological triangulation as a second main feature of the design.

The analysis of the evaluation data of Studierstube should result in a detailed insight into the students` and teachers` perspectives and allow the researchers to spot and improve weak points of the educational application of a VE as well as to learn about the pedagogical effectiveness of this new teaching method.

6. Conclusion

We have shown how our VE could be applied as an educational tool. Its features and properties have been discussed in respect of their influence on the teaching process. The Delphi method as evaluation tool for this setting promises to deliver meaningful results without relying on initial assumptions, which could limit or even skew the empirical findings.

While we now believe to posses a new educational device and a method for its evaluation, the implementation is still under development. A lot of work has to be done before a representative survey could be conducted. A widespread use of Studierstube in the educational system faces not only technical difficulties – our system has so far only been applied under laboratory conditions – but also administrative obstacles, like the integration into the curriculum and sufficient funding.

The next steps in our work will be to conduct pilot studies of selected classes by applying the evaluation design presented above to a small sample of evaluands. As to the technical aspects of the implementation we will develop software tools for the easy and fast integration of teaching content.

Further information on Studierstube: http://www.cg.tuwien.ac.at/research/vr/studierstube/

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