The Playground Game: Inquiry-based Learning About Research Methods and Statistics

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Abstract: The Playground Game is a web-based game that was developed for teaching research methods and statistics to nursing and social sciences students in higher education and vocational training. The complexity and abstract nature of research methods and statistics poses many challenges for students. The Playground Game aims to address this issue and bridge the gap between theory and practice by providing students with a playful practical problem case that they have to analyse and evaluate: the player's task is to make substantiated judgements about a study that was carried out to decide upon the most suitable location for laying out a children's playground in a fictitious town. This paper reports about the evaluation of the Playground Game among 103 students of the bachelor psychology programme from Leuven University. A pre-questionnaire preceding the game was used to collect information about the students´ individual characteristics and included a self-assessment. A post-questionnaire collected the students´ appreciations and comments, and included the same self-assessment as well as five additional test questions. This set-up allowed us to not only collect the players' judgements and appreciations about the game, but also to assess achieved learning gains. All student activities were carried out online. As an additional step we have set up a quasi-experiment for exploring to what extent score mechanisms and audio cueing could be used for influencing (reducing) the players' trial-and-error behaviours. The students were randomly distributed over 4 groups each of which was linked to a different version of the game. We implemented two different game score mechanisms and either used short audio cues indicating a correct or incorrect decision, or omitted these. Technically the Playground Game was implemented on the EMERGO platform, which is an open source educational gaming platform developed by the Open University of the Netherlands (www.emergo.cc). The game (so far only a Dutch language version is available) is an outcome of the CHERMUG project (Continuing and Higher Education in Research Methods Using Games), which was sponsored by the Lifelong Learning Programme of the European Commission.

Keywords: Serious gaming, statistics, methods, evaluation, audio cueing, incentives

1. Introduction

This paper studies learning gains and student behaviours in the Playground Game, which is a web-based game that was developed for teaching research methods and statistics to nursing and social sciences students in higher education and vocational training. Establishing the learning gains obtained with games is relevant because a critical examination of the effectiveness of games in education is often omitted (Connolly et al. 2012; Baalsrud-Hauge et al. 2014). Generally, the pedagogical benefits of serious games are assumed to be in learning by doing as contrasted with learning from reading others' instructions or descriptions, or listening to others' instructions or lectures (Reese 2011; Schank, Berman, & Macpherson 1999). Unfortunately, just doing things and having the associated experiences are not a sufficient condition for learning. Research into computer-assisted instruction and simulations has shown to favour trial-and-error learning strategies that involves a lot of doing, but readily lack any thoughtful analysis of experiences (Vargas 1986). Likewise, games foster the tendency to act before thinking. Especially, game interactions that put little cognitive load on the users, such as interaction by direct manipulation with graphical objects, tend to induce a more implicit, trial-and-error learning mode (Guttormsen Schär et al. 2000). The main purpose of this paper is the evaluation of the Playground game. In addition we have carried out an exploratory study about identifying and influencing trial-and error behaviours in the game. We have specified trial-and-error indicators that are based on the players´ logging data, e.g. based on speed of user actions and number of retrials in finding the correct answer to posed questions. In order to investigate to what extent trail-and-error behaviours could be influenced by different game score mechanisms we have arranged four slightly different versions of the Playground Game and made a comparison between those. The scoring mechanisms in the game basically differ in the ways the students' mistakes are signalled and accounted for. Below, we will first describe the context of the Playground Game and outline its design. Second, we will explain the set-up of the study and the instruments that we've used. Thereafter we will present and discuss the results.

2. The Playground game: context and design

2.1 The teaching problem

Professional work in a wide range of sectors, e.g. in health, business and education, is increasingly informed by social sciences studies. Consequently, understanding research methods and statistics is becoming a core requirement in many professions. Students in many social sciences disciplines including psychology, medicine, nursing, pedagogy are supposed to acquire basic methodological and statistical competences in order to either design scientific studies themselves or to critically analyse and assess the validity of research outcomes. However, research methods and statistics pose significant challenges for many students, because these require an understanding of various interrelated aspects of complex material involving abstract concepts and mathematical models. Students need to learn how to define and operationalise variables, how to select an appropriate design to examine links between variables, how to decide on a suitable method of data collection, how to select the data processing methods and how to make inferences from the outcomes. Many students experience problems in coordinating relevant information from diverse sources into a coherent representation of the problem. Various studies report anxiety among students and negative attitudes toward statistics (Beurze et al. 2013; Griffiths et al. 2012). One of the big problems in methods and statistic teaching is the gap between the formal methods and procedures, which all seem to work fine under well-defined constraints, and practical problem cases, which generally display a larger number of variables, a higher degree of complexity and unclear boundaries. Although games for learning about research methods and statistics are widely available, they generally fail to include the complex context of doing research. Most of these games take up an instrumental view, while they present small, quiz-like exercises about basic statistical concepts, such as mean, standard deviation, and correlation. Very few educational simulations about doing research include the context of operation, but thereby tend to be highly specialised, e.g. addressing Master of Science level students (Westera et al., 2008). For wider audiences, various games are available that allow players to participate in and contribute to scientific research via a crowsourcing model, for example the EteRNA project (http://eterna.cmu.edu/web/), which involves players for reconstructing RNA molecules, Foldit (http://fold.it), which requires players to link, bend and fold amino acids, and EyeWire (http://eyewire.org/), which lets players construct the 3D wiring of nervous cells in the retina. Although participation in such games may be informative, the learning about research methods is not their main goal.

2.2 The game design

For bridging the gap between theory and practice and contextualising the topic of research methods and statistics we have developed a serious game, the Playground Game, which offers a playful practical problem case. Following an inquiry-based scenario players have to assess the quality of a research approach and the validity of its outcomes. The game was developed as part of the CHERMUG project (Continuing and Higher Education in Research Methods Using Games), which was sponsored by the Lifelong Learning Programme of the European Commission. A demo version of the Playground Game (in Dutch) is available at http://goo.gl/mwH9YL. In the Playground Game the player's task is to decide upon the most suitable location for laying out a children's playground in a fictitious town, while taking into account the playground's purpose of reducing the problem of child obesity. This is not a straightforward decision, because the population of children at risk to obesity is not uniformly distributed over the different town districts. The starting point of the game is a research report written by a "consultant". This report, however, contains deliberate flaws, some of which are manifest and some of which are obscured or subtle. The player's task is to judge the correctness of the approach and the validity of the outcomes by interrogating the consultant who is the author of the report and a contra-expert who criticises the report - both represented in interactive videos (cf. Figure 1). Also, the game offers background instructional materials and a separate set of mini-games dealing with specific aspects of the research cycle, e.g. formulating hypotheses, defining relevant variables, selecting appropriate methods for data analysis, identifying ethical issues and interpreting the outcomes. Upon entering the Playground Game, a video tutor explains the problem, the task, the role and the expected outcome. After this introduction, the player gets access to the consultant's report and may choose to watch a short presentation about the report by the consultant. The inquiry part of the game is structured along eight problem issues surfacing in the consultant's report, which the players can address in arbitrary order.

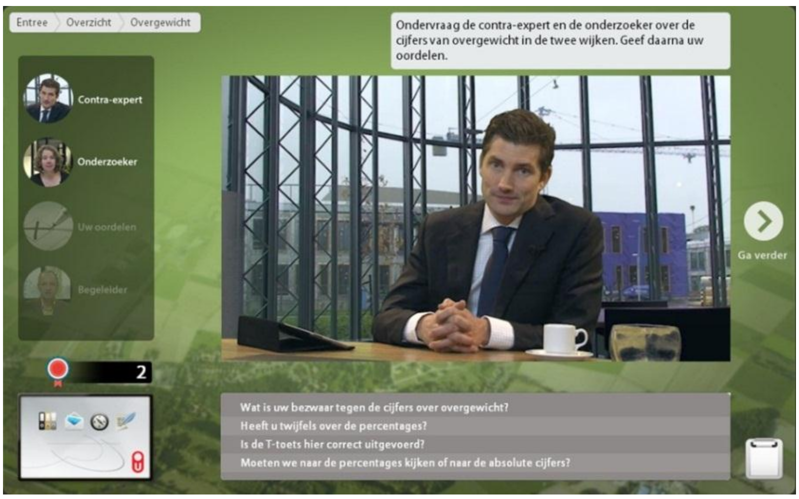

Figure 1. Screenshot of the Playground Game: interrogation of the contra-expert.

The problem issues include the risks of obesity in different districts, costs against benefits, the sample taken in the study, the questionnaire used, the effect of available sweetshops, existing playgrounds, the body-mass indexes observed in different districts and the actual abundances of obesity in the districts. Upon selecting a problem issue the players may interrogate the consultant and the contra-expert by asking (pre-defined) questions, which will be answered through pre-recorded videos. The answers of both the consultant and the contra-expert may contain fallacies. The players are challenged to critically analyse the arguments and uncover the flaws. When a sufficient number of questions have been asked, a decision screen pops up, allowing the players to make their judgements about the problem issue. The decision screen contains up to eight statements that may be qualified as correct or incorrect. Importantly, the players are invited to keep revising their answers until most of the answers are correct. This set-up would allow for a trial-and-error approach, be it that a score mechanism could be used to discourage it. Next, the video tutor will appear and provide feedback on the outcomes. The same structure applies to all eight problem issues. During the game the video tutor may pop-up and give some hints when the overall performance is low. When all eight problem issues have been completed, the tutor once again appears and provides overall feedback on performance.

2.3 Reward systems in serious games

The involving nature of video games and their promise for using games as learning tools are widely recognised. Malone and Lepper (1987) noticed that games appear to strongly motivate players to engage in problem solving and critical thinking. It's main drivers were identified to be related to curiosity, control and phantasy. According to Gee (2003) the secret of a videogame as a teaching aid is not the high quality, immersive 3-D graphics, but in the underlying architecture, which balances the challenges offered to the player with the players' abilities seeking at every point to be hard enough to be just doable. In psychological terms this mechanism is easily linked with Csikszentmihalyi's theory of cognitive flow (1991) and Vygotski's (1978) zone of proximal development: challenging people slightly beyond the boundaries of their abilities, while avoiding both frustration (too complex tasks) and boredom (too easy tasks). The successful mastery of a task beyond one's ability is a satisfying achievement that constitutes a reward by itself. Many games, however, include explicit scoring systems that express player achievements in a quantitative way. These scoring systems can act as an extrinsic motivator, because of the frequent feedback a score provides about progress and performance against desired score levels, e.g. previous scores, personal records, or opponents' scores. Such reward systems largely rest on the tradition of behaviourism, which views the process of learning as a result of rewarding desired behaviours and disapproving unwanted behaviours. In principle, such reward systems could help players to adjust their behaviours in favourable ways, e.g. by discouraging or encouraging certain approaches. This substantiates our study: by negatively awarding trial-and-error behaviours, we aim to help players to develop thoughtful and productive strategies. Our presupposition is that error-discouraging scoring models will reduce trial-and-error behaviours in favour of more involving strategies.

3. Quasi-experimental design

For evaluating the game and for testing to what extent different score models may affect trial-and-error behaviours we 've set-up a randomised controlled trial, including a pre-questionnaire and a post-questionnaire.

3.1 Pre-questionnaire

A pre-questionnaire of 52 items was used to collect basic information about the participants. Among the most documented variables as predictor of cognitive performance and academic achievement are intellectual ability (Sternberg and Kaufman 1998), achievement motivation (Pintrich and Schunk 1996) , personality (Blickle 1996) and learning style (Felder and Silverman 1988; Vermunt 1998; Kolb 1984). We have operationalised a sub-set of these determinants in the pre-questionnaire. An aggregated metric for prior knowledge level was based on 1) an overall self-assessment score, 2) a set of questions about familiarity with statistical concepts, 3) a set of five methodological test questions. Personality is commonly described by 5 underlying factors (the big five): extraversion, agreeableness, conscientiousness, social stability and openness to experience (e.g. Blickle 1996). For each variable we have included 3 items from the 5PFT instrument in the pre-questionnaire (Elshout and Akkerman 1975). Learning styles are generally considered as personal strategies of learning (e.g. Vermunt 1998; Kolb 1984; Felder and Silverman 1988). Many scholars, however, have criticised the notion of learning styles as invariant personal traits and pointed out that there is little evidence for the appropriateness of most learning style models. As a replacement the term learning dispositions was suggested (Carr and Claxton 2002) a mixture of intelligence, motivation and experience, which may vary across contexts. But in turn learning dispositions also received severe criticisms (Sadler 2002). In his 2010 update Felder (2010) admits that learning styles aren't suited for giving students career or curriculum recommendations, and he repositions learning styles as not either-or categories, but as preferences that may be mild, moderate, or strong, while the optimal teaching style would strike a balance (not necessarily an equal one) between the poles of each dimension of the chosen learning styles model. In the pre-questionnaire six learning style items are included from the Solomon-Felder Index of Learning Styles Questionnaire (http://www.engr.ncsu.edu/learningstyles/ilsweb.html) and four items from Vermunt's approach (1988) for covering: active, global, undirected, reproduction-directed, application directed and meaning directed style, respectively.

3.2 Post-questionnaire

A post-questionnaire was composed of 28 items concerning the players' appreciations, judgements about the game, self-test and five post-test questions. An aggregated metric for the post-game knowledge level was composed in the same way as the prior knowledge metric.

3.3 Game conditions

We have arranged 4 different game instances defined by different scoring systems and error signalling (Table 1).

Table 1. Four experimental conditions of the Playground game

	Neutral score system	Error-discouraging score system
No error-signalling effects	Condition A	Condition B
Acoustic error-signalling effects	Condition C	Condition D

The neutral score system allows for unrestrictedly making adjustments. The error-discouraging score produces extra penalty points upon incorrect decisions. In addition, error signalling is arranged with sound effects that indicate the correctness (high tone) or incorrectness (low tone) of an answer given. The basic presuppositions are that the error-discouraging score model will amplify cautious behaviours and reduce trial-and-error. The error-signalling effects may either encourage trial-and-error because of the easy rewards they provide, or in contrast evoke caution.

3.4 Operationalising trial-and-error behaviours

Since trial-and-error behaviour is associated with thoughtless, impatient guessing, one may expect that it goes with more user actions, higher error rates and faster decision making. Such effects, however, may also be explained by the level of prior knowledge that the player has: an excellent player stays away from trial-and-error, but would still display fast decision making; ignorant players may substantiate their decisions, but still are likely to produce a lot of errors. Because of these confounding effects we have to take into account the players´ knowledge level. Table 2 lists five proposed indicators for trial-and-error behaviour.

Table 2. Suggested trial-and-error indicators.

Indicator	Expression	Description
Error rate	$TE_1 = \frac{N_{errors}}{N_{decisions}} / (1 - K_{prior})$	N_{errors} is the number of errors $N_{decisions}$ is the number of decisions taken K_{prior} is the player's prior knowledge ratio
Speed of action	$TE_2 = \frac{(1 - K_{prior})}{T_{decisions}}$	$T_{decisions}$ is the time required for all decisions
Speed of action	$TE_3 = \frac{(1 - K_{prior})}{T_{total}}$	T_{total} is the total time required for the game
Speed of action	$TE_4 = \frac{T_{total} \cdot (1 - K_{prior})}{T_{decisions}}$	Increased pace during decision making
Self-report	TE_5	Self-reported guessing ratio in the post-questionnaire

3.5 Participants and groups

Test persons were psychology students recruited from the bachelor programme of Leuven University; their participation in tests and experiments is a mandatory part of the curriculum. Out of 125 subscriptions, 117 participants completed the games and questionnaires. Regarding the distribution of prior knowledge we've detected and removed five outliers, and regarding time spent we excluded nine outliers all in the high-end tail of the distribution, displaying a lot of inactivity. The resulting sample contained 103 participants. Students were randomly allocated to conditions. A group comparison, which was carried out by planned contrasts ANOVAs with respect to constructs for prior knowledge, personality traits and learning styles, respectively, did not reveal significant differences between groups.

4. Results

4.1 Learning gains and appreciations

We have used the questionnaire data and player loggings for evaluating the Playground Game, while temporarily neglecting the fact that we have four slightly different versions of the game. Learning gains are represented by comparing the score of the pre-test and the scores of the post-test. After playing the game, the test score mean has increased from 0.515 (SD=0.086) to 0.571 (SD=0.099) representing an overall relative gain of 10.9 %. A paired t-test analysis qualifies the overall increase as highly significant: $t(111)=-5.670$, $p<0.01$, $r=0.383$.

In the post-questionnaire the participants were invited to express their comments on the Playground Game (Table 3). All judgements involve a quality score, which are all aligned as percentages (0-100%).

Table 3. Quality scores about the Playground game.

Topic	Judgement (%)	Standard deviation
Clarity about what to do	49	28
Structure of the game	50	28
The role of the videos	69	21
The quality of the videos	63	22
Quality of tutor feedback	68	22
Operating the game	51	23
Fun	63	24
Concreteness	66	20
Instructiveness	59	26

Clarity, structure and operation of the game receive moderate (neutral) judgements. The quality and role of the videos are positively evaluated as is the quality of tutor feedback. Students indicate that playing the game is instructive and makes statistics concrete. These findings are confirmed by the participants´ answers to open questions on the Playground game´s strengths and weaknesses. Up to 40% of the students referred positively to the videos used in the game (e.g. “you are completely absorbed in the game and part of the story”). Another 20% referred to the degree of realism and concreteness that the game offers; 13% commended the feedback given by the video tutor; 10 % referred to the game as highly motivating by its playful approach to learning. Three students explain that the game amplifies a critical attitude toward proclaimed pros and cons in research. On the downside, quite some students (30%) were a bit puzzled at the start and would have preferred more instruction; 17% of the students had some technical issues (e.g. browser issues, or slow internet connection, which affected performance of the videos). Some students didn’t like the approach, or found that the approach was too practical and that it should include more theory. One quarter of the students didn’t mention any weaknesses. Overall we conclude that the Playground Game is well appreciated by the students, in particular for its realistic and playful approach to making statistical methods concrete and tangible.

4.2 Trial-and-error behaviours

In table 4 some of the key outcomes of the four different game conditions are listed.

Table 4. Knowledge levels, time spent and trial-and-error indicators for all conditions.

Indicator	Condition A (control group)	Condition B	Condition C	Condition D	Overall
Number of participants	25	29	26	23	103
Knowledge level before	0.518 (0.081)	0.511 (0.103)	0.523 (0.067)	0.479 (0.083)	0.508 (0.085)
Knowledge level after	0.599 (0.109)	0.561 (0.096)	0.586 (0.067)	0.523 (0.111)	0.568(0.100)
Total time	7034 (4141)	8956 (6624)	6823 (4055)	7396 (5359)	7603 (5203)
Test time	837 (464)	668 (247)	676 (327)	720 (298)	723 (343)
TE_1	.763 (.169)	.786 (.209)	.752 (.137)	.744 (.212)	.760 (.183)
TE_2 (*10,000)	6.94 (2.89)	8.25 (3.35)	8.66 (3.89)	8.37 (3.43)	8.06 (3.32)
TE_3 (*100,000)	8.38 (3.36)	7.96 (4.75)	8.84 (4.39)	8.87 (4.02)	8.84 (4.15)
TE_4	4.48 (2.45)	6.87 (6.42)	5.31 (2.85)	5.78 (3.48)	5.65 (4.26)
TE_5	.540 (.225)	.541 (.242)	.413 (.186)	.457 (.289)	.490 (.240)

It can be read from table 4 that in all groups considerable learning gains have been achieved. Paired t-tests revealed significant differences in conditions A and C ($p<.01$) and condition D ($p<.05$). The probability value for condition B was slightly too large: $p=0.059$. The various trial-and-error indicators (cf. table 2) seem to suggest differences between groups. Differences between condition A and condition C for TE_2, TE_3 and TE_4 suggest that acoustic error-cueing increases trial-and-error behaviour. TE_1 and TE_5, however, display the opposite. A damping effect of error-discouraging scores can only be seen in TE_3. In all these data, however, the standard deviations (and mean errors) are considerable. The statistical power is weak, as was confirmed by ANOVA statistics.

4.3 Regression models

As a baseline we have checked the control group (A) for correlations between the trial-and-error indicators and the scores for prior knowledge, personality and learning styles, respectively, and identified linear regression models for these. For TE_1 we found a significant model involving autonomy and meaning-directed learning style, $F(2,22) = 4.508$ ($p<0.05$); for TE_2 we found a significant model involving autonomy and emotional stability $F(2,22)= 8.173$ ($p<0.01$); for TE_3 we found a significant model using autonomy, $F(1,23),=4.507$ ($p<0.05$). Transferring these three models from the control group to the experimental groups and by reverting to the first order moments (the means) of the models, their shortcomings in the experimental groups can be expressed as a ratio (observed indicator/model indicator) that suggests how trial-and-error would differ across groups (Table 5).

Table 5. Ratio of observed mean trial-and-error indicators and mean model values for each group.

Model	Group A	Group B	Group C	Group D
1 (TE_1)	1.00 (.18)	1.050 (0.288)	.969 (0.188)	.965 (0.268)
2 (TE_2)	1.00 (.30)	1.130 (0.539)	1.324 (0.884)	1.052 (0.600)
3 (TE_3)	1.00 (.40)	0.947 (0.572)	1.146 (0.737)	1.026 (0.464)

Table 5 shows that the models do not provide an unambiguous description of the effects. Yet, we see more pronounced effects in TE_3: trial and error being reduced in group B (error-discouraging score) and increased in group C (acoustic error signalling); the acoustic signalling dominates the effects of the error-discouraging score (group D). Note that an increase in group B as compared with group A (e.g. TE_2) is hard to understand, as it would suggest that the penalty points are counterproductive.

5. Conclusions

Based on a substantial group of participants we conclude that the Playground Game substantially and significantly contributes to procuring learning gains. The participants highly appreciated the integration of statistical learning contents in a game environment. The contextualisation has successfully bridged the gap between theory and practice, which is known as a notorious problem in the domain. Many participants have qualified the Playground Game as highly motivating by its playful approach to learning. Generally the participants commended the involving nature of the game, which successfully made statistical problems tangible and accessible and at the same time enforced an active role for the players during interrogations and decision making. Even though the videos were just provisional recordings with colleagues who kindly adopted the roles of the Playground Game's actors, the students appreciated the videos' involving qualities. Likewise the instructions and feedback provided by the video tutor were considered positively. Quite some participants, however, would require more specific instructions and theory. With respect to trial-and-error behaviours we have presented five indicators, four of which are based on game logging analysis and one is based on a post-questionnaire item. The log-based indicators all accounted for the confounding effects of prior knowledge. Although we have observed differences between the control group and the experimental groups, the differences were not consistent across all indicators and the data showed too large variabilities for producing clear evidence. Effects of personality and learning style were weak, if present at all or if not obscured by variance. A few comments may help to guide future research on the topic. First, it should be noted that the trial-and-error indicator-constructs are conjectures rather than direct observations. For deciding about the validity and reliability of the indicators a separate calibration would be required, e.g. through direct observations or direct interventions. Second, from the pre-questionnaire we found that the participants were not particularly intrinsically motivated beforehand to play the game, since participation was externally motivated through credit points in their educational programme. Although most students seem to have been highly engaged in the game, this may have blurred the data. Third, in the game the score mechanism wasn't displayed all too manifest and it lacked a reference to what would be a good score or a bad score. Fourth, while taking into account the players' levels of prior knowledge (or ignorance), we have neglected the fact that the knowledge levels progress during the game, which may lead to false inferences. Fifth, so far the logging analysis that we've presented only used mean values of whole game sessions, but omits the dynamics of game play and progression over time. In principle, players may have neglected the penalty points and the sound effects during an early phase of accommodation, and may have started responding to these at a fairly late stage. In that case, obviously, the mean trial-and-error indicators would not be representative for the players' responses to these constructs. Our main conclusion, however, about the effectiveness of the Playground Game remains unaffected.

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