Theorising the Utility of Combining Game Theory and Frame Theory: Consequences for Design and Technology Education

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Abstract

A review of the three research domains of design, frame theory, and Game Theory, reveals that they offer new and relevant perspectives that have the capacity to inform Design & Technology education. Generally, at some point in everyone's life they will have learned to play some sort of game. Over time theoretical models of game play have emerged and evolved, and while games are often played against known opponents, the games that are played against unknown opponents have the most relevance here. Further, during game play the process of making sound incremental decisions is important. This also holds true for design decisions that are made incrementally, often in relation to shifting frames of reference. Consequently, the design process can be considered one of co-evolution with respect to the problem-solution nexus. These shifting frames of reference (manipulable variables of context/contexts) play a central role in the design process; therefore Framing Theory has significance for design. This paper reviews core underlying constructs within the domains mentioned above. Further, this paper will present the case that new perspectives derived from a number of core themes which have resonance within the three domains have implications and consequences for Design & Technology Education.

Introduction

Often design problems are ill-defined and ill-structured. Frequently as the design process moves forward, the 'rules' that designers use change. Subsequently, problem solution possibilities change. Consequently, design decisions are made incrementally in relation to shifting frames of reference and shifting perspectives and heuristics, as the design process can be considered one of co-evolution with respect to the problem solution, as discussed in Dorst & Cross (2001). Further, as discussed in Harfield (2007), both the context and the proposed solution changes and evolves, dependent upon the individual designer. These shifting frames of reference are viewed as being manipulable variables of context/contexts, and they play a central role in the design process. To a large extent this co-evolution of problem-solution is dependent on the personal perspectives, biases, knowledge base, sensibilities, and previous patterns of experience of the individual designer. In short, these form the individual designer's personal perspectives and heuristics which are limited by their personal pattern of experience. Harfield (2007) suggested it is not the case that when giving one brief to fifty different designers, fifty different designs will emerge. He contends the one brief is merely the starting point, and the true case is that by giving one brief to fifty different designers each will recontextualise the brief resulting in fifty different new briefs yielding fifty different designs. It can be argued that if a designer or group of designers is able to externalise and share the way in which they process and draw upon their understanding of a design problem, then sharing their perspectives and heuristics both the design brief and potential solutions may be enhanced

and more creative.

Frequently, in Design and Technology Education, the learning experiences in which students engage, require them to individually develop their problem solving abilities and design ideas. This is borne out in a recent study by Barlex & Rutland (2008). Their study of Design and technology teacher trainees in England, investigated the design & making assignments specified by Design and Technology trainee teachers taught in the schools. They also investigated in what way the trainee teachers perceived these assignments in terms of the subject knowledge required, and the pedagogy employed.

The study revealed the majority of designing and making assignments taught by the trainees during their time in school were those already in place in the schools' existing schemes of work. Further, inspection of the activities used to prepare and support pupils for working in the designing and making assignments reveals these were mainly to meet a making/skills agenda as opposed to developing design ability and creativity. The design and making assignments reported by the trainees, in the main, do little to reflect the character of the subject when described by the importance statements or the range of pedagogy necessary. Subject knowledge was cited by trainees, signifying a central concern focused on making skills, and knowledge about how things are made. This had the largest number of citations by the largest number of trainees. Further, the study found that when asked to describe clearly the pedagogy they used to teach, they generally gave demonstrations to the whole class or presentations/Expositions to whole class. Further, in terms of the reason for teaching design & technology a majority of the trainees saw developing the ability to design and make as the most significant. One third saw developing problems solving skills and understanding the relationship between technology and society as important. More importantly and problematic is that only ten percent of the trainees cited developing an understanding of discriminating consumer behaviour and informed users as important. It would appear a detailed understanding of potential users is not seen as significant.

If a central goal of Design and Technology Education is to shape our students thought process and design experiences, then, as often is the case in the industrial commercial world, design and technology problems are often resolved by groups of people working in a synergistic way, in order to develop solutions to problems presented to groups of individuals (Users). This activity draws upon the individual knowledge bases, creative abilities, and shared understanding / identification of the problem's constituent parts. These individuals operating as a synergistic whole are by definition developing a 'collective intelligence', that is to say while each student draws upon their personal perspectives and heuristics they may both adopt and adapt the group's collective perspectives and heuristics. The recent work of Barlex & Rutland (2008) makes it clear this does not tend to occur in design and technology classes. While the use of group work is seen as a significant activity by the Design and Technology teacher trainees in their study, in reality the use of group work and the use of "collective intelligence" within the Design & Technology classroom is minimal at best. Nonetheless, it is encouraging the trainees see group work as important, as there exists the risk that designing and making may be perceived as an individual almost solitary pursuit, as the recent work of Shih et al. (2006) suggest cooperative learning in the design studio is important.

If collective intelligence is cultivated by giving student designers the opportunities to work with other students this activity enhances their personal problem solving abilities. However, when taking a game-theory based approach to the analysis of design studios cooperative learning, the recent work of Shih et al. (2006) suggests due to the fact that each student's grade may be dependent upon cooperation in the studio complex and competitive behaviours emerge. Shih et al. (2006) argue the central purpose of the design studio is to facilitate information sharing among peers. They found that the students often face the dilemma "to share or not to share'. In essence they argue this is not unlike the "prisoner's dilemma" found in game theory literature. If the students in the design class do not participate and share, they often lose out in relation to acquiring the rich learning experiences often derived from the development of alternative perspectives and heuristics. In short, there is a need to develop both an understanding of, and methods for, shifting/developing the perspectives and heuristics of both individual designers and groups of designers within a Design and Technology classroom context. The question then is how, and from where, we might develop a fresh perspective on the designer's shifting frames of reference, which plays a central role in the design process. This paper suggests an analysis of both game theory and frame theory offer support.

Design and Game theory

For all the discussion above, in relation to the co-evolution of problem-solution, it is clear the individual designer's personal perspectives and heuristics are limited by their personal pattern of experience. Additionally, as evidenced in Shih et al. (2006) and suggested in Barlex & Rutland (2008), group work and cooperation is important in the classroom/studio context. As the link to game-theory, made clear by Shih et al. (2006) has significance in terms of design learning, the notion of games is worth exploration. In the recent literature as discussed in Lawson (2006), relating to design as a game, Designers /Architects tend to examine issues surrounding architectural design problems. Consequently, the players in the "Game" of design [designers, users, clients etc...] are treated as part of the team in contrast to being considered as opponents who need to be second-guessed. As an example, clients, builders, manufacturers, and users need to be convinced the design proposal is workable and appropriate in order for the architectural structure to become reality. Conversely, with respect to product design there are greater numbers of unknowns during the design process and potentially a greater number of users. Additionally, recent literature surrounding user centred design suggests there is an ever growing importance in considering users in the development of design solutions [see for example: Karat (1997); Bodker (2000); Redstrom (2008) Jacobs & Ip (2005)].

When Dorst (2006) discusses the notion of 'design as a game', he notes, in addition to the fact that design problems are extremely complicated, the activity of design has very few rules. Further, in order to develop a design solution he suggests we endeavour to use a trial and error methodology via experimenting. Further, he suggests as a designer gets more and more personally involved in their design proposal they become driven to make that particular idea workable. This suggests the game of designing is played more as 'puzzle' solving rather than practicing thinking strategies relating to anticipating behaviours. While this trial and error game may prove useful, depending on the complexity

of the design problem, more complex design problems may not benefit from this strategy. We may need to use a strategy or enact games that involve other people in the design process when considering users.

With respect to product design, the perspective introduced above is even more problematic when an imagined user or set of users and imagined alternative environments are considered. Let us take for example the task of designing an office chair for an Australian furniture manufacturer. If a product designer was charged with developing an office chair many issues would need to be resolved. Additionally, these are heavily dependent upon the imagined contexts, anticipated rituals of use, and scenarios generated by the designer, as s/he endeavour to be the 'advocate' of the imagined and largely unknown user. The product designer must both anticipate and address the needs, wants, and desires of an imagined user.

In the 'Chair' example above, while the designers are developing the chair they will never actually know who will end up sitting in it, where it will be used, or even how it will be used. Consequently, to a large extent, the unknown user should, in terms of product design and development, be considered as if they were an unknown opponent in a game, that is to say it is as if the unknown user were making decisions in relation to the product. It is then up to the designer to anticipate those decisions, accommodating them. In a sense there should be no disequilibria between the designer and the user. This is not unlike the notion of seeking equilibrium in game theory.

In game theory, as discussed in Osborne (2004) [see also: Figuieres et.al. (2004); Luce & Raiffa (1957); Hargreaves Heap & Varoufakis (2004)], equilibrium is based and modelled in relation to achieving a steady state among experienced players, in this case an experienced designer and an experienced user of a product. Further, equilibrium in game theory is based on an understanding that firstly, decision makers are rational [in this case the designer], formally optimising well-defined exogenous objective functions given a number of constraints [product constraints], and secondly, efforts are made to make explicit the ways in which decision makers [designers] deal with 'strategic uncertainty' in resolving problems. As a result, for equilibrium to occur both players [in this case designers and users] need to be satisfied. However, often when playing games both elements of matching conjecture and conjectural variation occur. In brief, the concept of Conjectural Variation Equilibria (CVE), Figuieres et.al. (2004), posits that players choose most favourable decisions/actions taking into account that rival strategies are a conjectured function of their own strategies. This concept of conjecture is a correlate with the personal imposition of self, discussed in Harfield (2007), in that designers often conjecture how users would act based solely on their own individual personal experiences. This maybe problematic therefore, it should be the responsibility of the Design and Technology educator to address this problem.

While the discussion above presents the notion of seeking equilibrium in game play, the core assumption was all information for both players was complete and all 'rules of the game' remained static. However, we are reminded that the 'game of designing' often evolves due to the shifting and evolving contexts. While there are many types of games which require players to be decision makers forcing them to deal with 'Strategic uncertainty', for example playing chess. In the game of chess there is generally one known

opponent [player] and a known set of 'rules'. By contrast, there are many games that are played in which both the opponent player/players are unknown and the 'rules of the game' are both unknown and shifting. This serves to further exacerbate the problems in relation to 'Strategic uncertainty'.

In a sense this notion of unknown players and unknown rules parallels playing war games, more specifically war games against terrorist forces. In many terrorist situations [scenarios of game play] often the number of terrorists is unknown. Further, the motivations of the terrorists and the rules they intend to play by are equally, unknown. Consequently, when it comes to playing war games in relation to terrorist activities, government agencies are neither fully-informed nor 'playing' against fully-rational agents. In game theory parlance they deal with imperfect information and irrational players. In the context of the 'Design Game', the Users are considered to be unknown players and their views and decisions in relation to a possible design solution proposed by a designer remain unknown. In a real sense designers also deal with imperfect information [shifting criteria] and irrational players [Users]. This puts the designer in an awkward situation when making 'Strategic Decisions' in relation to design proposals and conjectures. As suggested earlier, when people play games they generally operate within relatively defined structures with relatively defined goals. Players generally have a shared understanding of the 'rules', along with a shared understanding of the possibilities/probabilities of outcomes, and the players of the game as they play the game, however, as is often the case designers they do not.

In the context of Design and Technology education, continuing the 'Chair' example, some design 'rules' exist, for example quality and safety standards [specified by governmental regulation] and ergonomic and anthropometric standards in relation to the development of an office chair. There are other 'rules', however, some aspects of chair design may be purely conjectural [imposed personal perspectives on the part of the designer], for example material selection, geometry/shape, and various aspects relating to possible rituals of use in relation to the chair. Often these rituals of use may be linked to the context of use and the environments the chairs are used. As a result, the designer must imagine a large variety of possible environments and contexts in which the chair may be used. In essence, the designers make conjectures in relation to the development of the chair. In other words the designer chooses most favourable decisions/actions taking into account issues that are a conjectured function of their own personal pattern of experience. This is a correlate to the discussions of conjecture by Figueres et.al. (2004), and the concept of the personal imposition of self, discussed in Harfield (2007). In general, this development process used by the designer may be enhanced via scenario development, in relation to various aspects of office chair design and office chair use. If we are to assist design and technology students in their intellectual growth, we will need to develop classroom exercises that enable them to shift/develop the perspectives and heuristics of both individual design students and groups of design students. The use of collective intelligence via scenario development within a design and technology classroom context may hold great promise. In fact it could be useful to combine team scenario building and game play within a design and technology classroom context.

The suggestion above in relation to the use of scenario development exercises in a classroom context is a noteworthy possibility. However, there are some issues in need of

consideration. Firstly, as already noted, when designing an artefact designers conjecture an understanding of how an unknown user may interact with the object, we could take the position that a statistically normed probabilistic approach would assist in moving a design forward. Therefore, we may be tempted to advance our designs based on Bayesian probabilistic outcomes and probabilistic conjectures. However, a critical analysis of Bayesian game theory reveals that Bayesian games consist of a finite set of players, a finite set of nature states [contexts], and a finite set of actions [rituals]. While determined probabilistic outcomes are comforting, in that they appear to lead to tangible results, in the context of design we often do not know precisely the users [players], the environments the artefacts are used [contexts], or how they may be used [actions]. This being the case, it is posited here that if a designer develops conjectures derived of their person pattern of experience [perspective and heuristics] plus the enlarged personal pattern of experience [perspective and heuristics] of others an enlarged design search space for solutions should emerge. This however, will require testing.

If a designer was open to developing collective intelligence, as discussed earlier, they may develop divergent perspectives and heuristics because of the group interactions in resolving design problems. Each person in the group would bring to any classroom discourse their individual perspectives and their previous pattern of experience. That is to say each person has their own particular 'Frame' of reference. If we are to properly develop classroom exercises for Groups of students within Design and Technology subjects, we will need to have an understanding and grounding in "Frame Theory".

Framing issues

Framing theory began in the domain of Artificial Intelligence [AI]. They were endeavouring to understand human actions/decision making processes and apply them in an AI context. They were searching for a way of using mathematical logic to describe the effects of actions/decisions without having to explore and list all the concomitant non-effects of alternate actions/decisions. Essentially, in terms of problems solving AI researchers saw routine, obvious, non-effect solutions as surplus to need. Therefore, they sought to use mathematical logic and formulae to describe the effects of actions/decisions minus the actions that are considered inconsequential [actions surplus to need]. This begs the question, in the context of design and solving design type problems, which target non-effects are to be considered inconsequential and therefore do not need to be considered when solving problems. Their core challenge was to identify a way to confine the non-effects of actions/decisions concisely within the parameters of formal logic. When solving design problems and taking actions/decisions, being either human or part of an AI system, non-effective actions/decisions need to be grouped and set aside. When given fixed problems with fixed 'rules' to resolve this may be straight forward. However, as discussed earlier design problems are less than straight forward, and from the perspective of design problem solving often designers must cope with ever shifting frames of reference.

Over time, the core concepts relating to the "Frame problem" have migrated/transferred to other domains [i.e. Social Sciences, Philosophy, politics etc...]. In relation to the frame problems and the philosophical perspective, according to Dennett (1978, p. 125) a central question focuses on how "a cognitive creature... with many beliefs

about the world" is able to update those beliefs when acting in it so as to remain "roughly faithful to the world"? This notion of finding consistency in shifting beliefs (perspectives) has relevance in design as designers must adapt their individual perspectives and heuristics when moving through the design process.

As a designer endeavours to dynamically interrelate the design sub-problems/issues embedded in a design problem/Brief they are essentially seeking congruence. If there is dissonance amongst the issues, the designer needs to resolve those. However, if the designer proceeds in isolation, remaining ignorant of other possibilities and alternative frames of reference when framing the problem and possible solutions to the problems at hand, or fails to fully comprehend the implications of a design issues their search space for creative solutions may remain narrow. Therefore, we need ways to address this in the context of the Design and Technology classroom. A way forward may be found in developing an understanding of how Social Scientists understand "Frame Theory".

A 'frame of reference', within the context of Social Science, is seen as a schema of interpretation that individuals rely on to understand and respond to events. Goffman (1974) argued 'Frames' are nothing more than 'Schema interpretation' which allows both individuals and/or groups to "locate, perceive, identify and label" events and occurrences, thereby portraying meaning, structuring experiences and determining actions/decisions. If, as suggested above, designers or design students constantly map the world around them via interpretive frames of reference which permit them to 'make sense of the world', they tend to fix these frames of reference. It can be argued that design students will only shift their frame of reference when incongruence or dissonance occurs, thus calling for a 'Frame' shift. In general, designers can only be cognisant of the frames of reference they are using until something or someone forces them to exchange one frame for another. While it is accepted designers may self initiate these shifts, in the context of this paper it is argued that divergent perspectives caused by discussions with other Design and Technology students, may significantly increase the probability of incongruence occurring. In essence it is argued that design and technology students may benefit from exercises in framing and reframing problems and solutions in consort with other Design and technology students.

Framing and Reframing in Design

Within the domains of Psychology, Sociology, Politics, and media studies the concept of 'Framing' has a specific meaning. In these domains of research, it relates directly to the mental process / activity of an individual and the perceptions and meanings they attribute to words and phrases. The way in which we tie together words and phrases may both encourage and discourage specific interpretations of concepts. In essence it is the way we communicate and how we communicate with others that cause shifts in our frames of reference and perspectives. However, a counterpoint in terms of types of communications which may shift our frames and perspectives is discussed in the work of Dzhor & Zdrahal (2002) in which they investigated engineering problem solving problem framing. They investigated the relationship between the problem specification and solution development, by conducting 24 experiments with design practitioners, by looking at the patterns of 'problem framing', and developed a conceptual model of framing with two illustrative

schemas. Their research particularly focused on the designer's reflective behaviour resulting in problem re-framing in relation to diagrams. In addition, the work of Barlex & Rutland (2008), investigating Design and Technology education, found designers are best placed to use drawing as a method of communication and it was a skill considered by many design & technology teachers to be essential to communicate ideas and help make design decisions. While it is acknowledged diagrams have the capacity to invoke reframing, it is argued here that discussions among larger groups of people may elicit and excite larger numbers of divergent frames of reference utilising words and phrases. Individuals may refrain from forcing themselves to change their frames of reference via studying diagrams in contrast with group discussions.

The work of Lawson (2006 p. 277) highlights this when he suggests "... this is a process of turning the problem around, describing it in different ways, explaining it to other people...." Further, he contends such activities/abilities are generally attributed to how creative designers progress their design solutions. Schön (1984) argues that the practitioners 'know' how to achieve their goals, and shape (frame) the design situation to reflect this tacit and experiential knowledge. Additionally, he argues proposed solutions depend on a designer's ability to develop a 'Normative Frame' of a design situation; it is presented as a discourse between two individuals. It may be argued discourse between and among larger numbers of designers, may force group incongruence /dissonance to occur when both discussing the design problems and the solution proposals. This in turn provides a significantly increased opportunity to more fully develop a larger and increasingly rich 'Normative Frame' with respect to a design situation or set of situations.

As suggested earlier, designers in the context of the 'Design Game', the Users are considered to be unknown players and their views and decisions in relation to a possible design solution proposed by a designer remain unknown. Design and Technology students should practice developing what may be a conjectured 'Normative Frame of a set of unknown users. While on the surface the work of Stumpf & McDonnell (2002) may appear to parallel this discussion, the 'Normative Frames' of development clearly focused on the design team and not the users. That is to say, they did not practice developing 'Normative Frames' of others but sought to investigate how the subjects develop an agreed 'Normative Frame' among the team. Their investigations and research related to team building and team framing not a development of "user" frames. If we are to enhance the abilities of our Design and Technology students with respect to developing 'Normative Frames' of others, we need to offer classroom experiences and exercises which compel them to put themselves "in someone else's shoes". As suggested earlier the designers need to be an advocate of an unknown user. In a sense the students need to practice their ability to "2nd Guess" the needs wants and desires of sets of unknown "Players" [in this case "users"] in the "Design game". If the appropriate experiences and exercises are to evolve, we must first propose and evaluate these experiences and exercises as it was clear from the work of Barlex & Rutland (2008), group work has not play a significant role in the Design and Technology classroom.

Relationship to Technology education

Given the discussions above, if we are to assist our Design and Technology students by

having them utilise collective intelligence to shift their personal frames of reference via game play, we may ask what game play characteristics would assist them. Game play typically falls into three prototypical classes: 1.) Cooperative games, 2.) Non-cooperative games, and 3.) Hybrid Cooperative and Non-cooperative games.

Since Cooperative games allow players to communicate and form binding commitments and Non-cooperative games do not, the concept of playing a hybrid Cooperative and Non-cooperative game seems appropriate in the context of this paper. The reason for this is that given the discussions above, a Design and Technology classroom exercise, in the form of a game, should compel the students to practice developing 'Normative Frames' of others [put themselves in someone else's shoes]. Further, the game would need to have groups of students working together to develop a 'Collective intelligence' as they play the game. This suggests a cooperative approach is required as they would be a coalition of players. Conversely, as the student groups would be playing against unknown players they would not be entering into conversations and binding commitments with the unknown players. Consequently, this may be conceived of as being a non-cooperative aspect of game play. This notwithstanding, prior to any game play all of the students would need to reflect upon their individual frame of reference it they were to play a 'Design game'. This would ensure they 'brought something to the table' when they were placed in a group in order to develop 'Collective intelligence'.

Design & Technology classroom assignment "2nd Guess"

As suggested earlier if the design students are to practice being an advocate of an unknown user, a game we will call *"The 2nd Guess Design Game"* is proposed here. It is understood that any number of design problems/briefs may be set. However, in keeping with our previous chair example, for the sake of this exercise, we will propose setting the students the task of designing an office chair for an Insurance company's office.

The game would begin when the classroom teacher would gather representatives of office chair users, who work within an insurance company and use office chairs. These people would constitute a representative set of target users. The views of the target users would be obtained. These views/perspectives would consist of, and relate to, their understanding of particular rituals of use of the chair plus their wants, needs, and desires in terms of the design features of an ideal office chair. Their perspectives both as individuals and as a collective group would remain unknown to any students or groups. In a real sense these would be unknown players. The teacher would distribute an appropriate open ended questionnaire/survey instrument enabling each individual target user to express their personal perspectives in relation to aspects of an ideal office chair and how it should operate and be used. The teacher and each target user would have a copy of the user's responses. Subsequently, the target users would be placed into a group in order to develop a shared perspective [collective intelligence] in relation to aspects of an ideal office chair. Each target user would bring to their group their views and perspectives. As a group, the group would complete the questionnaire. The 'Normative Frames' of both the individual target users' personal perspectives and the various groups' perspectives would be saved for comparison with the data to be generated by the students.

Once the target user information is collected, the teacher distributes the same open ended questionnaire/survey instrument that was given to the target users to each student

in the class. The teacher and each student would have a copy of that student's "2nd Guess" in terms of what constitutes an ideal office chair in the eyes of a user of an office chair within the insurance office context/contexts. Subsequently, the teacher would split the class into groups of five students each. The students would be placed into groups in order to develop a shared perspective [collective intelligence] in relation to aspects of an ideal office chair. Each student would bring to their group their views and perspectives and learn from the views and perspectives of their fellow students, in terms of trying to "2nd Guess" what the target users said. As a group, the student groups would complete the questionnaire. The 'Normative Frames' of both the individual students' personal perspectives and the various student groups' perspectives would be saved for comparison with the data generated by the Target user responses. The aim of the game is to have the students 2nd guesses 'hit the target' with respect to views and perspectives of the target users. The closer the responses are to the target, the more points the students receive. The highest score wins the game.

Discussions and conclusions

This paper reviewed core underlying constructs within the domains of Design, Frame Theory, and Game theory. Further, the case that new perspectives derived from a number of core themes had resonance within the three domains having possible implications for Design & Technology Education. It was suggested that when people play games they generally operate within relatively defined structures with relatively defined goals. Players generally have a shared understanding of the 'rules', along with a shared understanding of the possibilities/probabilities of outcomes, and the players of the game as they play the game. This is clearly not the case in the process of Design. In both the design process and the game proposed above [*"The 2nd Guess Design Game"*], shifting frames of reference [manipulable variables of context/contexts] play a central role in the design process; therefore framing theory and the game proposed above has significance for design.

While it is yet to be investigated in an empirical way it is argued that requiring the students to develop a design context and contexts together, developing a 'Normative Frame' of unknown users playing a game with an imagined player [User] or set of players [Users] offers the opportunity for a polemic transcendence to occur. While it may well be argued that the notions of playing games in the classroom and "frame shifting" in the classroom is not new, it is clear in the context of the Design and Technology classroom, there is a long journey ahead. The proposed game is merely the first few steps in that long journey.

It is argued the game proposed would teach Design and Technology students to both frame and reframe issues within the context of design. Rich learning should take place during the course of student discourse within a Design and Technology classroom. Further, it is not difficult to see how we might empirically evaluate how student learning with respect to framing and reframing design problems/issues may be developed. As an example, it would not be difficult to video tape the development processes of both the target users and the students as they develop their responses to the questionnaire. In essence this would be a think-aloud protocol study. Transcripts of the discussions could be reviewed and analysed for emergent themes and patterns of learning. This would serve

to advance both our understanding of specific aspects of the design/development process and education/learning issues. In addition, this would in turn advance design research in general.

References

Barlex, D. & Rutland, M., (2008) DEPTH2: design & technology trainee teacher's use of a subject construct model to enable reflective critique of school experience. *International Journal of Technology Design Education*, 18, 231–246

Boker, S. (2000)

Dennett, D., (1978). *Brainstorms*. Cambridge, MA: MIT Press.

Dorst, K., (2006). *Understanding Design _175 Reflections on Being a Designer*. Amsterdam: BIS Publishers.

Dorst, K., & Cross, N. (2001). Creativity in the design process: co-evolution of problem-solution. *Design Studies, 22*(5),425-437.

Dzbor, M. and Zdrahal, Z., (2002). Design as interactions of problem framing and problem solving. In Van Harmelen, Frank (Ed.), *Proceedings 15th European Conference on Artificial Intelligence (ECAI)* (pp. 210-214). Lyon: France.

Figueres, C., Jean-Marie, A., Querou, N., & Tidball, M. (2004). Theory of Conjectural Variations : Series on Mathematical Economics and Game Theory – Vol. 2. Singapore: World Scientific Publishing.

Goffman, E., (1974). Frame Analysis: An Essay on the Organization of Experience. London: Harper Row.

Harfield, S. (2007). On design 'problematization': Theorising differences in designed outcomes. Design Studies, 28(2),159-173.

Hargreaves Heap, S.P., & Varoufakis, Y., (2004). Game Theory: A critical text. New York: Routledge.

Jacobs, G., & Ip, B., (2005) Establishing User Requirements:Incorporating Gamer Preferences Into Interactive Games Design, Design Studies, 26(3), 243-255.

Karat, J. (1997) Evolving the Scope of User-Centered Design, Communications Of The Acm 40, (7), 33-38

Lawson, B., (2006). How Designers Think: The design process demystified. London: Architectural Press.

Luce, R.D., & Raiffa, H., (1957). Games and Decisions : introduction and crucial survey. New York: John Wiley & Sons.

Osborne, M. J., (2004). An Introduction to Game Theory. Oxford: Oxford University Press.

Redstrom, J., (2008). RE:Definitions of use, Design Studies, 29(6), 410-423.

Schön, D. A., (1984). Problems, frames and perspectives on designing. Design Studies, 5(3),132-136.

Shih, S., Hu, T., & Chen, C., (2006). A Game-theory Based Approach to the Analysis of Learning in Design Studios. *Design Studies, 27*(6), 711-722.

Stumpf, S. C. & McDonnell, J. T., (2002). Talking about team framing: using argumentation to analyse and support experimental learning in early design episodes. *Design Studies, 23*(1),5-23.