Cognitive Task Analysis (CTA) in the Continuing/ Higher Education Methods Using Games (CHERMUG) Project

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Abstract
Research methods and statistics are core competences across various disciplines but pose significant challenges for many students. The CHERMUG project aims to develop a digital game to support students in acquiring methodological and statistical expertise. A key issue that has to be addressed in developing a game is to identify the desired learning outcomes for students. The current paper describes a cognitive task analysis (CTA) which was carried out in the CHERMUG project to identify the component cognitive skills, knowledge and competences that are required in developing a comprehensive and usable understanding of research methods and statistics. Structured interviews were carried out with research methods experts. The experts were provided with a briefing sheet which introduced them to the CHERMUG project and the aims of the CTA. In a subsequent interview, participants were asked to describe a prototypical research problem and for this problem identify and discuss the most prominent and relevant issues and difficulties they experienced with their students in working on this. They were asked to consider these for the four main steps in the research cycle: research question, data collection, data analysis, and discussion & conclusion. This approach to CTA focused on the experiences of experts teaching or supervising projects in research methods and statistics and provided valuable concrete suggestions and recommendations relevant to the design of the game.

Keywords: Serious Games; Cognitive Task Analysis; Game Design; Research Methods; Statistics; CHERMUG

1. Introduction

Digital games-based learning provides a potentially useful and attractive new method of learning with electronic media (de Freitas, 2006). An important reason for this interest is the evident engagement that digital games provide. In addition games also provide activities which seem to reflect modern theories of effective learning which suggest that learning is most effective when it is active, experiential, situated, problem-based and provides immediate feedback (Boyle, Connolly & Hainey, 2011). However firm evidence that games can help in learning and the ways in which different kinds of game can help has been lacking.

It is acknowledged that a major constraint in introducing games into the curriculum is identifying the relevance of the game to the curriculum (Kirriemuir and McFarlane, 2004). There is still a lack of knowledge about exactly which features of games are most effective in supporting which kinds of learning. An important requirement for the success of a game is that the game should meet the desired learning outcomes. Understanding the match between the desired learning outcomes and the affordances offered by a game is a complex process.

1.1 A game for research methods and statistics

The CHERMUG project aims to develop a digital game to support students in learning about research methods and statistics. Acquiring expertise in this area poses significant challenges for many students. The subject material is challenging because it is highly abstract and requires the coordination of different but inter-related knowledge and skills that are all necessary to develop a coherent and usable skills base in this area. Many students struggle to acquire a solid understanding of the higher level logical reasoning and critical thinking skills that underlie research methodology. However these skills are precisely those required to tackle the ill-defined problems that we face in the 21st century and students across many disciplines are expected to acquire a working knowledge of research methods and statistics in their subject area.

A games-based approach to teaching research methods and statistics is worth exploring for several reasons. Games offer a range of features that could be usefully deployed in teaching methods and statistics. Killi (2005) argued that games can offer players support by providing clarity about different stages in solving a problem. Games can provide clear goals, match challenges to the players' skill level and provide immediate feedback about the correctness of the player's response.

1.2 Cognitive task analysis

A first step in developing a game to support students in learning in specific curricular areas is to identify the skills and competences required. A technique which has been developed to help analyse the higher level cognitive functioning required in tackling complex tasks is Cognitive Task Analysis (CTA). CTA is defined as "the extension of traditional task analysis techniques to yield information about the knowledge, thought processes and goal structures that underlie observable task performance" (Chipman, Schraagen and Shalin, 2000, p. 3). Cognitive task analyses have been used for a number of different purposes including the development of training.

CTA is typically carried out when knowledge about how a task is performed is uncertain. On one level the knowledge which is required in developing an understanding of research methods and statistics is quite well known and is presented in many textbooks on the subject. What is not so certain however is the best way in which to present this knowledge to students. Lovett (1998) argued that CTA can help in describing the curriculum to be taught and decomposing the curriculum into the knowledge and sub-skills that students must learn. Lovett applied CTA to exploratory data analysis in statistics.

The current study describes a method of CTA which was used to identify the component cognitive skills, knowledge and competences that are required in developing a comprehensive and usable understanding of research methods and statistics. Experts in teaching research methods to nursing

and social science students were interviewed about the processes required and difficulties which arise. It is hoped that the analysis will provide an idea of the main difficulties and misconceptions that students encounter in this area and issues where they would benefit most from support in a game.

2. Methods

2.1 Design

The CTA focused on the experiences of experts teaching or supervising projects in research methods and statistics.

2.2 Participants

In a period of 6 weeks during March and April 2012 a total of 13 interviews were carried out. The interviewees were selected based on their knowledge of and involvement with teaching research methods and statistics. 11 respondents considered themselves experts in both qualitative and quantitative methods and 2 as experts in qualitative methods only. Faculties covered included Nursing and Medicine, Social Science, Psychology, Learning Sciences plus one expert who advised and supported several faculties. The experts were spread over universities and professional universities, some of them covering both. The experts consulted were located in UK (7) and Dutch (3) and Romanian (3) higher education institutions.

2.3 Materials

2.3.1 The briefing sheet

The briefing sheet provided an outline of the aims of CHERMUG project and a short description of the objectives of the cognitive task analysis and of the interview. The briefing sheet also included a description of the different stages in the research methods cycle (the research question, data collection, data analysis and discussion & conclusion) and a short description of three papers about games which had been identified as relevant either to the content area of the game (i. e. research methodology) or to the possible design of the game. Asbell-Clarke et al (2012) described a massively-multiplayer online environment (MMO) which was developed to support different stages in the process of scientific inquiry. Hummel et al (2011) described a game based on scripted collaboration for the acquisition of complex skills and Hulshof, Eysink and de Jong (2006) described “ZAPS”, short duration “mini-games” which allow students to experience basic psychological concepts in an engaging way and which could be modified for use with statistics and research methods.

2.3.2 The semi-structured interview schedule

The semi-structured interview schedule asked participants about their views about the research cycle, using Figure 1 (Van Buuren, 2008) as a reference point. Participants were led though the different stages in the research cycle and asked about the main tasks/concepts required at each of the stages as well as issues, problems or difficulties which arise for students at each stage. They were then asked about the knowledge and skills which they thought were important at each stage in the cycle. Participants were asked to consider whether the three different game approaches might be useful in teaching research methods and statistics.

1. Research question
    a. …
2. Data collection
    a. ….
3. Data analysis
    a. ….
4. Discussion & conclusion
    a. ……

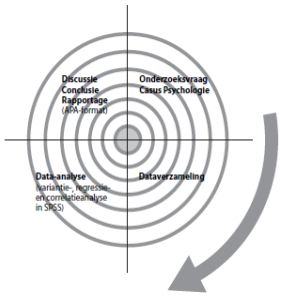

Figure 1: The four stages of the research methods cycle (Van Buuren, 2008).

2.3.3 Procedure

Prior to and in preparation for the interview participants were sent the briefing sheet to read. Participants were interviewed individually in a mutually convenient location following the semi-structured interview schedule. During the interview, the interviewer wrote down the participants' responses to the questions by hand. These were then word processed and sent back to the interviewee who was asked to check the transcript to make sure they agreed that it was an accurate record of the interviewee's views. Some interviewees added further brief explanations or clarifications of what they had said during the interview.

3. Results

Below, the detailed outcomes are described. They are organised into three sections (1) general findings; (2) specific findings related to the research cycle proposed and its steps; and finally (3) recommendations, either directly proposed by an interviewee or based on an analysis of the interviews, with regard to the game design or useful suggestions for the game.

3.1 General findings

Overall, research methods are seen as a complex and challenging topic for students. The complexity of research methods knowledge is similar to the complexity of writing described by one respondent as "*one of simultaneously solving multiple, possibly conflicting constraints*" OUNL13.

Students have differing objectives with regards to research methods depending on the modules they are doing. Social sciences students typically carry out research methods modules to acquire a basic understanding of research methods prior to carrying out their Bachelor's or Master's dissertation. Nursing students study modules such as evidence-based practice which is a research methods module focused on (a) critiquing research papers and (b) critically evaluating the relevance of research to their practice. Research methods students tended to have only a basic understanding of research but are now having to develop their own research proposals from scratch. This reveals large gaps in their working knowledge especially at the initial stages. The different reasons for studying research methods tend to place different emphasis on the skills required.

Superficial observation suggests that statistics cause the main challenges, but in practice all steps in the research cycle are equally demanding. As one of the interviewees stated, opting to carry out a qualitative research methods project in order to avoid statistics does not necessarily pay off, since in practice analysing, interpreting and abstracting qualitative data can be very difficult. Moreover, the steps in the research methods cycle are tightly connected and choices made or lack of understanding at one step directly influences the following steps.

3.1.1 Universities versus Professional Universities

A fundamental difference in perception between universities and professional universities on what level of competence or skills is expected with regard to research methods. The position taken by

professional universities varied between 'being able to understand research methods' or 'being able to assess research papers in function of evidence based practice' to 'defining and executing a research plan', however, with parts of the cycle, in particular the use of statistics, being actively supported by a supervisor. Universities, on the other hand, in principle do expect that students can define and execute all steps of a research plan. A number of the interviewees related this difference to the different foci of the two types of universities. Moreover, for professional universities the importance of research methods is seen as relatively new. For many, research methods have become a regular part of the curriculum in the last decade. As a consequence also the staff competences in research methods vary and, therewith, influence the demands imposed upon the students.

3.2 Specific findings related to the research cycle

Importantly for the design of the game, the research cycle presented in the briefing sheet was generally accepted by staff as providing a useful framework for presenting research methods to students. "*everybody has to know the "steps" of the research to understand and interpret what they read.*" ROMANIA 3. There was some discussion about the number of stages and the contents or activities required at each stage. Some respondents felt that it would have been useful to highlight other stages in the cycle as separate stages, such as the literature review and design. Similarly, application to practice was variously regarded as part of the research cycle as a whole or more relevant to the latter (discussion) stage of the cycle. The research cycle and the different stages were seen as relevant for both qualitative and quantitative experts, although the focus, the specific contents and procedures found at each stage differed for the different approaches.

The spiral nature of the cycle, where the same topic was visited at higher levels where students had increasing levels of knowledge, was recognised as a useful metaphor. When asking participants about which level of students they felt the game would be appropriate for, many thought it would be relevant for students at all stages. However in the initial development of the game it was thought best to focus on the early stages of acquiring research methods expertise.

3.2.1 The research question

The research question was perceived by many experts as providing a key challenge (frequently the key challenge) in developing a coherent approach to research methods. Getting the research question right is very important because "*The research questions help to identify the design and methodologies to be used.*" UWS1. Scoping the study was also viewed as a difficult problem: "*The scoping of the research objective, research questions and usable hypotheses tend to be the most problematic phase for students*." OUNL13; "*Students must be … taught how to limit or focus the question*. " ROMANIA 2.

A major difficulty is that students have little or no experience with this first step. Typically, their experience is limited to practice with analysing data which they have been given or analysing existing articles. Formulating their own research question requires sufficient background knowledge of the literature, the ability to scope their research so it results in a question which is focussed, not too complex, can be operationalised in a research design including dependent (IV) and independent variables (DV), *and* fits with their time constraints and the available respondents. To support this step, common practice is to offer guidance by a supervisor and/or in course settings where students discuss each others' research questions, plans and planning and/or by offering templates to be adhered to. For students it is important that they understand that the research question/design is the foundation of their research and that all flaws will impact on the next steps.

Students doing research projects had frequently decided on whether to adopt a qualitative or quantitative approach prior to starting their research. However they still had difficulties in formulating the research question. Qualitative researchers provided useful advice to students about narrowing down the scope of the study or the research question: "*First of all they have to think about specific*

issues and key concepts in that area. I then get them to ask "I wonder" questions. This leads them into the formulating the research question." UWS 6

3.2.2 Design

Many participants regarded design as very important. Some felt that it was better viewed as a separate stage in the cycle while others regarded design as part of formulating the research question. Success in formulating the research question and specifying the design are fundamental to the success of the project. Both qualitative and quantitative experts viewed design as important and impacting on subsequent stages of the cycle. Most respondents acknowledged that both qualitative and quantitative approaches were important and could provide complementary insights on a topic and several respondents felt that a game to distinguish qualitative and quantitative approaches to research would be useful. One nursing interviewee made it clear that, while he thought that both approaches are useful, quantitative research could tell us things that qualitative can't. For example in his research on homeless people: "*quantitative methods made it clear that they were homeless because they were depressed not the other way round*." UWS3. However the added value of qualitative research was highlighted by this respondent: "*Qualitative research can offer insights which illuminate the broader brush approach of quantitative research*." UWS1

Students have many problems with quantitative design especially around identification and operationalization of variables and levels of variables. "*Operationalising variables is a sensitive aspect for all the students*." ROMANIA 3. Understanding variance was also regarded as problematic: "*Understanding variance causes problems at all stages in the research methods cycle. It's important to have measures which display variance so we can explain underlying IV variables which account for variance*." UWS1. Students also have problems with within, between and mixed design.

Although students perceive qualitative research as easier than quantitative, it still presents problems. In some cases problems with qualitative design are due to lack of knowledge about which method is appropriate for collecting which kind of data: "*They wouldn't know that there are 3 different kinds of interview: closed, semi-structured and open. They don't appreciate that some designs would be better to answer their question than others*." UWS5.

3.2.3 Data collection

It was emphasised that this phase, like all the following phases, inherits the unresolved or unclear choices made in the first phase. Students tend to go through the research cycle step by step, only addressing problems as they arise. At a practical level planning can be a problem in this phase partly because student projects have limited execution time. At the conceptual level, it is hard to understand how many respondents are required and what constitutes a representative set of respondents. For quantitative studies there is a preference for surveys/questionnaires. However, it is difficult to assure the right questions and scales to be able to answer the research question at the next stage. Finally, ethical issues influence both the planning (permissions required) and how data are collected and stored.

3.2.4 Data analysis

The data analysis step is complex and (as discussed above) the expectations of the students vary depending on the approach taken. Many problems which emerge with quantitative research at the data collection stage are related to lack of clarity at earlier stages. Students need to understand links between stages: "*They need to hold design, flow chart, terminology, levels of data, normal distribution in their mind; we expect them to know these but these skills are not embedded*." UWS2

Since understanding inferential stats depends upon having a good understanding of descriptive stats, a number of respondents felt that it was imperative to provide students with a solid grounding in descriptive stats prior to teaching inferential statistics: "*For grounding the interest of the students in*

statistics it would be sufficient if the data analysis part emphasises descriptive statistics and pays only limited attention to evaluative statistics." OUNL16. Therefore a preliminary conclusion might be to restrict the design of the game to descriptive statistics to give students insight (and interest) in the data available and include evaluative statistics only voluntary and limited.

There are also pragmatic problems at the data analysis stage. The problems encountered include the quality of the data sample (both flaws in the data collection method used as well as with problems getting enough respondents in the available time) and the understanding, knowledge of and practical experience with statistics itself. More or less all students face problems due to too limited hands-on experience or their backgrounds in both concepts of descriptive statistics (means, variance) as well as in selecting and applying evaluative statistics. So stats might be more about doing than about knowing what is done.

Qualitative analysis presents problems too. It is at the data analysis stage that students begin to realise that the qualitative approach is not easy: they have problems in coding and analysing data.

3.2.5 Discussion and Conclusion

This stage was seen as less problematic if the previous stages had been carried out correctly. "*They seem to realise that they have to link their research to research in the field. These are not big problems. It is methods and analysis which are bigger problems*." UWS 7. The discussion is different for quantitative and qualitative approaches in that there was more continuity between the tasks of analysis and discussion with a qualitative approach: "*Identifying patterns in the data is kind of moving into the discussion.*." UWS5

3.3 Design and Game Recommendations

In each of the interviews special attention was paid to discussing and eliciting suggestions about the game. With respect to suggestions for games from the three papers identified, there was most support for the ideas of ZAPS or "mini games" similar to those described in the domain of psychology by Hulshof, Eysink, & de Jong (2006). Most respondents regarded such as an approach as viable and useful for teaching research methods and statistics where there are many different but relatively discrete sub-skills to acquire. Several respondents identified areas where such "Stats-Zaps" might be useful including: Literature review; formulating research question; differences between quantitative and qualitative approaches; data collection; quantitative and qualitative data analysis.

Respondents found it more difficult to understand the relevance of the other two approaches, but some respondents could see that the data collection approach of Martian Boneyards (Asbell-Clarke et al, 2012) could in itself be a mini-game where players were looking for evidence to support specific hypotheses. Perhaps due to the more abstract nature of evidence in social science, experts in this discipline found it more difficult to appreciate the relevance of this game. Some respondents could also see that the scripted collaboration approach of Hummel et al (2011) might be relevant for example in contrasting two differing perspectives, for example a qualitative and a quantitative approach to research.

3.4 More specific suggestions

Respondents also came up with more specific suggestions and ideas for a game-based approach:

- ***Provoking research interest.*** The first impression of what research is all about (and also of a game) is important. As two interviewees stated things are not always what they seem and this should motivate us to examine the world in detail. The suggestion is to open the game with a potpourri of quick, enticing introductions (e.g. as video) to research, grouped under the motto "things are not always what they seem".

- ***Challenge students in their question definition and research design & show the dependencies of the full research cycle.*** The first step in the research cycle is of particular

importance because it also defines the other steps. At the same time students have no experience in setting up their own research. Many interviewees suggested making use of a flow chart / decision diagram in an interactive game-like way or to employ a polyphonic approach of criticising by questioning the design from various view points (e.g. Wiemer-Hastings & Graesser, 2000). A number of respondents felt it might be possible to include a decision making game for quantitative stats to help students to select the appropriate statistical test. "*What is currently available with respect to design are various flow charts in books which could be converted into a game based on decision making."* UWS1

- ***Getting students to predict results/next stage*** Related to the above is developing a game which requires students to make predictions about the next stage given the specification at the current stage.

- ***Experience the difference in research methods: qualitative or quantitative?*** Several respondents suggested that it would be useful to illustrate differences between and advantages and disadvantages of qualitative and quantitative approaches.

- ***Experience by being part of the experiment*.** While an abstract dataset might be easier to apply across different domains, a personalised dataset might be more appealing and intuitive. One proposal was to put students' own data in focus, i. e. have them participate in a data collection exercise and open up the opportunity to represent & understand it by 'playing' with it.

- ***Visualisation.*** Several respondents mentioned the potential of a game-based approach in helping students to visualise data: "*To include in the game perspectives to enable 'understanding before analysing' data e. g. looking at extremes, making use of graphical representations as part of the process to get a global understanding of the data before making use of evaluative statistics*." OUNL13

- ***Structured approaches.*** Respondents mentioned a number of structured approaches which might help students to categorise information or make links between categories. Examples included: the use of templates for literature review where papers are analysed with respect to prescribed criteria; the use of templates for qualitative data analysis where data are analysed by generating and extracting codes; providing constraints: "*Maybe it is possible to make use of the constraints imposed by a particular statistical method and have the students create a "visual sudoko" fitting and giving insight in choices which fixate the kind of methods available*." OUNL13.

- ***The Discussion and Conclusions step*.** Several interviewees pointed out that students tend to make too much out of their data. The suggestions discussed above such as e.g. in 'Provoking research interests', 'Experience the difference in research methods' and 'Experience by being part of the experiment' can also be used to illustrate the importance of critically reflecting on and positioning one's own results.

- ***Interactions between peers*.** Many interviewees mentioned the importance of proposing, discussing and exchanging ideas between peers. For example, the main steps could be complemented with discussion and idea-sharing games (see e.g. digital dialogue games: http://www.interloc.org.uk/about.htm (Ravenscroft, McAlister, & Sagar, 2010)).

- **Game as a safe place.** Finally, many of the suggestions mentioned relate to the importance of giving students the opportunity to experiment at their own pace and without having to worry about mistakes so they can see what may be right, wrong or misleading, instead of being directly confronted with it in a classroom or by their supervisor. Relevant examples include 'provoking research interests', the exploration of qualitative versus quantitative research, the use of stats. *"They would like to gamble on PC with a correct story and a wrong story about how to make an appropriate research (on the same subject) – and see where they can arrive in the two situation."* ROMANIA 1.

4. The CHERMUG Game

The CTA has been useful in identifying ideas to guide our choice of game in the CHERMUG project. To support scientific enquiry and a collaborative approach, the project has decided to use an Alternate Reality Games (ARG) genre. An ARG is a blend of online narrative and puzzle solving (similar to an online scavenger hunt), where the narrative is gradually revealed through a series of media such as websites, Instant Messenger conversations, text messages, emails and in some cases, TV and newspaper adverts and telephone calls. A central role in the development and running of an ARG is played by the *puppetmaster* who steers players in different directions as the game's story unfolds. Collaboration among players forms a key role as players must work together in solving puzzles and ultimately successfully completing the game, which is why as well as being a form of computer game, ARGs are also viewed as being heavily built around social networking (Connolly et al., 2009). The puppetmaster can adopt the role of an adversary to the players by placing obstacles in their path to solving a quest, or an ally by providing deliberate clues that enable players to find resources to overcome obstacles.

One of the earliest ARGs was developed in 2001 to market the film *A.I.: Artificial Intelligence* and a series of Microsoft computer games based on the film. It was based on an elaborate murder mystery played out across hundreds of websites, email messages, faxes, fake ads, and voicemail messages. At its height, it had more than three million active players worldwide; in effect, it was a type of massively multiplayer online game (MMOG). Microsoft also created an ARG called "I Love Bees" for the launch of the XBox game *Halo 2*. This game wove together an interactive narrative set in 2004 and a War of the Worlds-style radio drama set in the future, broken into 30-60 second segments and broadcast over telephones worldwide. McGonigal (2008) argued that the gameplay within *I Love Bees* develops 'collective intelligence' through three stages: a) collective cognition, b) cooperation, and c) coordination. She believes these distinct stages of collaboration occur through three aspects of game design, namely: a) massively distributed content, b) meaningful ambiguity, and c) real-time responsiveness, and that this game type may be used to help design future learning systems.

In recent years the value of using ARGs in the educational field has been recognised. An early example of the use of ARGs within an educational context was the eMapps project (Motivating Active Participation of Primary Schoolchildren in Digital Online Technologies for Creative Opportunities through Multimedia), which combined online games and mobile technologies to demonstrate how an enriching learning environment can be provided for children (9-12 year olds) in New Member States in Europe (Davies et al. 2006). Another example was the ARGOSI project funded by the Joint Information Systems Committee (JISC) in the UK, which aimed to support the student induction process in a Higher Education Institution, as a more engaging and interactive approach than more traditional methods. Areas that the ARG focused on included gaining library and information skills, creating social networks, as well as navigating the city and university campus. The ARGOSI project encouraged students to establish friendships and work within communities in undertaking challenges within the game (Whitton, Wilson, Jones, & Whitton, 2008). From a series of interviews, the ARGOSI project identified six motivation elements of ARGs that may engage students, as shown in Table 1 (Whitton, 2009). Perhaps one of the most widely piloted ARG in education was the Tower of Babel game that was created to motivate secondary school children to learn a second language. The game was played with 328 secondary school students and 95 language teachers from 17 European countries in 2009 and using a quasi-experimental methodology it was found that the game did indeed engage and motivate students (Connolly, Stansfield, & Hainey, 2011).

Table 1 Possible motivations elements of ARGs

Element	Possible Implementation
Community	Collaborative activities, communication tools
Competition	Prizes, leader board
Completion	Overview of complete structure, pieces needing filled in
Creativity	Creative challenges that involve making artefacts
Narrative	On-going storyline that contains a mystery
Puzzle-solving	Challenges based on puzzle-solving

5. Conclusions

The structured interviews with experts in research methods and statistics achieved their objectives in providing a clear overview of the processes required in developing an understanding of research methods and statistics and identifying the main problems and difficulties that experts felt that students encounter in doing this.

Respondents did not appear to view the level of expertise at which the game was targeted as a problem. While initially it was thought that the game should be targeted at beginners, the target audience is extremely heterogeneous and it seems that the game could potentially be useful for students at all stages. Research methods and statistics is complex and there are very many different components where a game based approach might help in learning. Even experts have areas where they might find it useful to revise their understanding.

Several respondents indicated that many students lack confidence in their ability to do research methods and maybe the most important aim in teaching research methods is trying to increase student motivation and get them excited about research and interested in being part of the research community. As one respondent stated, one of his students "*was frightened of SPSS initially but when showed how to use it he suddenly found it was wonderful and became quite evangelical about it*". UWS2.

Overall the interviews carried out for the CTA were time consuming, but it is felt that the results produced were worth the effort in providing various concrete suggestions and recommendations for the design of the game and in guiding our choice of an ARG game for the CHERMUG project.

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