The Impact of Second Life Experiences on Mathematical Beliefs
Relationship with mathematics anxiety and perceived learning potential of Second Life for mathematics learning.

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Introduction

Teachers are not cognitive-but-lacking-affect robots. Mathematics education for pre-service teachers, and educationists must address teacher beliefs and affect in addition to acquisition of knowledge and skills (Schoenfeld, 1998). In the present paper, we examine the potential to influence student teacher beliefs around mathematics, drawing on the recommendations of Langrall, Thornton, & Malone (1996). In line with these recommendations, we utilize a constructionist learning environment situated in Second Life, that can be used to provide virtual experiences that rival first life experiences. Teachers are then asked to re-examine their attitudes around mathematics. In addition they are interviewed about the learning potential of the Second Life experience in view of learning mathematics.

Theoretical framework: teachers– beliefs – mathematics - learning environments

A key component of teachers' identities are their beliefs (Beijaard, Meijer, and Verloop, 2004). Fishbein and Ajzen (1975) define beliefs as a representation of the information someone holds about an object, or a "person's understanding of himself and his environment" (p. 131). This object can be extremely varied and "be a person, a group of people, an institution, a behavior, a policy, an event, etc., and the associated attribute may be any object, trait, property, quality, characteristic, outcome, or event" (Fishbein & Ajzen, 1975, p.12). It is also clear beliefs can be as varied as the teaching profession itself and therefore reflect issues related to learners (e.g., beliefs about inclusion, about diversity), knowledge (epistemological beliefs), teaching components (beliefs about the curriculum, beliefs about what learning content is important, beliefs about media (ICT), teaching strategies, evaluation, etc.), parents, instructional context, and organisational dimensions. The former can clearly be related to the focus of the present study. Ernest (1989) reviewed studies focusing on teachers' beliefs about mathematics, and concluded that three belief components have a critical influence on mathematics related instructional practices: conceptions about the nature of mathematics, the nature of mathematics teaching, and the process of learning mathematics.

Considering the role of beliefs about the "teaching of mathematics", Askew, et al. (1997) found that highly effective primary school teachers embodied constructivist beliefs that are in sharp contrast to 'transmission' beliefs of less successful teachers. Quillen (2004) discussed comparable contrasts between relational beliefs versus instrumental beliefs. The beliefs about the way learners have to be taught will clearly influence teachers perceptions of the learning potential of specific learning settings. In the context of this study, these beliefs will be reflected in the perceptions of student teachers about the potential of the Second Life experience in view of learning mathematics.

Building on the central role of "beliefs about mathematics", we focus in the present study in particular on the role of mathematics anxiety, and teacher attitudes towards mathematics. Swars (2005) points in this context to the close relationship between math anxiety and perceived self-efficacy. Research also points out how mathematics anxiety inhibits cognitive processing (Ashcraft and Kirk, 2001). The attitudes towards mathematics have intensively been studied in the literature. Taipa & Marsh (2002) integrated this literature when developing the Attitudes Towards Mathematics Inventory (ATMI). The attitudinal processes in the context of mathematics are related to variables such as self-confidence, mathematics anxiety, the considered value of mathematics, the enjoyment experienced in relation to mathematics, the motivation to be involved in mathematics, and expectations as to being successful in mathematics.

Specific learning environment related variables seem to have an impact on the beliefs in general and mathematical beliefs in particular. Langrall, Thornton, & Malone (1996) suggest to put pre-service teachers in a sufficient number of "real-life" situations and oblige them to re-appraise their existing beliefs, attitudes, and knowledge. Zahorik (1987) stresses the importance of observing the practices of fellow teachers. Schelfhout, et al. (2006) point at the necessity to develop powerful learning environments to influence (student) teachers. They stress the importance to redesign the learning environment so that it reflects the following characteristics (ibid, p.473): "These can be summarised in the following definition: learning is a constructive, cumulative, self-regulated, goal-oriented, situated, collaborative, and individually different process of knowledge building and meaning construction."

In the context of the present study, we especially refer to web and game based learning environments. Bragg (2006) summarizes research that points at the relevance of virtual and game based environments to influence mathematics learning. In a recent research overview, Tobias and Fletcher (2008) refer to clear empirical evidence that – though no learning performance gains were observed, a significant impact on attitudes towards mathematics could be observed in learners playing computer-based learning games. The same authors also refer to studies that report more time on task, less off-task behaviour, and higher motivation levels when learners are put in computer game-based contexts. In the context of 2nd life, *Fractal Village* presents learners opportunities to "play" with geometrical objects.

The interaction between virtual game-based learning environments, cognitive processes, and affective variables as described in the former paragraphs can be integrated by building on the expectancy-value theory of Wigfield & Eccles (2000). Their model implies that beliefs consist of affective components, goal orientations, competency judgments and perceptions about the tasks to be carried out. These beliefs are influenced by cognitive processes about attributions and earlier experiences. This complex set of beliefs, affect and cognitive processes is influenced by experiences within the learning environments and the wider instructional context (appraisal, success experiences, values of peers, teachers, parents). This helps to understand how this results in choices, persistence, duration and, engagement in specific behavior in teaching and learning contexts. The model also points at the reciprocal impact of this behavior on external and internal processes.

Design of the study

Research questions

Building on the theoretical base and the potential of 2nd Life Experiences, we put forward the following research questions:

- What is the impact of the Second Life experience of student teachers on their attitudes towards mathematics?
- What is the perception student teachers about the potential of the Second Life experience in view of learning mathematics?

The first research question will be studied in a quantitative way, based on a single sample pretest-posttest design that focuses on the impact on a set of mathematical attitudes. The second research question is studied on the base of a qualitative analysis of responses of respondents to structured interview questions.
The research design is limited due to the naturalistic context. All students enrolled for the course took part in the experience.

Sample

The research sample consists of 53 third-year undergraduate Educational Science students enrolled in a course about Mathematics Education (47 female, 6 male). This course centres on the theoretical base of teaching an learning mathematics. The Second Life activity was set up as a formal part of the course , and a set of minimal participation criteria was put forward in view of guaranteeing a base engagement level. It is to be stressed that the Second Life learning environment was not discussed during the weekly work sessions, nor was theoretical and/or empirical work discussed with students about Second Life.

Research Instruments

To measure the attitudes towards mathematics, we adopted the Attitudes Towards Mathematics Inventory (ATMI), developed by Taipa & Marsh (2002). This instrument integrates findings from previous studies as to nature and importance of attitudinal processes in the context of mathematics (confidence, anxiety, value, enjoyment, motivation, and expectations. The authors report a Cronbach alpha coefficient of .97.

The 2002 ATMI version consists of 40 items, reflecting a four factor structure. The following list gives an example item of each factor and the subscale reliability:

- Self-confidence: Mathematics does not scare me at all (α .95)
- Value: Mathematics is important in everyday life (α .89)
- Enjoyment: I really like mathematics (α .89)
- Motivation: I am willing to take more than the required amount of mathematics (α .88).

Respondents are asked to indicate on a 5 point Likert scale the extent to which they agree with the statements. The original Attitudes Towards Mathematics Inventory (ATMI) was translated into Dutch, using the Translation-Back translation approach described by Behling and Law (2000). After administration, factor analysis was applied to reanalyze the factor structure of the translated version. The four factor structure could be replicated, but a number of items reflected additional loadings on other factors. These items were omitted from the translated versions. This resulted in a shorter version, consisting of 27 items. The following list explains the number of items per scale and the reliability level : Self-confidence (9 items, α .92); Value (8 items, α .71); Enjoyment (6 items, α .83); Motivation (4 items, α .75).

To determine a level of Mathematics Anxiety, we administered the Mathematics Anxiety Rating Scale for Adolescents (MARS-A) as it was developed by Suinn & Ruth (1982). Also this instrument was translated into Dutch, using the Translation-Back translation approach described by Behling and Law (2000). The Cronbach alpha coefficient for the complete instrument of 98 items is α =.97.

Since working in Second Life also builds on a basic level of Computer experience, a Computer Experience Scale was administered that presented the students with a variety of computer and Internet applications and asked them to rather their level of experience. This results in an average CES score, with a maximum score of 10. The scale reflect a Cronbach alpha reliability level of .78.

Procedure

The experience started by the administration of the three research instruments discussed above: the MARS-A, the ATMI and the CES.

During an eight-week period, the respondents, after being introduced to the technology and the Second Life environment, started working in the Fractal Village. Weekly new tasks were put forward to challenge the activities of the research subjects and to help them to centre on new approaches, new ideas, etc. This was done by a "coach" in a standardized way, so that all groups received the same information at the same time. The coach presented them e.g., with scripts to be manipulated (program "seeds", new ways to develop objects, etc. The coach never discussed mathematics in an explicit way (e.g., adopting explicit mathematical concepts to assign shapes, characteristics, procedures, …).

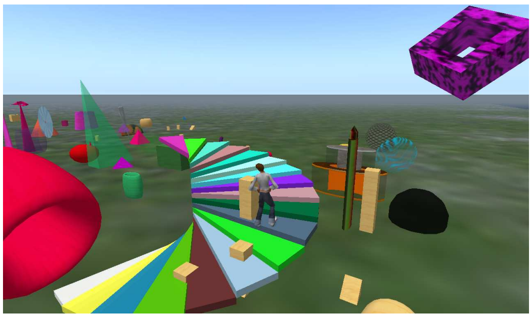


Figure 1

Figure 2

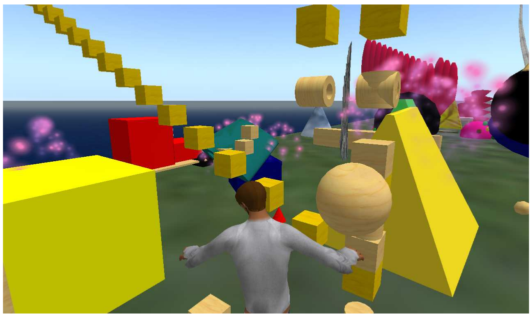


Figure 3

Figure 4

Student teachers worked in groups of 4 students. Next to the Second Life environment, students were also assigned to work in asynchronous discussion groups were they could exchange experiences with their groups. Work in the discussion groups was also part of the formal course requirements. The discussion groups were part of their regular course support learning environment. Moreover, students were well experienced in working in discussion groups considering their experience in other courses and related requirements in earlier years. The discussion focused on developing the group objects in the Second Life space. Figure 1 to 4 give an impression of the activities the students were involved in when manipulating the 3D objects.

Activities of the students centred on the active manipulation of the 3D objects. They were progressively invited to build more and more complex activities that resulted in changing shapes of objects, developing “behaviour” of the objects when being touched or when touching each other, developing dynamic scripts that combine shape, behaviour and reactions to contexts, and fractal like constructs (e.g., stairway constructions, box-in-a-box constructions, etc.

In the environments students were able to observe each other’s work and to give comments. Discussion could focus on technical difficulties (e.g. objects disappearing, properties of objects, parts of scripts that can be manipulated, …), their perceptions about the environment (usefulness, relevance, significance, ..) or other issues. On average students worked about for three hours a week in the Second Life environment; resulting in about a 25 hour learning Second Life experience.

At the end of the research period, students were invited to fill out again the ATMI to get a picture of the possible impact on their mathematics attitudes. In addition, all individual students were invited to fill out a structured interview form that focused on their perception of the learning potential of the Second life experience. In view of the qualitative research questions put forward above, we will centre on the analysis of one particular question that asked students to reflect on their Second Life experience in view of what they considered as variables that influence – positively and/or negatively the learning of mathematics.

Analysis approach

A content analysis approach was adopted to analyse the responses to the open-ended questions in the structured interview. The procedure followed the guidelines of Krippendorf (1980). Interview responses were coded by two independent coders. These coders were acquainted with learning and teaching related research issues. All answers to the questions were studied by the individual coders to find "themes" that represent the central ideas in the student teacher responses. Both coders developed in this way a saturated list of themes. After all the student replies were studied by both coders, they put together the themes list to develop a shared coding system. Overlap was discussed and merging or splitting up of categories was helpful to resolve discussions.

In the next phase, both coders applied independently the coding categories to all student replies. A total of 346 statements was identified. In only 28 cases, the two coders differed in their coding (92 % interrater agreement as an indicator of reliability).

Results

Descriptive results, relationship between variables

The scores for the Mathematics Anxiety Rating Scale for Adolescents (MARS-A) indicate that on average this group of student teachers reflect a rather low anxiety level. This sample reflects an average MARS-level of 70.45 and a standard deviation of 30.96. The maximum MARS score in this sample is 143, whereas the theoretical maximum is 392. This makes this variable of lesser importance to include in the subsequent analyses. Additional analysis results indicate that the Anxiety scores correlate with the mathematics attitudes. The Mathematics anxiety correlates significantly with Self confidence (.390, $p<.001$), Motivation (.283, $p<.05$), and Enjoyment for mathematics (.340, $p<.05$). There is no significant correlation with attitudes about the value of mathematics. The attitudes are predicted - to a certain level - by the math anxiety level: Self confidence (R^2 .152), Motivation ($R^2 = .08$), Enjoyment for mathematics ($R^2 = .115$), and Value of mathematics ($R^2 = .014$).

The computer experience of the research subjects is rather low ($m = 3.50$, with a minimum of 1.80 and a maximum of 6.20). The small standard deviation also indicates that the sample is rather homogeneous as to their computer experience level ($\sigma = 1.07$). This low computer experience level is of importance to consider the results that will be discussed below.

What is the impact of the Second Life experience of student teachers on their attitudes towards mathematics?

A paired sample t-test was carried out to measure whether the four dimensions in computer attitudes differ significantly before and after the Second Life experience. Table 1 summarizes the t-test results:
It is clear that there is a – small – but significant increase in three of the four mathematical attitudes: Motivation, Enjoyment and Value. The increase in self-confidence is not significant.

Table 1: summary of paired sample t-test results (n=53, degrees of freedom 52)

Attitude dimension	*pre*	*post*	*Mean Difference*	σ	*t*	*p*
Motivation	1.62	1.90	.91	.13	-2.23	= .030
Enjoyment	2.24	2.50	.55	.07	-3.40	< .001
Self confidence	1.35	1.38	.50	.07	-0.27	= .785
Value	2.70	3.00	.53	.07	-.3.54	< .001

What is the perception student teachers about the potential of the Second Life experience in view of learning mathematics?

The Second Life experience was set up in the context of a course about Mathematics Education. Research subjects were explicitly invited to manipulate 3D objects during group work activities. The Second Life experience was expected to influence the conceptions of the student teachers about learning mathematics. In the structured interview, a key questions asked them to develop their ideas about the way the Second Life experience fostered/hindered the learning of mathematics. The qualitative analysis focused – as explained above – on detecting emerging themes that reflect ideas about the learning potential of the Second Life experience. In the following paragraphs, the content analysis results will be documented with a selection of relevant "quotes" form the student teachers.

Table 2 gives a quantitative breakdown of the themes and clusters of themes that point at the supportive impact of the Second Life experience on the learning of mathematics. In the table, the labels for the sub-clusters start with a capital letter and the total number of statements that was coded for this category is shown.

The largest subset of themes is related to the impact on characteristics of the learning process. The research subjects clearly state that they perceive the learning environment to foster active and creative learning, with opportunities to experiment in an authentic settings that is more challenging than a traditional classroom.

Typical statements of respondents that reflect these themes are:

- *"You can hardly make large errors since you can easily restart and edit your work."*
- *"Your are really "doing" mathematics, you are actively engaged."*
- *"You manipulate actively objects and your are working with mathematical shapes, without being aware that your are actually involved in mathematics".*

A second set of themes centres on the nature of the way mathematics is being learned. The respondents indicate that the Second Life experience allows them to develop a more insightful understanding, and link this to the possibility to apply concepts/procedures. Additionally they appreciate the multiple representations they are allowed to see and build when developing mathematical concepts, such as shape, distance, functions, relationships, etc. Typical statements are:

- *"You don't look at mathematical objects in a single-minded way."*
- *"you really learn to manipulate objects".*
- *"You can clearly see the results of your scripts; in this way the abstract scripts are related to concrete experiences. You now know what your are doing."*

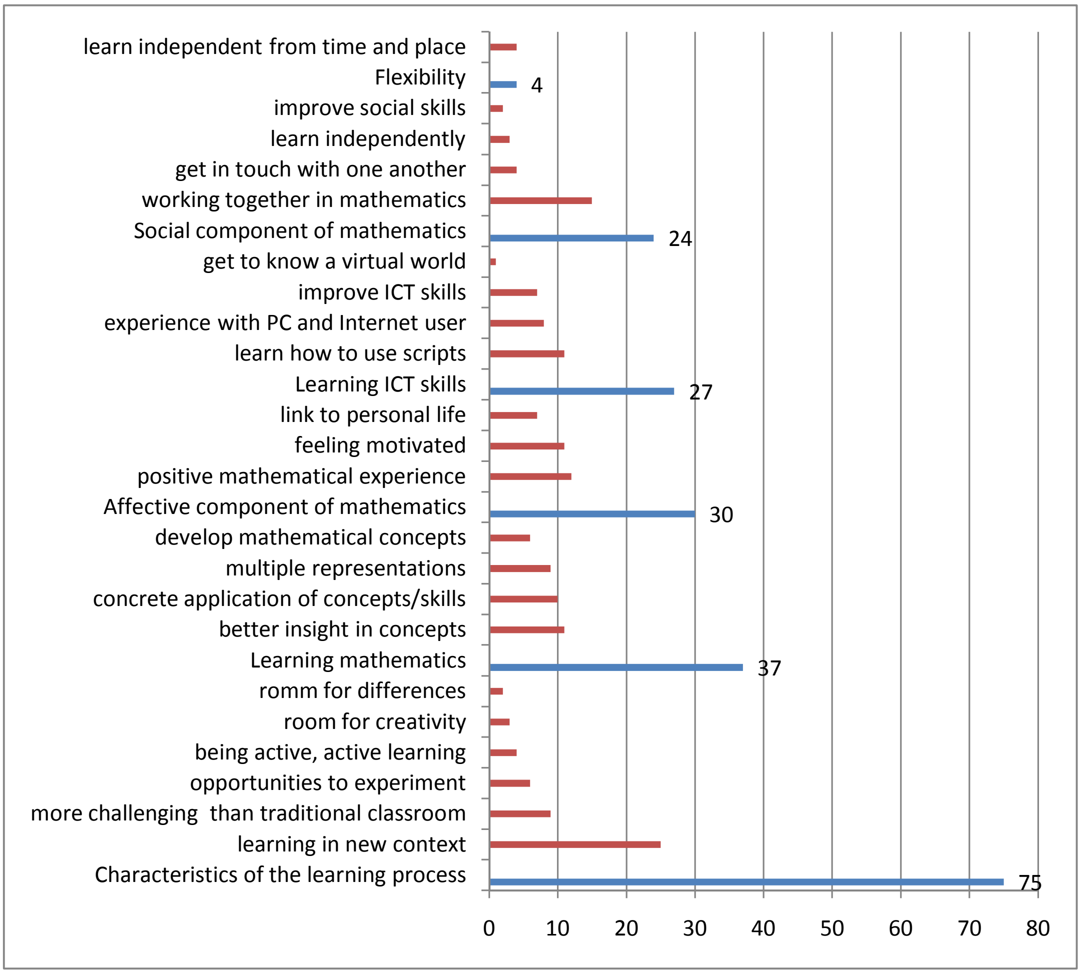
A third set of emerging themes is linked to the affective/emotional component of mathematics. Respondents point at their positive experiences with mathematics in this environment, how they could link it to their personal activities and life, and how they really felt motivated.

- "It is motivating, to involve learners who are not that interested in mathematics."
- "It is a fun task to do; it attracts learners."
- "learners like to work in such a learning environment; it is linked to their computers kills. "

A fourth set reflect the impact on the integrated development of information and communication technology knowledge and skills. A fifth, and interesting cluster of themes centres on the social dimension of mathematics learning they could experience in the Second Life set up. In this context, respondents especially stress the fact that they get the opportunity to work together in the context of learning mathematics:

- "You can get help with someone who is working on the same problem."
- "You get in touch with people you normally would not get in touch with."
- A limited number of themes centred on the flexibility dimension of learning mathematics in this learning environment, since learners can do it independently of a specific place and a specific time.

Table 2: Overview of themes that point at supportive impact of the Second Life experience in view of learning mathematics



The qualitative analysis also revealed a number of themes that raise issues, concerns, preconditions, … in view of the learning of mathematics in this Second Life setting. Table 3 summarizes the results of the content analysis.

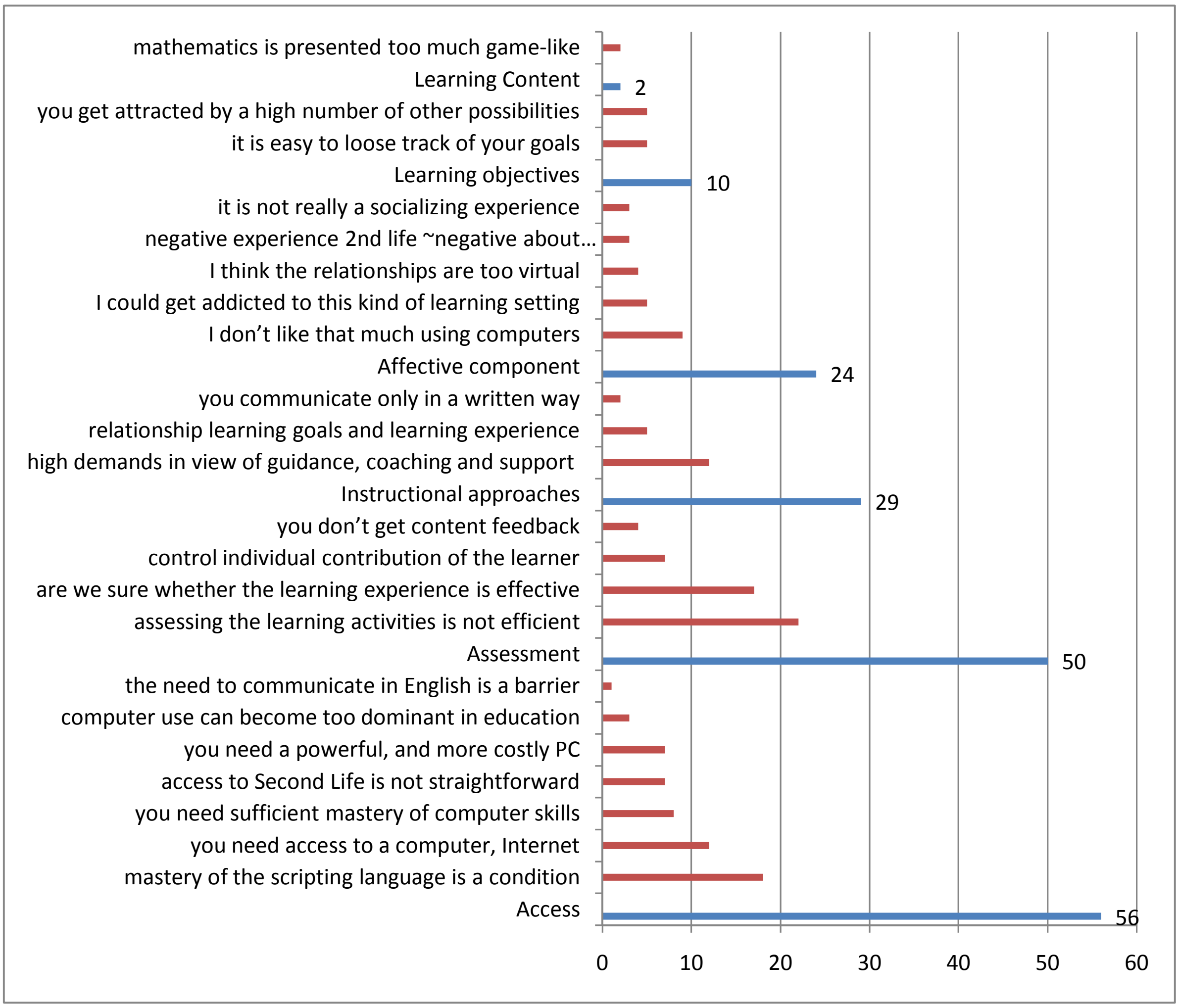
It is clear from the table that student teachers especially raise concerns about technical issues. As will be pointed at in the discussion, the research subjects were – to our surprise – less experienced in using the technology. This clearly explains their concerns about access, skills and level of technology. In the context of the Flemish (Belgium) educational system, they also raise the issue of communicating in English. This language issue interferes with the learning of mathematics; though the communication in the asynchronous discussion groups was carried out in the mother tongue.

Of critical importance in the context of the present study, is the recurrent theme related to assessment. The learning environment is clearly considered as a very open - and less controlled - learning setting where a focused assessment approach is considered to be less feasible. They link to this issue topics about the possibility to get sufficient feedback and their question marks about the available evidence that grounds a potential learning impact on mathematics:

- "It is frustrating since you don't get clear feedback."
- "If this is not followed by a clear reflection, I doubt whether this will result in learning gains."
- "How can you be sure a specific individual learner really developed his/her insight?"

A third set of themes is to be linked to the instructional strategies that are available to support or invoke learning. Some respondents doubt the matching between the nature of the environment and specific mathematical learning objectives

Table 3: Overview of themes that point at critical issues, preconditions, negative side effects of the Second Life experience in view of learning mathematics



A recurrent theme in the student teacher responses was their concerns in relation to a potential negative impact on the affective component of mathematics learning. They refer to a dislike of computers or technology, the “danger” of working too much in a virtual reality, the limitations of the social experiences presented to learners, etc.:

- “This type of computer game environments can make you addicted.”
- “Not everybody is that enthusiastic about working with computers and/or working with script languages”
- “It will makes things more difficult if you don’t understand grounding concepts and procedure.”

Discussion and conclusions

In this study, a single sample of student-teachers was involved in an 8 week mathematics related learning activity, positioned in Second Life. The focus was on the impact on their mathematical attitudes and their perceptions about this learning environment in view of the learning potential of this particular game-like experience.

The results of the quantitative study present basic evidence to point at the potential of the Second Life experience to influence mathematical attitudes in a positive way. Nevertheless, the – though significant - impact is rather small. Additionally, as stated in the introduction, the design of the study does not allow us to conclude that the positive impact on mathematical attitudes is solely to be assigned to the Second Life experience. But the results nevertheless are in line with the empirical findings of other studies about the impact of mathematical games on attitudes towards mathematics (see research overview of Akinsola and Animasahun, 2007; Bragg, 2007; Randel, 1992 and Tobias & Fletcher, 2008). Also studies, focusing in particular on student teacher come to the same conclusion (see e.g., Hazzan, 2002-2003).

The results of the qualitative study clearly reflect themes related to the learning potential of the Second Life experience. Firstly, the results reflect that the Second Life based learning environment respects the broad nature of the mathematical disposition. This is clearly in line with theories and practices that redirected approaches to mathematics and mathematics learning towards a more realistic-based mathematics education. De Corte (1995), e.g., cites in this context the importance of approaching mathematics as a disposition that goes beyond abilities, knowledge and skills. State-of-the-art approaches towards mathematics consider the mathematical disposition to be an integrated complex of (1) basic conceptual knowledge, (2) procedural knowledge, (3) metacognition, (4) emotion, an (5) language components (see De Corte, Greer & Verschaffel, 1996). The results in table 2 clearly reflect this multidimensional nature of the mathematical disposition. Secondly, the results reflect nearly all the critical characteristics of a constructivist learning environments as described by Jonassen (2005) and that are the base to develop powerful learning environments as described by De Corte (1995),

The next series of themes that were found in the replies to the structured interview, reflect a wide variety of concerns, pre-conditions, etc. that – in the opinion of the student teachers – might affect the success or failure of learning mathematics in this particular context. Part of these reflection re-occur in the research literature, and this since the start of up taking technology in education (see e.g. Schacter, 1999). The results have partly to be related to some characteristics of the respondents that are education students enrolled for a Mathematics Education course. This has clearly influenced the nature of their responses. Secondly, the predominance of issues related to technology is not surprising, considering the rather low level of experiences with computers, as discussed earlier in the results section.

Some limitations of the study have to be stressed. These limitations put forward – at the same time – alternative directions for future studies in Second Life. First of all, this was a single sample study, in which the quasi-experimental group, was not compared to a sample in a control condition or an alternative experimental treatment condition. Future studies could be set up in a cross-sectional way to compare the results of these students with other student teachers that are involved in alternative experimental (other computer games, or learning environments). Therefore, the impact on the mathematics attitudes cannot be conclusively assigned to the 2nd Life experience. Other variables - not related to the course, e.g., other courses and/or instructional approaches in the wider educational context - could therefore have influenced the results.

Secondly, this study lasted only eight weeks. This can explain the rather small impact on the mathematics attitudes. More long-lasting experiences should be presented. Thirdly, the results obtained in this study are based on “reported” impact, and perceptions of the potential impact. This implies that the impact on real mathematical conceptions and behaviour has not been studied. Future studies should therefore either focus on a qualitative analysis of the real-time Second Life activities, and this in relation to e.g., stimulated recall interviews during which the Second Life users reiterate their conceptions, decisions, ideas, … when working together in the virtual learning environment.

To conclude, we can state that the present study opened promising directions for more focused follow-up studies. A key issue will be to develop up a more controlled study design in which the Second Life experience is contrasted to alternative experimental treatments and control conditions. In addition, the discussion above also points at the need to focus in the follow research on a qualitative analysis of the actual work and activities in Second Life in view of determining the impact on mathematics learning and mathematical attitudes.

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