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DEVELOPING, IMPLEMENTING, AND TESTING MIXED REALITY AND HIGH INTERACTION MEDIA APPLICATIONS IN SCHOOLS

ABSTRACT

Current pedagogical approaches emphasize the procurement of media literacy in classroom learning. In this respect, mixed reality systems and high interaction media applications provide potentially exciting learning experiences for children by bridging the gap between theoretical and experiential learning in the physical world. We describe the constructive implementation of digitally augmented learning environments in elementary and secondary schools during an ongoing research and knowledge transfer project at the University of Luebeck, Germany. Three class projects are introduced that focus on storytelling within vision-based action scenarios, and mobile and ubiquitous learning, respectively. Evaluation data from different variables (e.g., motivation, achievement of learning goals, problem solving) and different target groups (e.g., students, teachers, team members) show the overall success of the projects. However, the data also indicate the complexity and difficulties of implementing digitally augmented learning in schools.

KEYWORDS

Mixed reality, pervasive computing, constructivist learning

1. INTRODUCTION

Digital augmentation has been repeatedly demonstrated to provide exciting indoor and outdoor learning experiences for children (Rogers et al. 2005), but the major step to introduce this kind of interactive technology on a daily basis into school has not been taken.

What makes mixed reality (MR) systems and high interaction media applications attractive for students? Of course, it is technology that is novel and exciting to children. Children like to play and work with interesting new materials; they feel intrinsically motivated and challenged (Eisenberg 2005). More importantly, children’s natural curiosity especially fuses well with digitally augmented systems because, though these systems are highly sophisticated and technologically advanced, they are compellingly intuitive in nature. Interacting with digital information in MR environments is done, for example, by acting in physical spaces or manipulating (e.g., touching, moving, lifting) familiar physical artifacts. This form of machine perception and actuation fits more naturally with the way children act and interact with their everyday world. The dense interaction structures immediately lead to immanent presence experiences between the children, their physical space and the digital models within the computers (Herczeg 2004). The current situation of computer use in schools, however, is still dominated by conventional computer-used interactions (consisting of a computer box, VDT, keyboard, and mouse), which are limited to abstract representations.

The first part of the present paper addresses issues, as well as their implications, for projects transferring MR systems and mobile and ubiquitous high interaction media into classroom situations. We then describe three different applications for MR systems and mobile and ubiquitous high interaction media developed by and currently in use in the KiMM (Kids in Media and Motion) initiative at the University of Luebeck, Germany. This ongoing project introduces constructive and creative uses of digital media and technology in both elementary and secondary schools. As we shall see, though the projects within the KiMM initiative are theoretically and practically complex, challenging, time-consuming, and also economically demanding, the outcome is highly rewarding for all participants involved.

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2. MEDIA LITERACY, DIGITALLY AUGMENTED SYSTEMS, AND CLASSROOM LEARNING SITUATIONS

The omnipresent advances of technology and its ever-increasing importance in the lives of young people pose serious challenges for future society. It has been argued that digitally augmented systems might create a pervasive change in children's future artifacts and activities (Eisenberg 2005). In this context, school officials and teachers are confronted with public, political, and parental demands to make children "media-safe" for the future. Though being ill defined, media literacy has nevertheless emerged as a key term representing the essential skill needed to succeed actively and participate constructively in versatile forms of social and technological interaction (Groeben 2004). Given the aforementioned applicability of digitally augmented systems the design, development, and successfully implementation of digitally augmented systems for children may aid them in their procurement of media literacy.

A number of implications emerge when planning the transference of digitally augmented systems into classrooms. These are strongly influenced by factors including characteristics of students, teachers, the school's curriculum requirements, and the features of the to-be-implemented systems. All of these implications must be dovetailed to ensure successful transference. In addition, quantitative and qualitative evaluation is needed to accompany the transition and assure the significance of the method. This also extends to the issue of sustainability (i.e., anchoring significance of the method in well-grounded long-term studies).

2.1 Heterogeneity of the students

One of the most difficult aspects in designing and developing software applications for educational purposes is the heterogeneity of the target group. Though students in any given grade share, more or less, the same biological age, their mental abilities and sensor motor skills differ dramatically. This has serious implications with regard to the complexity of content and the interface design of the MR system (playability of game controls; Hoeysniemi et al. 2005). The software application must therefore become self-explaining (intuitive) to minimize the length of the student's learning phase and to assure continued motivation.

In addition to differences in the availability of mental abilities, children are also likely to differ significantly in terms of their pre-existing level of media literacy (i.e., media experiences). Generally, children's exposure to different media tends to be unsystematic or "accidental" and this contributes to the heterogeneity of all age groups. Their experiences determine their perception of current situations and their expectations concerning software design. For example, children's experiences with computer gaming creates high expectations with regard to computer graphics. The consequence of bringing game-like digitally augmented systems (e.g., pervasive educational gaming) into the classroom is then evident: a certain level of sophistication is required for the children to accept the application (Robertson et al. 2005).

2.2 Students' motivation

Motivation is an essential prerequisite to memory and learning. The level of motivation of a person is positively related to the amount of attention the person (either voluntarily or involuntarily) devotes to ongoing events. Their attention determines how much information is processed in a given situation. This so-called *level-of-encoding* is an important predictor for the success of subsequent attempts to deliberately recall an event: the depth of information processing is normally positively correlated with the probability for later recall of the information (cf. Slavin 2003). Since motivation is a feature of common human information processing, subsequent discussions of motivational issues hold both for students and teachers.

Numerous studies on MR systems and high interaction media projects have addressed the motivation of children and adults (e.g., Rogers et al. 2005). For example, successfully creating non-textual media like educational games or interactive MR theatre, which can be enjoyed by an audience, is rewarding and increases children's motivation. This then has positive effects on self-esteem and promotes learning performance in school (Robertson et al. 2004). Motivation also depends on intuitiveness and physical appropriateness of the MR systems: providing an enjoyable playing experience leads to a decrease in learning time (Hoeysniemi et al. 2005). Finally, children's motivation and collaboration input benefit from practices of structured cooperative digitally augmented systems design (i.e., participatory design; Guha et al. 2005).

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2.3 Teachers' motivation

Teachers play a crucial role in determining the success of any digitally augmented system project. First, they translate the school's curriculum requirements into learning content. As mentioned above, this determines which type of digitally augmented system is most suitable for the project.

Though teachers, who agree to take part in transfer projects, are motivated to use digitally augmented systems, they are heterogeneous in their media literacy. Some of them are digital media experts, while others are technologically inexperienced. Thus, training is a prerequisite for teachers to cope with the technology before each project is launched. Various workshop methods and instructional strategies have been successfully applied to introduce computer technology to teachers (Tan et al. 2003). Sustainability will be possible and positive effects will persist after the end of the project only if teachers are well prepared for "multiplying" technological knowledge to their students. The teacher's motivation and cooperation thus positively influences the intensity and longevity of digitally augmented system transference.

3. DEVELOPING PRACTICAL DIGITALLY AUGMENTED SYSTEM APPLICATIONS FOR REAL WORLD CLASSROOMS

Within the KiMM initiative at the University of Luebeck, we introduce constructive and creative uses of digital media and technology for both elementary and secondary schools. Since 2001, we have been following a situated learning approach, which promotes the use of digital media for successful contextualisation of curriculum material in various learning scenarios.

We place an emphasis on using digital interactive technology in the students' daily learning environment and not exclusively in special projects (e.g., Winkler et al. 2005). Students participate in the following aspects of digital augmented learning:

- Research, design and use iconic programming with micro-computers, visual, auditory and tactile presentation systems, as well as sensors and actuators
- Invent, design and program interactive story rooms, installations or performances
- Create 3D mixed-reality environments or performances
- Use mobile equipment for inside and outside learning
- Make use of supported learning in a Web based interactive community system

The theoretical concept behind our work follows a constructivist approach (Papert 1980) that is influenced by Piaget's theory of child development. The constructivist approach is based on the assumption that, just as small children need to explore actively their environment, learners must individually and actively seek and gather complex information. With this form of top-down processing, students begin with complex problems or tasks and discover the basic knowledge skills needed to solve the problems or perform the tasks. Students benefit from cooperative learning and questioning or inquiry strategies, which are often implemented in discovery learning scenarios (cf. Slavin 2003).

Within the KiMM initiative, we consider the children's active use of media technology and its various effects on the children. In accordance with constructivism, we focus on creativity and problem solving processes in the children's thinking by emphasizing the role of children's self-initiated, active involvement in learning activities. This approach supports children's cognitive understanding of digital media, but does not aim at making them adult-like in their thinking. We address the effects of media technology holistically by considering cognition (e.g., development of problem solving skills), children's emotion and motivation (e.g., joy of learning), and also their behaviour (e.g., improvements in cooperative and collaborative behaviour). The overall evaluation concept has already been described elsewhere (Melzer et al. 2005).

Our concept is based on the relationship that exists between the progression of children's mental abilities and sensor motor skills, the type of to-be-transferred digital media used, and the amount and complexity of media literacy transferred. As the children's intuitive and technological boundaries expand, it is important to offer them more complex MR systems and mobile and ubiquitous applications, which also procures a deeper understanding of media literacy. This is reflected by the school projects described in the following section. These projects use MR systems and mobile and ubiquitous high interaction media in collaborative learning environment for 4th, 7th, and 8th grade students, respectively.

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3.1 RCX Command

The *RCX Command* is an iconic programming Java-based application using the LeJOS API (open source library available at http://lejos.sourceforge.net/). We use the *RCX Command* software for elementary school students to learn to program a multi-audiovisual performance (Figure 1). When they program a sequence of events (e.g. graphics, music, film), a LEGO©RCX™ microcomputer triggers the sequence, which is then projected onto a backdrop. This software was used in a 4th grade project called *The Missing Magic Flute*, which featured characters from Mozart’s Magic Flute opera.

The Missing Magic Flute was a MR theatre play with operatic influences. The play’s scenario followed the endeavors of three children detectives wishing to discover the whereabouts of Pamina and the missing magic flute. With the aid of a truth detector (i.e., the triggering RCX™ microcomputer), the detectives cross-examined the cast members of the Magic Flute opera, and tried to separate the truths from lies of the suspects’ testimonies (playback opera arias, flashback pictures and stop-motion animation).

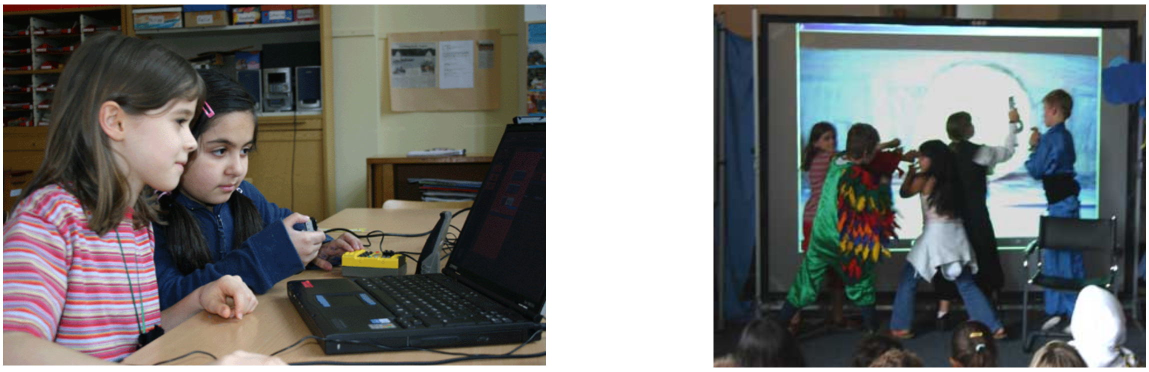

Figure 1. 4th grade students programming the *RCX Command* (left), the performers “pushing” a mirror (right)

The teacher and students were involved intensely in every aspect of the play’s production. They created the plot, wrote the script, drew the drawings and filmed the stop-motion animations for the scenery which were projected onto a backdrop, made the costumes and props, created sound effects, and programmed the multi-audiovisual performance (RCX Command). Through a collaborative effort the children learned to utilize different dramaturgic tools to explore the play’s central themes: searching for truth, wisdom, and magic. The students created multiple stage sceneries and virtual revolving doors and hidden cupboards. The MR systems thus assisted in expanding the physical boundaries of their classroom stage and helped to expand the students’ own artistic limitations (e.g., their inability to singing opera).

The evaluation of the project was based on informal interviews, KiMM team members’ logs, and the content of children’s compositions. The children derived much satisfaction working with the different media and were proud of the fact that they created every aspect of the production. The teacher was impressed how much the children and she learned during the project about the use of digital technologies.

3.2 Moles/Mini Moles

Moles is an XML-based content management system for high school students and teachers to create interactive questionnaires for indoor and outdoor activities (i.e., mobile learning). With the use of JAVA-based *Mini Moles*, previously edited questionnaires are transferred onto PDAs as input and output devices. The students use different sensors and measuring devices as well as observations to record their findings on the PDAs (Figure 2) during an outing. When their outing is completed, the data from each PDA is transferred back into *Moles* and the answers are checked for correctness. *Moles* takes the data from *Mini Moles* and other recorded material (e.g., digital photos) and converts it into HTML documents for further Web presentation via an export function. *Moles* was designed as a mobile learning application to extend the physical boundaries of the students’ classroom outdoors. This application facilitates the acquirement of scientific data, as well as it encourages self-sufficiency and collaborative problem solving.

A 7th grade chemistry class participated in the design and development of a weather project. The students researched and described various forms and measurement procedures concerning weather (e.g., air pressure, temperature, cloud formation, wind direction and speed, precipitation, and humidity). They then participated in a weather experiment outing, where they documented different weather conditions at five different measuring points in the city over a five hour time span and then transferred the data back into *Moles*.

Figure 2. 7th grade students programming an interactive questionnaire with *Moles* (left), students using *Mini Moles* on their mobile learning weather project outing (right)

The evaluation data for this project was accumulated through questionnaires, which the students (11 male, 14 female) and their teacher completed on two different measuring times. The first questionnaire (students: 25 items; teacher: 16 items) was presented before the project started. It determined demographics, preexisting level of media literacy, and availability of digital media in their homes. In addition, it focused on the cognitive, emotional, motivational, and behavioral aspects of their experiences with previous school projects. These latter aspects were also itemized in the second questionnaire (students: 48 items; teacher: 38 items), which was presented directly after the weather experiment outing and data transfer. A detailed description would go beyond the scope of the present paper, thus Table 1 illustrates only a sub selection of the findings.

Table 1. 7th grade students' ratings (mean scores; standard deviation in parentheses) and their teacher's ratings (absolute values) for selected items in the pre-project version and in the post-project version of the questionnaire for the weather project *Moles/Mini Moles* (ratings ranging from 1="I don't agree at all" to 6="I totally agree"; "–" indicates the lack of a matching item; see text for further details)

Participants	Item	Pre-project ratings	Post-project ratings
Students	Own computer expertise	1.76 (0.88)	4.28 (1.43)
	Computer should be used more often in school	4.63 (1.17)	5.08 (1.22)
	When problems occurred, I didn't give up, but tried to achieve my goal	4.78 (1.24)	5.00 (0.65)
	Problem solving was done by one member of work group only	2.92 (1.04)	2.60 (1.35)
	Though sometimes things were chaotic, teacher had everything under control	3.58 (1.61)	4.16 (0.80)
Teacher	Class project was fun	–	5
	Feel satisfied with the course of the class project	–	5
	Curricular goals were fully met	–	3
	Not enough time for conventional learning methods	3	4
	New materials/devices entail(ed) substantial increase in planning	4	4
	Compared to conventional forms of learning, class project(s) was(are) more demanding	4	6
	Students focused on technology/devices, rather than task at hand	–	4

Not surprisingly, students reported a higher level of computer expertise after the class project, which substantiates the increase in computer skills as part of gained media literacy. Students' experiences with digitally augmented learning environments also corroborated their already positive attitude towards the use of digital technology in schools. In addition, occurring problems did not reduce the amount of the students' reported goal persistence. Rather, problem solving was reported to be the result of team collaboration. This is

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an important finding because highly attractive material often causes monopolizing of the use of elements by the class leaders, which also reduces the possibilities of manipulation by shy students (LEGO 1999, 2001). With regard to the teacher, the students acknowledge her successful handling of difficult situations during the course of the class project.

What do we learn from the teacher's ratings? Though the teacher reported that she had enjoyed the project and also felt satisfied with the course of the class project, she also indicated some serious problems with the digitally augmented learning environment. Most importantly, she does not agree to the claim that all curricular goals were fully met. This is attributed in part to the time-consuming process of extra planning an unfamiliar learning situation. In addition, because the new classroom situation also demanded more attention than previous projects, there seemed to be not enough time for her to use her well proven teaching methods. On the basis of the teacher's observation that students tended to spend more time on the technology than on the project's task; we may speculate that this was due to ineffective handling of teamwork. This is a known issue, which has often been reported (e.g., LEGO 1999, 2001). Handling of teamwork relates to the teachers' initial concern about their own lack of computer literacy. This problem can only be addressed with continued teach-the-teacher sessions – an important lesson we have learned from the *Moles/Mini Moles* project.

3.3 White Spot History Hunt

Projects incorporating pervasive educational gaming create unique scenarios, which allow students to explore the real world in context to historical, cultural, or social issues. Pervasive or ubiquitous learning environments encourage children to reflect, explain, and hypothesize about the physical world (Rogers et al. 2005). They exemplify and augment the students' formal classroom learning experiences.

An important aspect of media literacy is the ability to deliberately select adequate media (digital or traditional) for individual purposes. Pervasive educational games are highly appropriate to address media literacy in this respect, because they do not require extensive technological resources. Rather, they simply pose a challenge to use available and affordable digital devices resourcefully depending on the content.

Recently, a Luebeck high school joined in the development of a pervasive game project called *White Spot History Hunt*. The design of the game was a three step process. First, the schools curriculum defined which subject material the 8th grade students had to research (i.e., the Industrial Revolution and its economical implications on Luebeck at the turn of the 19th century). Students' findings from the Internet were used to determine the game content. Then a member of the KiMM initiative designed a pervasive game, an interactive scavenger hunt, which played in Luebeck, but was settled in the time of the Industrial Revolution.

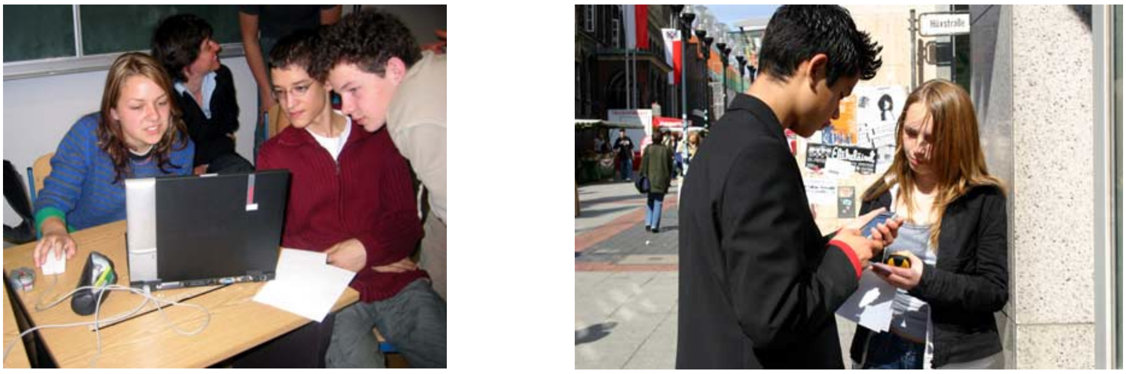

Figure 3. 8th grade students (game masters) sending clues to history hunters in another room (left), runners (right) sending in GPS coordinates to navigators in the *White Spot History Hunt* pervasive educational game

The *White Spot History Hunt* teams were given a virtual map of 19th century Luebeck with a series of white spots. They had to discover these uncharted territories. Each team consisted of students with different roles (e.g., runners or navigators). Most participants were located in school classrooms and used an Internet chat program to communicate with the runners, who had Smart Phones and GPS systems (Figure 3). Together they unraveled a series of clues, discovered the uncharted white spots and successfully completed challenges in a race against the clock.

Data from the post-project questionnaire (15 male and 12 female students: 29 items; teacher: 20 items) showed the overall success of the project. Most importantly, the teacher reported that the students' learning was substantial. However, she found that the class project was highly demanding. Interestingly, data indicated differences in the students' and their teacher's interpretation of the pervasive game project. Table 2 illustrates the main findings concerning this matter.

Table 2. 8th grade students' ratings (mean scores; standard deviation in parentheses) and their teacher's ratings (absolute values) for selected items for the pervasive game project *White Spot History Hunt* (ratings ranging from 1="I don't agree at all" to 6="I totally agree"; see text for further details).

Item	Students	Teacher
Class project was fun	3.48 (1.31)	5
Our Teacher had fun with the class project	4.23 (0.77)	*see above*
Feel satisfied with the course of the class project	2.43 (1.08)	4
Would have wanted more devices/technology	3.85 (1.63)	2
Digital devices and new forms of learning are now likely to be used more often in the future	3.16 (1.11)	4

Apparently, both groups differed in their estimations of the overall amount of fun they had creating the content and using goal-oriented digital devices in a gaming environment. In addition, the variability of the scores also indicates that some students were clearly dissatisfied with the class project. Further analyses showed that this was neither due to the different roles or teams, nor did it reflect gender differences (M_{male}=4.00, SD=1.36, M_{female}=3.33, SD=1.16). We speculate that the reason for the heterogeneity of the students may be due to differences in the preexisting level of media literacy. However, this hypothesis needs further testing. A clearer picture emerges with regard to the question of whether or not additional technology (i.e., more devices) should have been used in the class project. Not surprisingly, male students (M=4.93, SD=1.07) clearly agreed to this item, whereas both the female students (M=2.50, SD=1.24) and their teacher did not (see also next section). Finally, there were no gender differences (M_{male}=3.43, SD=1.22, M_{female}=2.82, SD=0.87) in the students' overall tendency to underestimate their teacher's willingness to bring new forms of learning to the classroom in the future. This is an important finding because relates to the students' motivation to accept their teachers as being "media literate", which is as a prerequisite to their own compliance in further class projects.

3.4 Further findings

Typical gender related issues were revealed at the beginning of each class project (e.g., the predominant use of computers at home for males is gaming, whereas females participate in chat rooms and other activities with more "social interaction"). For the post-project questionnaire, we thus expected gender differences for those items that focus on the amount of technology used in the project (see previous section). There was no reason to assume gender differences with regard to the overall success of the digitally augmented learning environments. In accordance with this prediction, students' reported increase in computer skills in the *Moles/Mini Moles* weather project holds both for male (M=4.73, SD=0.65) and female students (M=4.21, SD=0.89). However, and only after further informal interviews, it became apparent that by introducing digital media certain inequalities in group dynamics were intensified rather than resolved. In particular, the "distribution of tasks" was unequal: the male students primarily wanted to use the digital devices and the female students were asked to do the research and legwork. But even so, this discrepancy did not hinder the female students from feeling confident and secure in the use of the digital media.

We repeatedly experienced the problem that both the students and the teachers (albeit to a lesser degree) mistakenly assume a causal relation between using advanced technology in a creative process and what the resulting aesthetic outcome of this process will be (see also Table 2). They believe that "high-tech" inevitably produces Hollywood-like aesthetic effects. We encourage them to focus and reflect upon all that they have learned along the way. Once they are aware of how rich and positive the learning experience has been, their disappointment about the lack of aesthetic sophistication compared to professional productions diminishes.

Also, teachers and students expect that implementing digitally augmented systems into their classroom-learning environment will be very easy and a lot of fun. These expectations produce a low threshold of pain concerning technical glitches and disbelief about how much effort is needed to make sure everything runs

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smoothly. Current belief is that digitally augmented systems create a pervasive change in children's future artifacts and activities (Eisenberg 2005). If this is so, children (and teachers) must learn that media literacy comprises not only the acquirement of knowledge, but they must also learn to accept that things can go wrong and learn how to solve the problems posed. Knowing which limitations exist with regard to digital technology is a prerequisite to being media literate.

4. CONCLUSION

The procurement of media literacy is an important issue that has to be embodied in the school curriculum. Otherwise, children's unsystematic or "accidental" consumption of digital media and technology may lead to unpredictable effects. Implementing mixed reality and high interaction media applications in classrooms is a complex process. We found that the difficulties faced, though considerable, are not insurmountable. Yet, it would be incorrect to overlook negative criticism or the difficulties addressed by the teachers and students just because the overall results are positive.

With the criteria of school curricula, the abilities (or capabilities) of teachers, and the interests and abilities of students of several of age groups, we have analyzed issues concerning developing and implementing applications. We have described different MR systems and high interaction media applications, which have been shown to broaden successfully the creative scope of classroom learning.

However, the underlying processes are not yet fully understood. The positive effects are likely due to the intuitive nature of digitally augmented systems. Unlike conventional computer-technology, these systems and applications do not require the mental ability to infer meaning, and, thus, should be successful even with a low level of the child's cognitive development. However, this hypothesis is subject to further research, which can only be substantiated by continued close collaboration with schools.

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