Serious Games & Conceptual Change

M.C. Koops
M.H.H. Hoevenaar

University of Applied Sciences, Utrecht
Faculty of Education, Department of Physics

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Abstract

Conceptual ideas are persistent against traditional education, but the possible role of serious games with respect to conceptual change is still unclear. This research studies the contribution of serious games to the process of conceptual change.

The serious game lemniscate model (SGLM) offers visualisation and insight regarding learning processes in combination with serious games.

The serious game *Space Challenge* has been specifically developped for this research to facilitate conceptual change. The Force Concept Inventory (FCI) allows us to measure conceptual understanding.

1 Introduction

It is usually possible, up to a certain point, to describe, explain and predict basic everyday phenomena (within that very specific context) using an alternative conceptual framework. However, when the context of those phenomena changes, or when a more accurate description, explanation or prediction is required, this alternative conceptual framework becomes less and less useful (Krause, 2008), increasing the necessity for conceptual change.

Unfortunately, pre-existing alternative conceptual ideas prove to be very persistent (Krause, 2008; Stewart, Griffin, & Stewart, 2007; Thornton & Sokoloff, 1998; Wattanakasiwich, 2008; White, 1984), which is why students increasingly perceive physics as something difficult (Muller & Sharma, 2007).

Pre-existing conceptual ideas are so persistent because they are based upon acquisition of many (repeating) everyday experiences, which have accumulated over the years and are strongly anchored inside a powerful network of other conceptual ideas within the long-term memory (White, 1984). The creation of cognitive conflicts is required for conceptual change (Kearny & Pivec, 2007; Kolb, 1984; White, 1984). Difficulties in creating these cognitive conflicts also helps explain this persistence. Furthermore, students usually do not have a complete formal conceptual framework at their disposal to replace the existing one. Even if they did, it would immediately suffer from proactive interference (competition from the long-term memory) (Eysenck & Keane, 2005; Muller & Sharma, 2007). Also, if proactive interference would not exist, the new conceptual framework would be incongruent with the remaining conceptual models (White, 1984).

Serious gaming potentially pursues lots of educational goals, such as knowledge transfer, attitude change, conceptual acquisition, procedural knowledge or factual knowledge. Often a single serious game contributes to a multitude of those goals.

Through acquiring virtual experiences, which will compete with their real-life equivalents, the student allows to develop an accute sense (feeling) of the concepts invloved (which in our case would be the concept of motion in a frictionless environment), which would otherwise be nearly impossible to realise. This approach of serious gaming focusses on the added value of using a simulated environment, in which realistic experiments can be conducted safely by any student.

Not just the motivational aspects related to most games, but particularly the possibility to acquire concrete simulated experiences in a safe and realistic manner is the main reason why serious games are currently being developped and used by medical specialists, the police, fire departments, the army and industrial companies.

Vygotsky (1986) differentiates between *a*) formal concepts (explicit knowledge) and *b*) spontaneous concepts (implicit knowledge). Formal concepts are cultivated through traditional education and are characterised as being context-independent, abstract, global, organised and highly systamatic. Spontaneous concepts find their origin in concrete everyday experiences and are characterised as being context-dependent, specific, disorganized and non-systematic.

Forcing formal concepts on to students, without a solid base of realistic experiences to back them up, will not result in a deep and thorough understanding of this formal knowledge (Egenfeldt-Nielsen, 2005).

Kolb (1984) differentiates between *a*) experiential cognition and *b*) reflective cognition. Experiential cognition is related to direct and concrete situations and the creation of implicit knowledge (spontaneous concepts), whereas reflective cognition is related to careful and deliberate thinkprocesses (which require time) and the creation of explicit knowledge (formal concepts), which can be used in other contexts (Pivec & Moretti, 2008; Rieber & Noah, 2008).

The process of creating functional knowledge requires both experiential and reflective cognition (Kolb, 1984), which is visualised with the SGLM, (figure 1).

In the SGLM, the learning cycle equals Kolb's (1984) learning cycle, where the student uses concrete experience (CE), reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE). There are no timelimits to this cycle, which could last for days to complete. Although experiential cognition plays a role in the learning cycle, the creation of formal concepts is mostly due to reflective cognition.

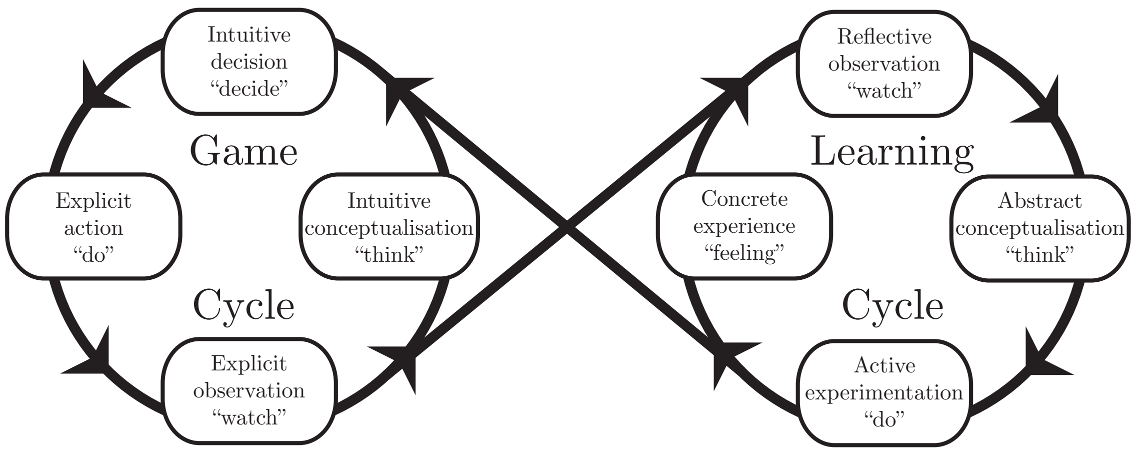

Figure 1: *Serious Game Lemniscate Model (SGLM)*

The game cycle is a representation of a similar cycle, reflecting the intuitive state of the gamer. The game cycle constitutes the experiential cognition, together with the creation of the related spontaneous concepts. In the game cycle, the game should have a clear goal, inviting intuitive experimentation (IE). An intuitive interface facilitates explicit action (EA), which triggers direct feedback, allowing explicit observation (EO) to occur, which leads to the creation of intuitive concepts (IC) to relate the feedback to the action.

It is at the junction between the two cycles that we can try to control whether the student stays in the flowstate or drops out of the flowstate, into the learning cycle.

This research focusses on the simulated experiences within a very simple serious game and if (or how) it contributes to the conceptual knowledge regarding motion within a frictionless environment.

Simultaneously we try to determine the best method to trigger reflection (relating the acquired experience to the conceptual framework).

The long-term flowstate implementation is a method in which the student is kept in the flowstate for a long period of time (figure 2), after which he switches from the game cycle to the learning cycle.

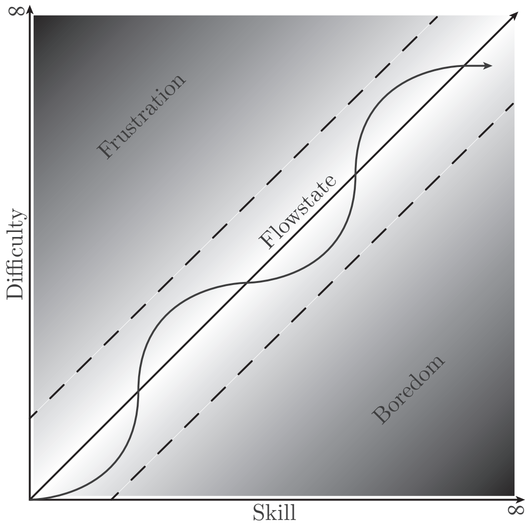

Figure 2: *Long-term Flowstate*

The short-term flowstate implementation is a method in which the student is frequently kicked out of the flowstate (figure 3), promoting multiple switches between the game cycle and the learning cycle and thus giving more opportunities to transfer the acquired spontaneous concepts to formal concepts.

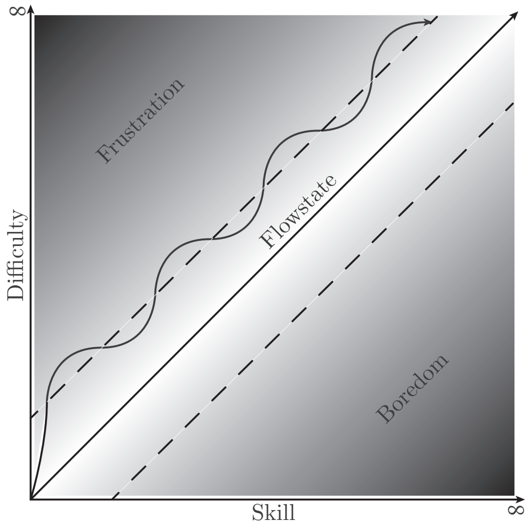

Figure 3: *Short-term Flowstate*

These two different approaches, regarding the method of reflection, are facilitated by the development of alternate versions of the serious game (*'Space Challenge'*), which we specifically developped for this research.

Space Challenge is inspired by White (1984), *'Space Shuttle Commander'* (Rieber, 1998) and *'Cyclons'* (Rabbit Software, 1984). *Space Challenge* mainly targets highschool students who are not yet formally introduced to Newtonian mechanics.

In the LT-version (Loose Timing) of the game, the level of difficulty stays similar with respect to the cumulative gameskills of the participating students, as to maintain a long-term flowstate.

In the HT-version (Hard Timing), we changed the level of difficulty in such a way that students are literally kicked out of the flowstate following a sudden increase in difficulty, allowing the process of reflection to occur.

2 Method

In this research, we used the Force Concept Inventory (FCI) to measure conceptual knowledge. The FCI is a reliable and valid instrument to measure conceptual knowledge regarding Newtonian mechanics (Hestenes, Wells, & Swackhamer, 1992; Krause, 2008; Muller, Bewes, Sharma, & Reimann, 2008).

To simultaneously measure the contribution of *space challenge* to conceptual change and determine which implementation contributes the most, we used 3 similar groups of students.

All 3 groups started and ended this period with taking the FCI, which allowed us to measure the conceptual change of all 3 groups.

Group 1 (N=14) and group 2 (N=10), each played different versions of *Space Challenge*, immediately after taking the FCI. Group 3 (N=17) received traditional education. Group 1 was introduced to the LT-version of *Space Challenge* which facilitates the long-term flowstate method, whereas group 2 was introduced to the HT-version of *Space Challenge* which facilitates the short-term flowstate method.

3 Results

The average FCI-results for each group are shown in figure 4. Further statistical analysis is required to determine whether the differences between the groups are significant or not.

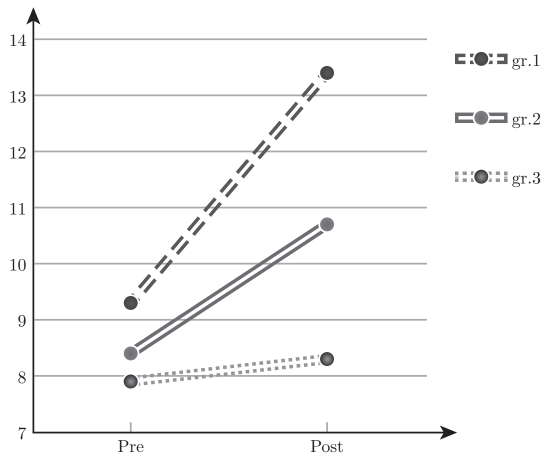

Figure 4: *Average FCI scores*

4 Analysis

A widely accepted method to compare the means of more than two groups is through the application of a unifactorial analysis of variances (ANOVA) (Hays, 1994; Ferguson & Takane, 2005).

For the ANOVA to be reliable, the data has to satisfy a Gaussian distribution. Hays (1994) suggests the use of the Kolmogorov-Smirnov test (table 1), which shows us that group 3 does not represent a Gaussian distribution. Because an ANOVA is very robust with respect to the normality of the data (Hays, 1994; Ferguson & Takane, 2005), we assume that this does not compromise the reliability of the ANOVA.

Group	N	Statistic	df	p
1	14	0,205	14	0,116
2	10	0,248	10	0,082
3	17	0,349	17	<0,001

Table 1: *Kolmogorov-Smirnov test*

Another caveat is that the variances within the groups are assumed equal with an ANOVA. This can be tested with the Levene test (Glaser, 1983), which shows a significant difference in the variances of our groups (table 2). This necessitates additional tests which do not assume equal variances. The Welch and Brown-Forsythe tests satisfy this additional requirement (Brown & Forsythe, 1974; Welch, 1951).

Statistic	df1	df2	p
7,068	2	38	0,00246

Table 2: *Levene test*

The applied ANOVA (table 3), accompanied by the additional tests (table 4), shows that there is a significant difference between the groups. Because an ANOVA is unable to determine which groups are different, further post-hoc analysis is required. The Games-Howell test (table 5) is suitable for this purpose, since it does not assume equal variances (Games & Howell, 1976). This shows us that there is a significant difference between group 1 and 3.

	Sum of Squares	df	Mean Square	F	p
Between Groups	103,244	2	51,622	11,329	0,000138
Within Groups	173,146	38	4,556		
Total	276,390	40			

Table 3: *ANOVA*

	Statistic	df1	df2	p
W	12,084	2	17,2	0,001
B-F	9,967	2	24,6	0,001

Table 4: *Welch & Brown-Forsythe tests*

(I)	(J)	(I) − (J)	Std. Err.	p
1	2	1,771	1,075	0,24899
	3	3,660(*)	0,779	0,00061
2	1	−1,771	1,075	0,24899
	3	1,888	0,835	0,10359
3	1	−3,660(*)	0,779	0,00061
	2	−1,888	0,835	0,10359

Table 5: *Games-Howell test*

5 Conclusion

The short-term flowstate implementation of *Space Challenge* has made a significant positive contribution in the process of conceptual change regarding Newtonian mechanics.

6 Discussion

This research is not a randomized double-blind experiment and contains some imperfections, such as different group sizes. We used 3 similar classes in highschool and left them intact for temporal and organisational purposes. Group 3 had a different teacher than the other 2 groups. During this research, we took over the physics classes of all groups.

Despite these imperfections, the result of this research is nevertheless a strong indication of the potential of serious games with respect to the process of conceptual change.

There were some unexpected problems during the introduction of the HT-version of *Space Challenge* in group 2 (concerning the short-term flowstate implementation). This method should encourage students to be kicked out of the flowstate, which initially seemed to work really well. What we did not anticipate was that many students dropped out of the flowstate at different times, sometimes for different reasons. Without the proper educational interventions, which would allow the students to individually and independently go through the learning cycle and back again, it became somewhat chaotic. We assume that this impeded their conceptual change to a certain extent.

7 Recommendations

We recommend further research with respect to the short-term flowstate implementation.

Theoretically this method should have more potential than the long-term flowstate implementation, because of the extra opportunities for transfer from spontaneous conceptual knowledge to formal conceptual knowledge through reflection and the use of individual and independent educational interventions.

Practically this implies that educational interventions should be developped, which allows students to be assisted and directed into the learning cycle whenever they exit the game cycle (flowstate). This safetynet is important to avoid a chaotic environment and to guide the student to a smooth and independent return back to the flowstate.

Examples of educational interventions could be *a*) F.A.Q.'s, *b*) tutorials, *c*) walkthroughs, *d*) mindmaps, *e*) reference books, etc. as long as they are specifically designed to be individually and independently used by the student.

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