Requirements Elicitation and Repeatable Processes - Interdisciplinary Collaboration between Software Engineering and Design

Leon Sterling
Centre for Design Innovation
Swinburne University of Technology
Melbourne, Australia
lsterling@swin.edu.au

James George Marshall
School of Design
Swinburne University of Technology
Melbourne, Australia
jgmarshall@swin.edu.au

Steven Murdoch
Department of Film, Games and Animation
Swinburne University of Technology
Melbourne, Australia
stmurdoch@swin.edu.au

Sonja Pedell
Centre for Design Innovation
Swinburne University of Technology
Melbourne, Australia
spedell@swin.edu.au

***Abstract*—Motivational modelling and the use of emotional goals has flourished from interdisciplinary interactions between software engineering, HCI and design. This paper discusses how interdisciplinary interactions produced outcomes that would not have been achieved if we had stayed within discipline boundaries. Innovation from a software perspective was the identification of emotional goals, the use of more engaging terminology and images, and improved requirements elicitation. Innovation from a design perspective was the introduction of an abstraction layer that produced helpful methods, spurred new research, and provided insight on repeatable processes.**

I. Introduction

At first glance, it may seem that design and software engineering are separate disciplines. Two naive stereotypes support that view. One stereotype is that design attracts creative students where artistic expression is key. The other stereotype is that software engineering attracts technical nerds with no social skills who just sit at a machine cutting code. Both stereotypes are misleading at best and harmful at worst.

In practice, a design project is similar to a software project in many respects. In both design and software projects, an individual, but more usually a team, collects requirements from a client. The team then comes up with a proposal for the client's approval, often iteratively. Once approval is given, the team must deliver the project to the client.

Both design and software engineering have developed processes and methods for projects [1], [2]. Software engineering popularised the waterfall approach with successive stages of requirements elicitation, design, implementation, testing and delivery. The waterfall approach has been largely superseded by agile methods which are more iterative and flexible, but still go through stages as above [3]. Design has developed the double diamond method which has four stages of discover, define, develop and deliver, though its emphasis was design innovation. Design thinking has become popular with five stages: empathise, define, ideate, prototype and test [4]. These methods provide insights and are not in conflict.

Projects today usually involve people and software, i.e. socio-technical systems, and are inherently interdisciplinary. This paper discusses how an interdisciplinary approach has enhanced the authors' experience in both design projects and software engineering projects. We discuss an overall approach of motivational modelling, and how it has led to innovation in design through a 'principle-led' design' process, a related design method and new ways of discussing animations. It has led to innovation in software engineering by increasing engagement with non-technical stakeholders and allowing better validation with requirements artefacts.

The paper is organised as follows. The next section discusses how the modern context of universities led to our interdisciplinary collaboration. It includes subsections on design and software engineering. Understanding context is always important. The following section discusses motivational modelling, while Section 4 discusses a case study. We conclude with some observations and an outline of our future research directions.

II. The university research imperative

Over the past thirty years universities have been under pressure to increase research output. That has led to less emphasis on teaching only roles and more discussion about what research-led teaching might entail. There is an expectation that all university academics should pursue doctorates if they don't have one already, and to investigate research possibilities.

The discipline of design at Swinburne University of Technology has exemplified the push for research. With the arrival of a new Dean a decade ago, the teaching staff of Swinburne's award-winning design program was charged with becoming more research-active, and for all staff to acquire doctorates.

This led to the initial interaction between the authors of the paper.

Leon was impressed with the computer games produced in the digital media capstone unit that James coordinated and to which Steven was a major contributor. Leon asked somewhat naively whether James and Steven could accurately articulate the process that was being followed by the students that seemed clearly repeatable. The question became a focus of two PhD theses [5] and [6] and was the birth of this paper. The authors constitute the supervisors and former PhD candidates. The aim of James' PhD research was to identify elements of wonderful design and incorporate them into a repeatable process, and to help designers create a future that enriches life. The aim of Steven's PhD research was to give a more systematic method for animators to produce animations. From Leon and Sonja's perspectives after bringing together software engineering and user-centred design, the aim was to learn how a designer perspective can improve the elicitation of requirements for socio-technical systems.

The successful interactions led to the first author being placed in the Centre for Design Innovation after a university re-structure. The placement was intended to help foster research with members of Swinburne's School of Design in general, and with the authors of the paper in particular. The collaboration has been unusual in a university context where interdisciplinarity, while formally desired, is not actively encouraged and difficult to practically realise.

It is rare for an academic to gain knowledge of another discipline due to the time and experience needed to learn the essence of the second discipline. Yet genuine interdisciplinarity between two disciplines requires deep disciplinary knowledge of both disciplines. In this instance the nature of the PhDs undertaken, the requirements of PhD supervision, the placement in a design research centre, and the support of Australian Research Council Discovery grants led to effective interaction across boundaries. The placement has been successful, with ongoing research output through the Future Self and Design Living Lab within the Centre for Design Innovation.

Capstone design projects turned out to be an excellent vehicle for advancing the collaboration. Student projects can be a fertile area for research, one that is currently underrated in our opinion and insufficiently tapped into. The projects were run with 70-80 students which is a scale unusual for testing a methodology. Ethics was obtained to study the outputs of the projects. Details of the evaluations are in [6] and [5]. There is a discussion of one of the projects in the Case Study section.

Before moving into the methods and approach, we comment about the two disciplines.

A. Design

Design has a long history of studio-based teaching and commercial, studio-based industry consultancy. Extending from the traditional master and apprentice model, the purpose of studio-based learning is to blend mastery of practical skills with a formal, professional discipline knowledge base. This combination was exemplified by the Staatliches Bauhaus, the German design school that operated between 1919 and 1933. The Bauhaus aimed to unify individual artistic vision with mass production, combining function and aesthetics. The studio-based model also exemplifies John Dewey's concept of experiential learning and his philosophical pursuit of aesthetic experience. The studio-based model, much like other aspects of design, was much revered following the massive revenue generated by design in the late twentieth and early twenty-first centuries.

The prerequisites to a successful design studio-based model are equatable to film and music studios. It requires talented designers (including students), a myopic goal-focused work ethic, creative vision, peer critique, group identity, mentors that can and do, and mentees with agency to investigate and develop work practices on real projects. In addition to being talented, skilful, and creative designers must have an inherent knowledge or tacit feel for the work and culture. The projects discussed in the case study section were created at the National School of Design, located in the suburb of Prahran in Melbourne Australia. The school opened in 1967, and was considered one of the best (if not the best) design schools in Australia.

B. Software Engineering

Software engineering is a term first used in the 1960s when it was desired to gain control over software development. Other branches of engineering knew how to deliver an outcome, and a systematic approach was needed to produce guaranteed outputs. The desire for a guaranteed outcome was strong for defence applications which is where the waterfall method emerged and subsequently improved to become the spiral model [7]. Large specification standards were developed. However detailed documentation and rigid following of process failed to guarantee success of projects.

Agile methods have been developed in reaction to difficulties in timely delivery of projects under the waterfall method. Extensive documentation has been eschewed in terms of working code which is developed incrementally. Various requirements artefacts have evolved including user stories and prototypes. In this paper we want to focus primarily on requirements elicitation as it is important to the success of a project. A useful survey on requirements engineering in an agile context can be found in [8].

Understandable concepts are needed as well as appropriate methods to help ensure all members of a project can easily reach a shared understanding. An important abstraction for socio-technical systems is an agent, which can stand for both people and software. Many methodologies for agent-oriented development have been proposed but none has had wide engagement. One attempt to describe how agile methods fit with an agent methodology is given in [9].

III. Motivational Modelling

Agent-oriented software engineering emerged as a way to systematically model and develop socio-technical systems which were conceptualised as multi-agent systems. The approach is described in [10]. It discussed the development of models to express functional and quality requirements. With the emergence of smart phones and tablets, and social media, and the increased consumer uptake of the Internet, many nonstandard requirements emerged. Examples are "increasing positive experiences between family members" and "having fun." Expressing how to achieve such nonstandard requirements traditionally has been seen to be the responsibility of designers rather than of software engineers.

The models of Sterling and Taveter, and indeed other software engineering methodologies, presumed that requirements would be available to do suitable analysis and design. A comparison of methodologies is given in Chapter 7 of [10]. All of the methodologies presented have an initial block of 'Requirements Elicitation' without much discussion of how the requirements would be elicited. As discussed in [8], researchers have looked to HCI and user-centred design to suggest ways of gaining the requirements.

A lesson from design is to embrace the stage of requirements elicitation. It is essentially the discovery stage from the double diamond method, and corresponds to the first stage of Design Thinking 'empathise with your client'. Seeing whether the agent-oriented models would be useful to capture design processes was an attractive proposition and a driver for the interdisciplinary collaboration. A series of design projects have applied the models to describe and provide direction, capture non-standard requirements and convey process.

The interdisciplinary interactions resulted in several significant changes to the agent-oriented modelling of [10]. The overall approach was recast as motivational modelling rather than goal modelling to emphasise the overall purpose. Emotional requirements were separated from other quality requirements and depicted separately as hearts within motivational modelling.

The terms were simplified and made more accessible to non-technical stakeholders, which is a more natural thing for designers to do rather than software engineers. Functional requirements were labelled 'Do goals', quality requirements were labelled 'Be goals', and the newly separated emotional requirements were labelled 'Feel goals'. Stakeholders corresponding to roles from agent-oriented modelling became the 'Who'. As a designer, icons were re-drawn which had a positive affect on people in projects. The icons are available from emotionalgoals.com which is maintained by James. The icons were also incorporated into the motivational goal modelling editor available at motivationalmodelling.com maintained by Leon.

An elicitation method was introduced as the first stage of motivational modelling and was identified as an activity in its own right. The method is called *do/be/feel elicitation*. The name is intuitive, memorable, and self-explanatory, which are important design concerns if the aim is to have a method that is broadly adopted. Using do/be/feel elicitation has resulted in more effective elicitation sessions in a range of applications as discussed in [11] for example. Do/be/feel elicitation allowed us to introduce motivational modelling to a much broader audience.

A do/be/feel elicitation session produces four lists - 'who' stakeholders, 'do' goals, 'be' goals, and 'feel' goals. While who/do/be/feel elicitation might be a more accurate name, do/be/feel elicitation has a better ring to it, as observed in over five years of use. Such considerations are another disciplinary difference between design and software engineering. Designers have more experience and success of engaging with a broader audience than software engineers and realise that nomenclature matters.

The approach to emotional goals differs from affective computing where the system is concerned with detecting and expressing emotions. Emotions are described as aspirational goals that are requirements for the user to feel when interacting with a system. Our view of emotional goals is compatible with the theory of constructed emotion as articulated and popularised by Lisa Feldman Barrett [12]. A good discussion of the issue for requirements engineering is given in [13].

Emotions play a key role in design. Famously, Apple designers ask how do we want people to feel? [14]. In addition Hartmut Esslinger, a designer of Apple products claims [15] that 'Form follows Emotion.' How emotions are used in capstone projects has been presented in [16]. In evaluating emotional goals Marshall has argued that the discussion builds a collective intentionality [5]. It is beyond scope to discuss in more detail how do/be/feel elicitation aligns with establishing collective intentionality.

From a design perspective, having a structured method during the discovery stage and constructing lightweight abstract models has proven useful. It became more easily possible to quantitatively evaluate student progress. It became possible to communicate a shared understanding. For the animations that were produced as part of the capstone projects, it became more easily possible to link various scenes in emotions being desired to be invoked by viewers of the animation.

Trying to describe the nature of the repeatable process has led to a principle-led design process and a design method in [5]. The process has five stages and multiple steps within the stages. The five stages are Leadership, Vision, Concept, Realisation and Application. The first two stages, as well as the final stage, are beyond scope for discussion here. Rather we discuss the third and fourth stages and the four steps they contain where motivational modelling is helpful, namely product branding, ideation, refinement, and evaluation and critique. Both the principle-led process and the design method have built-in appraisal and iterative feedback loops.

IV. Case study - Capstone projects in Design

The first application of motivational models in Design came in the capstone project developing the game Aspergion to help with an understanding of people on the autism spectrum. A large motivational model was placed on the back wall of the Design lab, and students found it helpful to both keep focus and monitor progress. The case study is described in [16].

Fig. 1. Project Logo

Fig. 2. Artwork for Gunter's Fables

In [5], there is a detailed discussion of the most elaborate application of the process in a project called Science Island. This is a massive project running over 5 years and is still ongoing. It contains a detailed evaluation of emotional goals, both qualitatively and quantitatively.

We describe a smaller study, previously unpublished, of a successful capstone project called Gunter's Fables. The Gunter's Fables project involved animating and promoting a series of storybooks created by the entrepreneur and sustainability activist Gunther Pauli. The primary goal of the project was to 'inspire kids' to become more interested and aware of sustainability projects.

Gunter's Fables was undertaken in 2012 by 75 final year Digital Media Design students, being supervised by four lecturers representing approximately 23,200 hours of research and development. The students were distributed somewhat evenly (18-19 per team) across four teams, each with a primary objective to animate one of Gunter's Fables and address one of the following secondary objectives. The overall logo is depicted in Figure 1.

A publication team was responsible for generating outputs for various platforms such as a PDF storybook, eBook, DVD and a website. An edutainment team developed a game for each of the four books being animated. A design team provided art direction including style guides, characters, environments, audio and visualisations. Finally, a marketing team was responsible for developing a promotional video trailer, branding and identity, promotional posters, a book and documentary of the development process. Examples of the artwork from three of the stories are given in Figure 2.

Figure 3 contains a picture of design students looking at a motivational model for the Gunter's Fables project. The project was printed on a large roll of paper and displayed on the back wall of the Design lab for the capstone students. Anecdotal conversations with the students suggested that having the model so visible was helpful for keeping a project focus.

The overall motivational model is in the left hand part of the diagram. The four separate teams each had a submodel which were in the columns across the page. The goals were developed with the students in the spirit of co-creation and so were a reminder of what needed to be achieved.

Note that the colour red is prominent in the model. The design project colour coded the goals, where red was at an incomplete stage and green represented a completed goal. This model was from the early stage of the project. More about the benefits of colour coding projects is given in [16].

Detailed goal models were created for each of the four animations produced. The models served as a project management tool that communicated a repeatable animation process for teams to follow, and is described in [17]. Primary goals and emotional goals were later incorporated into a new approach for communicating and producing three-dimensional character animation, and is the subject of [6]. Both the Aspergion and Gunter's Fables capstone projects demonstrated the use of multi-level agent-oriented goal models in developing, managing, and evaluating large Design projects.

V. Conclusions and Future Work

The interdisciplinary collaboration between software engineering and design at Swinburne University of Technology has been fruitful. It has led to goal-focused workflows and interactions between non-technical stakeholders (designers and clients), and novel methods for requirements elicitation and process communication within design.

Future work will expand on the data collected during the PhD research. There are new evaluation techniques involving motivational modelling. The techniques involve both a qualitative and a quantitative approach.

Acknowledgments

The authors would like to acknowledge discussions with members of the Future Self and Design Living Lab at Swinburne University of Technology. The current write up was partially supported by ARC Discovery grant DP200102955, 'Maturing design-led innovation processes with motivational models'.

References

[1] K. Aspelund, *The design process, 3rd edition*. Bloomsbury, 2014.

[2] I. Somerville, *Software Engineering, Tenth Edition*. Pearson, 2015.

[3] M. Answell, *Agile Project Management*. Independent, 2020.

[4] UK design Council, "What is the framework for innovation? design council's evolved double diamond," 2021 [Online]. [Online]. Available: https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond

[5] J. Marshall, "Towards wonderful design elements, principles, methods and applications," Ph.D. dissertation, Swinburne University of Technology, 2021.

[6] S. Murdoch, "A new approach for the communication and production of three-dimensional computer assisted character animation," Ph.D. dissertation, Swinburne University of Technology, 2021.

[7] B. Boehm, "A spiral model of software development and enhancement," *SIGSOFT Softw. Eng. Notes*, vol. 11, no. 4, p. 14–24, Aug. 1986. [Online]. Available: https://doi.org/10.1145/12944.12948

[8] E.-M. Schön, J. Thomaschewski, and M. J. Escalona, "Agile requirements engineering: A systematic literature review," *Computer Standards & Interfaces*, vol. 49, pp. 79–91, 2017.

[9] T. Tenso, A. H. Norta, H. Rootsi, K. Taveter, and I. Vorontsova, "Enhancing requirements engineering in agile methodologies by agent-oriented goal models: Two empirical case studies," in *2017 IEEE 25th International Requirements Engineering Conference Workshops (REW)*, 2017, pp. 268–275.

[10] L. Sterling and K. Taveter, *The art of agent-oriented modeling*. MIT Press, 2009.

[11] L. Sterling, S. Pedell, and G. Oates, "Using Motivational Modelling With an App Designed to Increase Student Performance and Retention," in *Early Warning Systems and Targeted Interventions for Student Success in Online Courses*, D. Glick, A. Cohen, and C. Chang, Eds. Hershey, PA, USA: IGI Global, 2020, pp. 161–176. [Online]. Available: http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-7998-5074-8.ch008

[12] L. F. Barrett, "The theory of constructed emotion: an active inference account of interoception and categorization," *Social cognitive and affective neuroscience*, vol. 12, no. 1, pp. 1–23, 2017.

[13] K. Taveter and T. Iqbal, "Theory of constructed emotion meets re," in *2021 IEEE 29th International Requirements Engineering Conference Workshops (REW)*, 2021, pp. 383–386.

[14] Apple, "Apple manifesto," 2013. [Online]. Available: http://www.apple.com/designed-by-apple

[15] O. Demirblek and B. Sener, "Product design, semantics and emotional response," *Ergonomics*, vol. 46, pp. 1346–1360, 2003.

[16] J. Marshall, "Agent-based modelling of emotional goals in digital media design projects," in *Innovative Methods, User-Friendly Tools, Coding, and Design Approaches in People-Oriented Programming*. IGI Global, 2018, pp. 262–284.

[17] S. Murdoch, "Agent-oriented modelling in the production of 3d character animation," Studies in Australasian Cinema, vol. 10, no. 1, pp. 35–52, 2016. [Online]. Available: https://doi.org/10.1080/17503175.2015.1133486

Fig. 3. Motivational Model for Capstone project