Serendipitous learning & serious games: A Pilot Study

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***Abstract* — This pilot study explores the use of serendipitous learning of mathematics in a group of Further Education students. Data was gathered from 28 students within a computer games design unit on a computer science course. The data was gathered using both quantitative and qualitative methods. The findings indicated that even at this early stage that student's view of mathematics had changed in a positive direction and students had learned mathematics during this process. The data analysis showed that further research into serendipitously embedding mathematics with a games design unit is of value and worth pursuing.**

Keywords—serious games; games design; education; serendipitous learning, pilot study, eLearning

I. Introduction

Educational research has taken place in both Schools and Universities for many years. Further Education (FE) Colleges unlike public bodies (such as schools) are privately funded. Each student enrolled on a course brings a set amount of money into the college system; however this money is only given if a student passes a course. Therefore no money is given for enrolled students until they have finished a course and passed it. Students who fail to complete a course or fail a course provide no finance to the college system. Therefore the college management is constantly driven to reduce costs whilst simultaneously attempting to increase standards. Then through a process of internal advertisements and internal interviews the FE system is generally geared towards promoting its own staff towards management. FE management does not perceive 'research' as an effective use of the limited resources that the collage has. It can be concluded that FE institutions such as colleges the organization are not structured for research, that is to say research is not promoted or supported as such within these types of organizations. Scaife discusses this reactive FE culture in his paper "The Culture of the Now: barriers to research in FE", Scaife says that there is little organisational 'space' or time available in FE for on-going research despite the obvious need [2]. The landscape for an FE Lecturer is to increase standards in a culture where little time is given towards research into new teaching methodologies. It is against this backdrop and this urgent need that the research presented in this paper took place.

A. *Passion for playing games*

Matt Renwick in his blog "Passion-Based Learning, Day 1: Probing Minecraft's Appeal" [3] discusses the appeal the popular computer game Minecraft has for the average teenager. Students are in class doing assignments, however they are often engaged (in a hidden way) in playing computer games. From this observation a conclusion came that if this passion for gaming was redirected to learning new skills in a classroom the results could potentially be huge. This observation is backed up a blog article written by Matt Renwick on Feb 5, 2014 who states that students find Minecraft "all-consuming"[3]. Minecraft is just one example of the many games that have been witnessed during class time. In addition, consider that these students are blocked internally by the IT department and also lecturers are actively stopping them. In Catherine Goode's article 'Playing the Game" [10] she discusses how a passion for playing computer games led her on to a career in computer games design. Many students feel this way. After all in computer games design, students develop and test all kinds of computer games. Many students who enrol on BTEC[1] course do not have a GCSE grade C (or above) in Maths. This is backed up by Professor Wolf in her review of FE education and found that less than 50% [1] of students obtain a GCSE grade C (or above). English and Maths GCSE (at grades A*-C) are fundamental to young people's employment and education prospects. Yet less than 50% of students have both at the end of Key Stage 4 (age 15/16); and at age 18 the figure is still below 50%. Only 4% of the students achieve this key credential during their 16-18 education (i.e. whilst within FE) [1]. This paper presents a pilot study that serendipitously embeds mathematics within a computer games design unit. Using the passion a typical student has for games and developing games to motivate

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1 Business and Technology Education Council [BTEC] is an awarding body that accredits vocational qualifications in the UK.

them to use and develop mathematic skills. The eventual benefits of this and further studies aim to develop this approach into a novel pedagogy employing serendipitous learning.

II. Related Research

A. Maths grades

David C. Geary argues [4] that "innumeracy is more common" than illiteracy and many adults are "functionally innumerate when they leave school" [4]. This links with Professor Wolfs report [1] that states that in the UK "50% of students obtain a GCSE grade C (or above)" [1]. This experiment is against a landscape of poor mathematical skills in the student body as a whole. The question remains however why do some 50% students fail to get a GCSE Maths grade C? Is it because the educational system in schools is failing? Wright [5] argues it is more due to the constraints schools have when developing the maths curricula they have to adhere to political education policies. Another major reason why students have poorer maths skills (and hence poorer GCSE mathematics grades) is poverty. Sylva K et al. [6] finds in their report that "challenges facing students in disadvantaged communities and differences in the quality of their school experiences". So in essence a poor environment at school and home can shape what GCSE grades a student can achieve. Sylva et al. [6] argues that the parent's qualifications can affect the student's grades, the poorer the parent grades the poorer the child's grades can be. Other factors can also affect a student's grade profile, such as a student whose parents are going through a divorce; a student may have emotional concerns or disruption at home. It is the belief of the author that these factors and more can affect the learning and development of students. These reasons and many more can all impact on a student's maths skills development.

B. Student's fear of maths

According to Professor Wolfs report [1] 50% of students do not have maths GCSE grade C (or above). So 50% of students have failed to get a grade C. Not getting a grade C is seen as 'failure' by the students (and society) and many students associate the process of doing an exam in a negative way and will subsequently avoid it. This is backed up by Putwaina and Symesb [7]: "consequences of failure were positively associated with performance-avoidance". They further argue that students actively avoid doing an exam in future. The advantage of a BTEC unit is there is no exam, it is an assignment. So no negative relation is associated with this process. Also in Grehan et al. [8] they find that with mathematics "Students were also reluctant to ask for help and feared embarrassment". Assignments and 'a student centered approach' to students developing their own maths puzzles resolved both of these problems.

C. Serendipitous mathematics

The Oxford dictionary defines 'serendipitous' as "Occurring or discovered by chance in a happy or beneficial way". The experiment presented here aims to get the students to use mathematics in a BTEC games design unit. It should be pointed out that for games design a student is naturally using mathematics. There is mathematics in doing 'coding', creating and using variables in code requires a certain level of mathematics. There is mathematics in room and sprite design. The sprites need to be created to 'fit' within a predesigned grid in a room for a game. This requires calculations of height and width of different sprites so they all fit together in a room. The question that comes to the fore therefore is why embedding maths at all if they are doing maths anyway?

The answer to this question is simple: students are allowed to search for and use code from other sources and modify it, and if this is what a student does then no maths is learned. Students can also search for sprites that fit in the room and once again will be doing little if no maths. There is no way to measure this process that the students are doing in games design. The serendipitous process in this experiment is a hidden process. The students focus is on games design *not* on mathematics. As discussed earlier the students are not focusing on any potential problems they have with maths but with a games design that has a maths element built into it.

D. Games design

Gamification was first discussed in 2002 by Nick Pelling. It is now a global subject and is not just about education, it is used in marketing, politics and even healthcare. Games design itself has been found to be a useful teaching pedagogy. As games design is inherently a creative process the student engages with. Students can in games design creatively solve problems and produce games. Yu-Sien Lin [9] argues that "Humanistic scholars also see creativity as the natural urge of individuals to develop, extend, express and activate their capacities".

III. Experimental Design Process

A. The participants and resources

A total of 26 (all of whom were male) students were engaged in the experiment. The age of students was 18 and 19 and all were in the second year of a BTEC National Diploma in IT. The students are further split into two groups of 13, Group A and Group B. All the students use laptops with 'Gamemaker' software installed and have wireless access to the college network and internet.

B. Methodology used

How do you embed STEM (Science, Technology, Engineering and Maths) subjects in computer games design units?

From the research described above, it can be seen that some students have significant barriers to learning mathematics. To overcome this barrier an approach of 'hiding' maths learning from the students has been used. Also using the 'excitement' students have when developing and playing games to help motivate them when they are unknowingly learning maths skills.

The students are given 2 assignments as part of a BTEC National Qualification course. The unit is computer games design and both assignments involve the creation of two computer games. The students will be using the same software and same techniques to create both games. The development process is identical for both. However in game 1, there is an added element to the game, maths, this element is missing in the game 2. It is the effect of this element that is been measured not the process of game development. In this experiment, one assignment is set as a *control* (the platform game) and the other assignment is the *experiment* (a maze game), however with a maths based twist. This is where the STEM element comes in. The maze consists of several levels of increasing difficulty in which several maths based components have been placed. This is a maths based puzzle to solve. The student will have to research maths based problems and puzzles at an appropriate level of understanding to complete this assignment. The target level should be GCSE Grade C Mathematics. The students are encouraged to access mathematics resources that are available within the college. This is particularly relevant to students who are doing additional Mathematics based units such as GCSE Mathematics' qualification's or Functional skills Mathematics units. It should be noted that for this unit the students would be required to complete two assignments to in order to complete the course. In addition in both games the final product will be tested, and the students would then be encouraged to reflect on the process and how they had overcome any problems, employing both problem based learning and reflective based learning pedagogies.

Fig.1 shows the chart of game making process for both the *control* and *experiment*

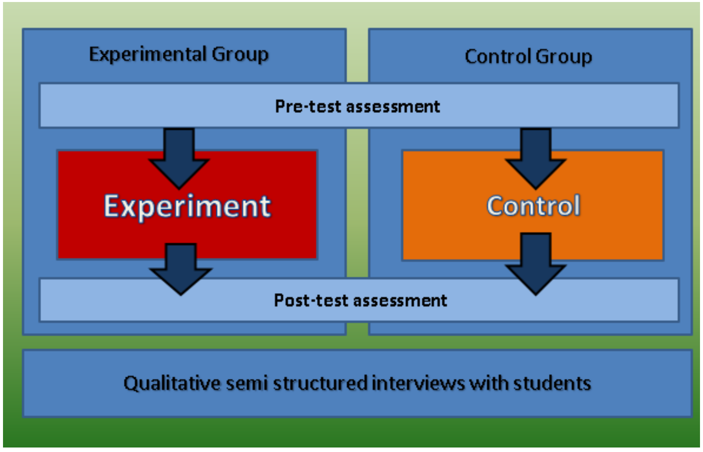

Fig 1. Experimental process

As can be seen in Fig 1 neither group is penalized as both do the control and experiment with each group.

What were the goals of Experiment?

The goal of this experiment to evaluate whether the mathematical ability of students is increased (or not) when exposed to serendipitous learning.

How was the analysis performed?

A mixed method was used this included a quantative analysis of the results using the average differences between the two groups for both the pre- and post-test. Also a qualitative approach was used where students are interviewed about their experiences doing both of the assignments.

What was expected?

It is expected that in the experimental group that on average post-test scores should be higher than the pre-test scores. In the control group there should be no increase. This would then show that maths skills have been developed in the experimental group. In addition to this quantative analysis, a qualitative approach is to be taken as well. A variety of different methodologies were considered for this approach, such as Ethnography, Grounded Theory and Phenomenographic. Ultimately a phenomenographic approach was used because of its approach to understanding how the world appears to others. In a sense stepping in someone's shoes and seeing the world as they do. Understanding the thoughts and feelings of a student who is doing these assignments will provide valuable data for further research.

Using a phenomenographic approach, the pilot study sought to:

- Understand the variation in experiences students have when doing mathematics.
- Explore the process students used when developing the maths puzzles in the experiment games design.
- To examine the impact of serendipitous learning of mathematics has on the students.

IV. The Results

The Maths test (both pre- and post-) was an online assessment which grades the students at a National Qualifications Framework mathematics level two, which is roughly GCSE A-C grade. The students can get a maximum of 40 points and 23 points is approximately GCSE grade C Mathematics.

Experimental Group			Control Group		
Pre	Post		Pre	Post	
19	14	Student 1	24	27	Student 13
12	16	Student 2	26	29	Student 14
32	18	Student 3	33	32	Student 15
17	25	Student 4	27	27	Student 16
23	21	Student 5	34	30	Student 17
22	15	Student 6	20	28	Student 18
22	22	Student 7	30	33	Student 19
23	20	Student 8	25	27	Student 20
19	23	Student 9	28	26	Student 21
27	26	Student 10	31	34	Student 22
18	26	Student 11	18	37	Student 23
12	26	Student 12	23	25	Student 24

Fig 2. Quantative data collected from experiment

A. *Quantative data analysis*

The data in fig 2 shows results of the initial maths assessment (pre-test) and the second maths assessment (post-test).This data was then analysed via a t-test. However before this there were some additional factors to consider. Interviews were conducted on both the control and the experimental groups. During this interview and as part of a general question that was asked to the class, certain issues were discovered. The data from Student 3 showed that they had gone from a score of 32 in the pre-test to a score of 18 in the post-test. When this student was questioned it was discovered that on the May attempt they "didn't try very hard". Given this fact this datum was removed. Student 12 shows a rise of 14 points from a score of 12 in the pre-test to a score of 26 in the post-test. When questioned it was discovered that this student is undergoing substantial Maths revision because they are doing Maths re-sits. Once again their datum is removed from the subsequent analysis.

Performing a t-test on the data between the pre- and post-test results, resulted in $p = 0.25$. As $p > 0.05$ there is no significant differences between the gain in score between the control and the experiment for these assignments. There was also a large standard deviation of: 5.2 (control) and 5.9 (experiment)

However of interest is the large difference between mean gain of the 2 groups (mean gain: is the difference between the average post-test and pre-test score).

The control group mean gain is 0.6, and the serendipitous learning group is 3, remember that this is on a 40 point scale and represents a 7.5% increase for the experimental group (compare this to the 4% average increase identified in [1]).

Another interesting aspect is this is that (as discussed previously) many students have 'a fear of failure' with regards to doing maths exams. The students have their maths ability tested using a maths test, which is very similar to a maths exam. So for many of the students the very process of checking mathematical abilities is putting them in a psychologically 'uncomfortable' place. In fact a student commented during one of the maths assessments "I always fail at maths" so this could explain the large discrepancy in the standard deviation scores.

This leads us to the qualitative interviews. 7 students were selected for the interviews, 4 from the control group and 3 from the experimental group. Students 2, 7, 11 & 12 were selected from the control group and students 13, 16 and 21 were selected from the experimental group. These students were selected because of the spread of the results they gained. Student 21 had a 2 point drop and student 13 had a 3 point increase and student 16 showed no change in their results.

The students were asked 10 questions. The first 5 questions about the assignments in particular and the following 5 questions were about how maths was used in the assignments. This approach was used in order not to make mathematics the focus of the interview at the outset. Maths was embedded within a games design course so these interviews should reflect this process. These 10 questions are the initial questions, further question would be asked depending on the answers the students gave (hence a semi-structured interview approach). The average interview time was 6 minutes 46 seconds. The longest was 11 minutes 15 seconds and the shortest 5 minutes 43 seconds.

The questions asked were:

1. What did you think of the assignments (both of them)?
2. How would you rate the assignment (easy/hard/difficult)?
3. Give me an example of something you have learned during these two assignments?
4. In the platform game name one thing you learned during this assignment?
5. In the maze game name one thing you learned during this assignment?
6. Did you learn mathematics in these assignments?
7. Do you feel you gained any mathematic skills when developing the puzzles for the maze game?
8. How do you rate your maths?
9. How hard did you find the maths?
10. So has your opinion of maths changed during the course of these assignments?

All students were told all interviews would be anonymous and no mention of their names would be used in any findings hence the use of student1 to student24. The students as a whole responded well to the interviews and engaged well with the process. Some only answered 'yes' or 'no' to the questions, in these cases further questions were asked to probe deeper. Student 13 is a good example, as they were part of the experiment group and their feedback on their experiences provided some good feedback for analysis.

Q: "Did you learn mathematics in these assignments?"

A: "To a degree yes."

Q: "Which assignments and why?"

A: "Err in the maze game because I had to think of questions that I could implement and had to work them out so that they had answers that correspond with .. that wasn't too hard also weren't too easy" [Student 13]

Here we can see the student engaging with the maths puzzle element of the assignment and considering how hard or easy to make the puzzles. Also and more importantly they demonstrate that they did learn mathematics in order to implement it in the game. This shows them engaging subconsciously with Mathematics in order to create the game. Here is student 12:

Q: "Did you learn mathematics in these assignments?"

A: "Yes I did obviously because erm because of the maze game you've got to do a lot of maths."[Student 12]

So this student also states that they learned mathematics as part of the experiment. More in-depth analysis of the interview data was processed using a lexical analysis software tool. The first 5 answers to the first 5 questions were looked at first. This was before the students were asked any direct maths related questions. Interestingly enough the word 'maths' came up 8 times (7 students with 5 answers each so a 22% hit rate on maths) in their responses. These students mentioned maths with no prompting from the interviewer on the subject. This is an impressive percentage for the initial set of questions and shows that a lot of the students at least at some level were thinking about mathematics. Some described the maze game as the 'maths games'. They didn't do this consciously and they swapped out maths and maze from time to time during these conversations. This seems to indicate that students are subconsciously reflecting on the subject and using maths in place of maze because they are aware of the maths element. When interviewing the students their answers are showing an awareness of maths and developing maths skills. An example of this is student 21 when even though when asked directly about it they said.

"No because everything I put in the game I already knew."

Then later the interviewer asked

"Did you learn mathematics in these assignments?

"No well erm it depends which way you look at it because maths no but the way in which you apply like well I learned how code requires maths that's the part that I learned. I have not learned any maths from it but learned like a mathematical sort of how can I put it the mathematical background behind coding how you need to make these sort of calculations in order to like the health bar erm in order to make the health bar work you need to have something an equation of something like hit points in variables ... You can see were the maths is and how its applied."

So this shows that they are applying new mathematics methods and techniques to the game and are developing maths skills in an indirect way, which is the point of this experiment.

V. Conclusion

Based on this small scale study, the conclusions are positive and encouraging in terms of achieving improvement in how mathematics are being taught and learned, especially when considering the 7.5% increase in a standardised maths test (for the serendipitous learning group) when compared to the average 4% increase normally achieved in FE [1]. However a larger scale study with more complex quantitative experiment designs and applying phenomenography on data collection, analysis design and study validation is necessary for validating these preliminary results and delineating a richer understanding of how students experience the serendipitous learning of mathematics through designing and using a serious game

In summary:

- The mean differences from both set of students, one control and one experimental is interesting. The control's mean gain is 0.6 and the experimental group's mean gain is 3. This seems to indicate that the experimental group has leaned more in maths during the same period as the control group.
- As shown, students are giving contradictory answers about maths. They are saying '*no I have not learned maths'* then later they are admitting that they are using and developing mathematic skills. This result shows they are developing mathematics in a serendipitous way.

This paradigm needs to be researched further and in further studies will need to be addressed. Much further work will need to be done in order to fully research this area. A similar study is to be conducted in the next academic year. These studies will form part of a longer longitudinal study researching embedding mathematics and other STEM based subjects in computer games and computer gamers design units, within a FE context.

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