Thinking with your Hands

A Constructionist Perspective on Design Pedagogy

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Abstract

This paper explores the domain of design pedagogy, in particular the development and evaluation of a novel pedagogic methodology for design students. It describes the research process for this pedagogic intervention, and is placed in the literature as Educational Action Research.

A Constructivist/Constructionist approach was employed to create 3 physical 'insight puzzles' that represented 3 Industrial Design examples of 'Design Thinking'. Participants (all design students) were invited to try and solve these puzzles. To solve them, the students would need to 'reframe' the original argument and rebuild the puzzle to create a design solution that satisfied the original design brief.

Students, instead of passively listening a lecture explaining an abstract concept such as 'problem reframing' through language and examples, can (re)enact those examples themselves, coming to an understanding of the same concept through active learning. The physical nature of the puzzles meant that students would also be 'thinking with their hands'.

The format of this pedagogic experiment was informed by a theoretical framework, based on Self-determined Learning, a macro-theory of human motivation that focuses on self-determined behaviour and the social conditions that promote it, and also general pedagogic engagement theory.

Keywords

Constructionism, Constructivism, Pedagogy, design, engagement, motivation, tangibility.

1. Introduction and Motivation

This research was motivated by a desire to contribute to educational practice, by examining why design pedagogy is the way it is, and then exploring what improvements could be made. The research questions are:

Q1. Can "thinking with your hands" improve a student's understanding of their design training, as they learn to think like designers?

Q2. Can "thinking with your hands" make a difference to their cognition and engagement with their design studies?

This paper explores the domain of design pedagogy, in particular the development and evaluation of a novel pedagogical methodology for design students. It describes the research process for this pedagogic intervention, and is placed in the literature as Educational Action Research.

After establishing a conceptual framework based on psychological theories of learning and pedagogical theories of teaching, a Constructivist/Constructionist approach was employed to create three physical 'insight puzzles' that represented three Industrial Design examples of 'Design Thinking'. Participants (all design students) were invited to try and solve these puzzles. To solve them, the students would need to 'reframe' the original argument and rebuild the puzzle to create a design solution that satisfied the original design brief. Students, instead of passively listening a lecture explaining an abstract concept through language and examples, could (re)enact those examples themselves, and come to an understanding of that same concept through active learning. The physical nature of the puzzles meant that students would also be 'thinking with their hands'.

The format of this pedagogic experiment was informed by a theoretical framework, based on Self-determined Learning, a macro-theory of human motivation that focuses on self-determined behaviour and the social conditions that promote it, and also general pedagogic engagement theory. This research paper describes the design and implementation of that novel pedagogic experiment, and presents the results from it, to inform improvements in pedagogic practice in design.

2. Literature Review

Educational research is fraught with difficulties, despite uniform opinion that it must always have the same focus; how to improve learning, and thereby how to improve teaching (Pring, 2004). The difficulties exist because researching education is about researching a complex series of relationships, all in an effort to produce actionable information. There always will be profound difficulties in reaching an understanding of the complex relationship between the teacher and student, between the student and their peers, and especially the relationship between the student and their own mind.

To understand teaching, you must first understand learning. If there has been no learning, then there has been no teaching (Fosnot, 2013). Any theories of how best to teach must be based on how best we learn. For example, research in the physical sciences is primarily founded on a positivistic outlook, where reality is separate from the individual who observes it. But, in Experience and Education, John Dewey criticized a Positivist educational strategy, pointing out that those who designed formal educational settings had “assumed that a certain set of conditions was intrinsically desirable”, but without ever considering the students’ individuality as a relevant factor, making “the process of teaching and learning accidental” (1938).

Jean Piaget’s ‘Constructivism’ is an anti-positivist psychological theory of learning. It describes how we all subjectively construct our own understanding through personal experience, learning by active participation in problem-solving (a cognitive conflict) and critical thinking regarding a learning activity that we find relevant and engaging (2013). Students ‘construct’ their own knowledge by testing ideas and approaches based on prior knowledge and experience, by applying these to a new situation and integrating the new knowledge gained with pre-existing intellectual constructs. Understanding is not brought about through the transmission of information; understanding is constructed with the information (Kanselaar, 2002). Learning is not the result of development; learning is development (Fosnot, 2013). The challenge for educators is to determine what this paradigm brings to the practice of teaching.

Constructivism has served as a foundational element of a remarkably successful teaching methodology; Problem-based Learning in Medical Training (PBL). Medical trainees digest a tremendous amount of factual knowledge and their future practice will require them to apply this knowledge through a hypothetical-deductive reasoning process (Savery 2015). In PBL, the tutor presents a ‘puzzlement’ to a team of medical students. They try to solve this medical puzzle by applying their knowledge of medical facts and reasoning abilities in a setting that mimics their future professional practice (Barrows, 1988). This is constructivist learning in a pure form, where students leverage their prior knowledge against a complex problem, and then the eventual solution is integrated into their “pre-existing intellectual constructs”, improving their abilities to think critically and to reason deductively in the future (Karpov, 2013).

However, PBL puzzles are always ‘well-defined’, where everything that you need to know to enable step-by-step progress toward a solution is available. Design problems are ill-defined by nature, meaning they cannot be solved by simply collecting information and applying it (Cross, 2006). Design problems typically require a restructuring in how they are even approached (Webb et al., 2016).

Nigel Cross (2001) delineates this process as follows:

1. The initial representation leads to an impasse, halting progress.
2. To break that impasse, the problem representation must be restructured.
3. This restructuring leads to a rapid and complete understanding of how the solution can be reached, and is often referred to as an ‘insight’.

A core feature of design ability is the ability to resolve these ill-defined problems. Design students already gain experience in the Design Studio, in developing ideas to fulfil a design brief. But, a design equivalent of PBL would be an excellent development. A tutor could present a ‘puzzlement’ to design students, and they could try to solve this design puzzle by applying their knowledge and reasoning abilities in a setting that mimics their future professional practice (Barrows, 1988). Well-defined problems presented as puzzles are defined in the literature as “non-insight” puzzles. Ill-defined puzzles are “insight puzzles” and can only be solved by reframing them (Weisberg, 2015).

Presenting such design puzzles in a discussion group is not the only option. Samuel Papert’s Constructionism theory, (directly inspired by Constructivism), posits that the comprehension of abstract concepts is accelerated by literal construction activities (1991). So, creating a physical insight puzzle allows for an exploration of Design Constructionism, a realisation of the metaphor that all knowledge is constructed, and all learning is a process of construction.

3. Methodology

Educational practices cannot be understood except within the theoretical framework that makes them intelligible as practices and policies (Peshkin, 1985; Pring, 2004). This paper's framework is Self-Determined Learning (SDL), a theory of motivation based on cognitive psychology and a foundational element of pedagogic engagement theory. When applied in an educational context, its purpose is to promote an interest in learning, to instil confidence in learners' own capabilities (Deci *et al.*, 1991).

Motivation is the "direction, intensity, persistence and quality" of one's activities (Maehr and Meyer, 1997), answering the question of "why am I doing this?" (Appleton *et al.*, 2008), while 'Engagement' is the behavioural "intensity and emotional quality of a person's active involvement during a task" (Reeve *et al.*, 2004). Motivation and Engagement are separate but not fully independent—one could be motivated but not actively engaged in a task (Connell and Wellborn, 1991; Furrer and Skinner, 2003). Motivation is thus necessary, but not sufficient for engagement. Motivation & Engagement theories are not theories about teaching, but they do provide a framework that a pedagogic practice can be measured against. To apply self-determination theory in an educational context, an institution should provide an environment that supports development of the following.

1. Competence: Becoming efficacious in performing requisite actions.
2. Relatedness: Developing secure and satisfying connections with others.
3. Autonomy: This refers to being self-regulating of one's own actions.

Pedagogic Engagement Theory suggests that, to measure engagement, four areas of focus as especially relevant, defined as follows (Reeve *et al.*, 2011).

1. Behavioural: on-task attention, effort, persistence, lack of conduct problems.
2. Emotional: the presence of enthusiasm, absence of anger, anxiety, & boredom.

3. Cognitive: the student’s use of strategic, active learning strategies.
4. Agentic: the student’s contribution into the flow of instruction they receive.

This paper details the design, testing and evaluation of an educational intervention with design students, to establish whether the introduction of tangible instructional puzzles would improve their educational outcomes. They were presented with three “Insight Problems”, a description of each scenario, the objective and some conditions. There were three clues associated with each puzzle, each more explicit than the last, which can be accessed *if* desired. The structure of the puzzles allowed the students to “contribute into the flow of the instruction they receive”, by choosing what levels of assistance they required.

For analysis, a 4-camera setup (see Figure 3.1) recorded all attempts (Heath, 2010).

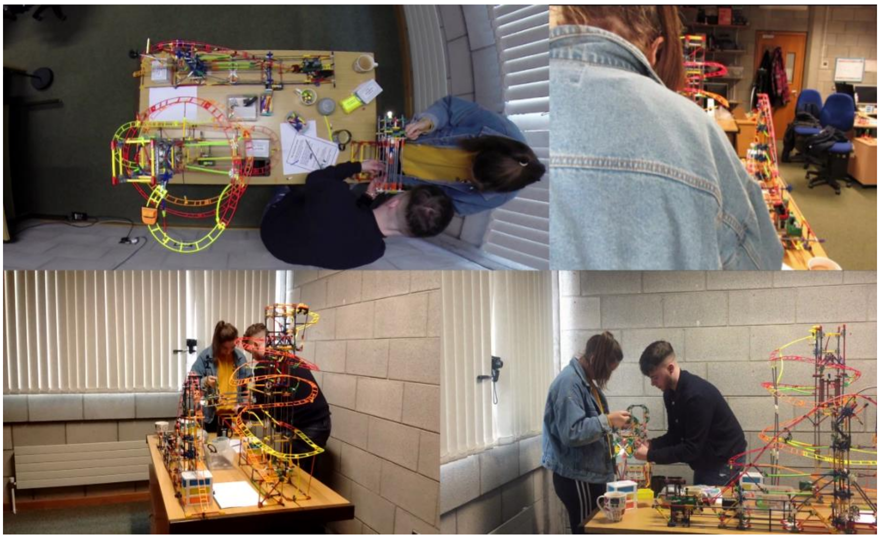

Figure 3.1 Participants 26 & 27 in action

In addition, all participants completed ‘The Academic Motivation Scale’ (Vallerand *et al.* 1992). This is based on SDL and is a Likert-style survey, composed of 28 items (subdivided into 7 sub-scales) assessing 3 types of ‘Intrinsic Motivation’, 3 types of ‘Extrinsic Motivation’, and ‘Amotivation’. It asks “Why do you go to college?” and provides 28 statements.

4. Results

This experiment purposed to engage the students in a pedagogical environment. The pedagogical element was their learning about ‘Problem Reframing’, an abstract design concept. The three puzzles were based on famous examples of design insight, often described in detail in design lectures: The Dalén Light; The Williams F1 Suspension System; and The New York Elevator Problem, see Figure 4.1 below.

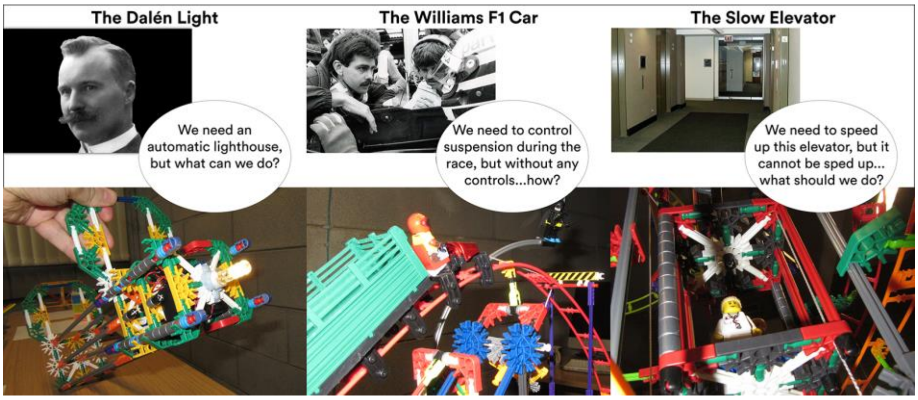

Figure 4.1 The 3 Puzzles

Students were given 45 minutes to solve these K'Nex™-based puzzles by reproducing those insights. The puzzles had been developed, tested and adjusted over and over, until it was judges it would be asking a lot of a student to solve all three puzzles within the time frame, but was still possible to do so. This was intentional, so that the participants would have to consider adjusting their expectations as they were actively problem-solving, and entertain the idea of having to use the clues. Solving the puzzle was not necessary for understanding, as a failed attempt could still involve a successful reframing and would at least provide some personalised insights see Table 4.1 below.

All Participants	Dalén Lamp	Smuggling Scarecrow	Slow Elevator
Solved?	9	12	14
Not solved, but at least reframed?	6	6	7
No progress?	8	7	1
Attempts?	23/25	25/25	22/25

Table 4.1 Design Puzzles Solve Rates

Regarding 'clue access', single participants were 1.5 times quicker to access their 1st clue than the pairs were (12.5 minutes vs. 18.5 minutes) and they also accessed more clues (53%) than the pairs (40%). In practice, single participants would regretfully access clues when they decided to, whereas paired participants would always enter negotiations with each other regarding the "giving in" of accessing clues. In Table 4.2, see below, the blue line relates to the single participants, and the yellow line relates to the pairs. P1 was the best performing 'single' and P17 & P18 were the best pair.

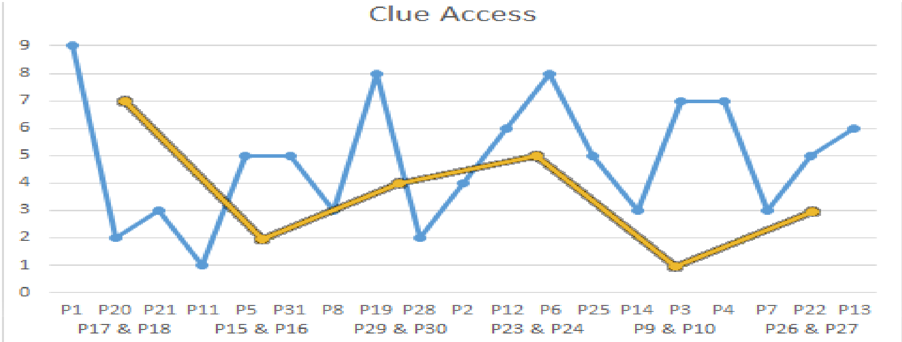

Table 4.2 Clue Access Rates

Regarding the Thematic Analysis, participants were emailed the questions ahead of time, to allow for considered responses. The questions were based on the varied elements of SDL and Engagement theory. Also, the video recordings of the participants' puzzle-solving attempts were reviewed, and notes were taken of any events of interest. Questions regarding these incidents were discussed during the interview. Otherwise, the questioning was consistent. The analysis of their interviews produced five themes:

Theme 1: The Physical-Cognitive Feedback Loop

Participants found that the physical nature of the structures aided their understanding of the problem-statement. They quickly developed the cognitive strategy of leveraging the immediate feedback from the puzzles. If their idea was working well, they continued. If not, they used the feedback to change direction in a specific direction.

Theme 2: The Emotional Loop; determined to solve, one step at a time

The physical nature of the puzzles provoked an emotional reaction. It encouraged, even impelled, them to focus on solving the puzzles. They were prideful in their efforts to solve. They also expressed a strong interest in the learning outcomes. The default position for many was one of doubting their own abilities. This hindrance was relieved by the incremental nature of the puzzles, always focussing on the next step.

Theme 3: The Bitterness of Failure

Participants' personal pride, where they felt they were rising to a challenge, was a strong factor in their personal engagement during their efforts. Their reaction to success was moderate, as was their reaction to any acceptable failures. However, when recounting fixation errors, they were visibly angry with themselves, a bitter feeling that they had let themselves down. ‘Fixation’ was when they had pursued a poor strategic choice when they felt they should have known better at the time.

Theme 4: Sharing is one thing, winning is everything

While relatedness/fellowship between participants was not unappreciated, it was only important when directly providing help solving the puzzles, rather than a sharing of the experience. Yes, they certainly appreciated the emotional support. It was, however, always a distant second to the individual getting help to solve the puzzles.

Theme 5: The Emotional Dilemma of Agency

It was a positive experience having the freedom to strategize as they pleased. It was relaxing and increased their feeling of control. But, their decision to consistently access the clues too late for them to be much use was because of their pride. They cared about their pride more than solving while engaged in the experiment, but afterwards they regretted that decision. It was always an emotional reaction, never an intellectual one.

5. Discussion

The mind remains a black box, and theories about how people think and feel will have to remain being based on the analysis of external, observable activities. Recording their puzzle-solving activities on video, interviewing them after the fact, and then analysing both sets of data were the best options for understanding this externalising of their internal mental processes. This “manual thinking” experience was engaging and educational (albeit self-declared). But, there were no patterns in strategy or any other activity with any of the participants. A rigid application of Constructivist theory would be that, as everyone is different, then everyone learns in a unique way. If their physical actions were a true reflection of their thinking while they were learning, then ‘no observable patterns’ supports that rigid interpretation. There were also no patterns between individual AMS scores (Intrinsic and Extrinsic Motivation) and any aspects of either Puzzle Performance, Academic Ability, Engagement, and no patterns in ‘relatedness’ activities of any participants. Even if the AMS is a reliable indicator of motivation, here it was not a predictor of engagement (many participants who scored ‘badly’ with the AMS claimed full engagement), nor an indicator of ability (there was no pattern between an individual’s AMS score and their performance with the puzzles).

6. Conclusions and Future Work

Methods to help design students learn to think like designers already exist. Sketching is exploratory, helping the designer to create unintended consequences, what Donald Schön calls a “reflective conversation” (1992). But, this novel methodology helped design students to learn to think in a ‘designerly way’ by engaging them physically. Students enjoyed learning about reframing but also had their individual strengths and weaknesses exposed, in real time. Some were quick to reframe the problems correctly, but struggled to realise solutions. Others were slow to reframe, but once they had, they found building a solution to be elementary. They left the experimental space knowing that they now had a concrete understanding of the abstract concept of ‘reframing an argument’, and also “fixation”. Whether they solved all three puzzles, or failed to solve any, they learned about the concept and themselves in a productive way.

Participants found that the physical nature of the structures helped them with developing an understanding of the problem-statement and a speculative formulation of their own solutions. Specifically, they leveraged the immediate physical feedback from the puzzles to guide their thinking. They were emotionally engaged by the puzzles’ physical nature, uniformly manifesting pride in their work. They enjoyed the feeling of control, and the ability to contribute “into the flow of the instruction they receive”, and genuinely cared about the learning outcomes, displaying a strong desire for “competence”, as they constructed their own solutions. All ‘singles’ choose to participate as such, preferring to be alone while thinking. While every pair were ‘best friends’, they always thought of their partner in terms of utility, rather than fellowship.

The purpose of this experiment was to provide a pedagogic environment that was engaging, where students would genuinely care about what they were learning. If this methodology was a part of a design degree course, if the students were constantly seeing the next ‘event’ as a way of continuing their success, or if having failed, to redeem themselves and improve on their performance, then that borders on describing Intrinsic Motivation, a panacea for educational progress and development.

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