Pearce, J., & Howard, S. (2004). *Designing for Flow in a Complex Activity.* Paper presented at the 6th Asia-Pacific Conference on Computer-Human Interaction, New Zealand.

# Designing for Flow in a Complex Activity

Jon M Pearce and Steve Howard

Interaction Design Group, Department of Information Systems, The University of Melbourne, Australia, 3010
jonmp@unimelb.edu.au showard@unimelb.edu.au

## Abstract

**Abstract.** One component of a user's interaction with computer systems is commonly referred to as 'flow'. Flow is an important consideration in interactive system design as it encapsulates some of the affective aspects of human behavior. The majority of current thinking conceptualises flow as a desirable and somewhat enduring emotional state that a user may enter during an activity. Analysis of data from 59 users engaged in an interactive online learning task contradicts this prevailing view. We show firstly that flow, rather than being enduring, is highly changeable during the term of an interaction. This challenges both current theoretical models of flow, and the current research methodology used to study the phenomenon. Secondly, we show that flow arises from an engagement either with the interactive artefact or the task being performed. This is an aspect of flow not well distinguished in other studies. Finally, we present initial analysis that suggests flow can be undesirable in some circumstances – that there may be competition between task and artefact for the attention of the user. In response, we present a 'process' view of flow as a counterpoint to the existing 'state' based models.

## 1 Introduction

In studies researching the role of affect in human interaction with computers, the related concepts of flow [1], motivation and play are frequently explored. These are often grouped as 'affective factors' and used to complement the effectiveness, efficiency and satisfaction aspects of user-experience [2].

In this paper we describe an experiment in which it was found useful to focus on flow as a *process* rather than a *state.* In the context of an online interactive learning system, we consider the manifestations of flow, how to measure flow and how to design to maximize it. We present a visualization of flow as a process as well as some of the experiences that users (in this case, students) describe when they have experienced flow in this online learning context.

## 2 Flow

In 1975 Csikszentmihalyi coined the term ‘flow’ to refer to ‘optimal experience’ events [1]. Flow describes a state of complete absorption or engagement in an activity and has been studied in a wide range of disciplines including HCI, psychology, information systems and education. For example: Web use and navigation [3]; Web marketing [4]; in everyday life [1, 5]; in group work [6]; technology use in information systems [7]; in HCI [8]; and in instructional design [9, 10]. This section gives a brief introduction to flow and the challenges encountered in measuring it.

### 2.1 Flow and online learning

Flow has been postulated by many as a desirable state to support learning [1, 4, 8, 11]. A ‘flow activity’ is one in which the mind becomes effortlessly focussed and engaged, rather than falling prey to distractions. Such an activity will usually comprise a clear set of goals, timely and appropriate feedback, and, most importantly, a perception of challenges that are well matched to the user’s skills. As a result, a user might obtain a high degree of control over the activity and experience deep engagement or concentration. The activity will become enjoyable for its own sake and will often lead to a lack of awareness of the passage of time.

Many flow studies use retrospective interviews and surveys to observe participants over extended periods of time: days or weeks rather than minutes or hours. Such studies describe flow as a state attained during a particular activity: for example, when engrossed in a computer game or engaged in aspects of professional work. Draper [11], in contrast, proposes that a user may ‘flick in and out’ of flow from moment to moment. In being critical of Csikszentmihalyi’s model of flow, he draws a distinction between flow during routine actions not requiring mental attention and flow requiring complete mental attention. It is during the latter that he postulates such rapid shifts might occur. Whilst he offers no evidence for these shifts, his postulation suggests that interviews and surveys may be instruments that are too blunt to observe flow in these situations.

In this study we were interested in monitoring flow during a short learning activity (40 minutes) in which deep engagement is essential. Whilst an educator might hope that participants maintain a high level of engagement throughout the entire activity, in reality we expected to see movements in and out of the flow state. Hence we designed an experiment to monitor flow attributes in a more fine-grained fashion and to observe users’ movements amongst the flow states.

This study was carried out in an educational setting where the motives of control, concentration and enjoyment are important. However, many of the attributes of flow are desirable in the design of other computer-based system in which the aim is to engage the user and maintain that engagement.

### 2.2 Flow models and measurements

The research referenced earlier [1 to 10] presents several different techniques for measuring flow. One commonly-used technique is to survey participants, after an activity, to obtain Likert scale ratings for the affective measures of control, engagement and enjoyment [8, 12]. From these measures a score is derived that represents the overall degree of flow for the duration of the activity. This technique is used in our research as one measure of flow.

An alternative established technique, also used in this research, is to monitor the balance between the user's perceived challenge of an activity and their perception of their skills to carry out that activity. Flow theory predicts that a user will experience flow if their perception of the challenge of a task is balanced with, or slightly greater than, their perception of their skills to carry out the task. If these are out of balance, then the user may become anxious (challenge much greater than skills) or bored (challenge much less than skills). The perception of these challenges and skills has been described as '*theoretically, the most meaningful reference point for the presence or absence of flow'* [13] and has been established as a reliable measure of flow [14].

Often this representation of flow is presented on a 2-dimensional plot of challenge versus skills. The space on this plot can be partitioned into three, four, eight, or even sixteen 'channels', each channel representing an emotional state of the user. We have chosen to interpret our data using the 3-channel model shown in Figure 1 in accordance with Csikszentmihalyi's early work on flow [1]. This choice was made in recognition of the nature of learning, which offers the potential of flow even though the learner's skills may begin low and increase significantly during the activity. For example, a learner might begin a task with low skills and recognise that the challenge presented to her is low, yet commensurate with her skills. This low-challenge/low-skills situation could still induce a flow state. As the learning progresses, and the task increases in complexity, we might expect the learner to move up the flow channel to a region in which she is more highly challenged, but still commensurate with her (now improved) skills.

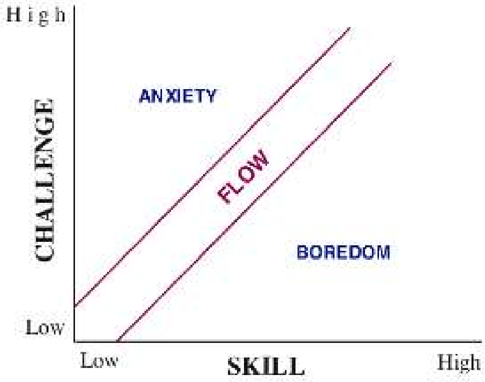

Fig. 1. Three-channel model of flow. We define the region where challenges and skills are balanced as 'flow'. An imbalance results in a state of 'anxiety' or 'boredom'.

## 3 An experiment to monitor flow

The experiment described here aimed to identify flow patterns in an interactive online learning context, using two measurement techniques that focused on flow as a *process* and a *state*, respectively.

### 3.1 Experiment

**Set-up.** An experiment was conducted involving 59 first-year university students who worked through an online learning exercise in the domain area of physics. The exercise included interactive multimedia elements. Students worked in a computer lab comprising about 25 computers. They were first presented with an introductory screen requesting general background information about themselves followed by a pre-test to establish their prior knowledge of this area of physics (19 multiple-choice items). After an introductory screen, they worked through the sequence of seven physics learning pages, each containing explanatory text, a simulation of a cart moving along a track with related motion graphs, and navigation elements. Although each of the learning activities was a discrete Web page, they each used the same interactive simulation and progressed naturally from one to the next. Finally, students were presented with a post-survey, which gathered information about affective aspects of their experience (control, engagement and enjoyment), and a post-test which measured learning gains using the same question items as the pre-test.

In a follow-up study, eight students individually worked through a similar exercise whilst being monitored by video in a usability lab. They were interviewed after the session about their reaction to the various elements of flow that they experienced during the session.

For students in both studies their navigation and interaction with the simulation were recorded by Web server logs for later analysis. In the discussion that follows, any references to statistics or patterns of interaction relate to the initial cohort of 59 students; references to interview data relate to the group of eight interviewed later.

Flow measurement. **To obtain a fine-grained measure of flow throughout the exercise, we monitored the students' challenge and skill perceptions at the end of each of seven learning activities. This was achieved using two 5-point Likert scale items which asked the questions: "How challenging (or stimulating) did you find what you just did?" and "Were your skills appropriate for understanding it?". Response choices were from "too low" to "too high". The challenge-skill ratios derived from these data enabled us to categorize students into one the three states 'anxiety', 'boredom' or 'flow' after each activity in the exercise.**

For comparison, we also obtained a singular measure of flow from the post-survey at the end of the exercise. These data were analyzed using two similar models of flow reported by others that involved measures of control, engagement and enjoyment [6, 8].

### 3.2 Analysis

Data from the seven challenge-skill probes were used to plot each individual's 'flow path' through the learning exercise. The plot for one student is shown in Figure 2. Each square of the space represents one of the 25 possible states defined by the two five-point Likert scales measures of challenge and skill. The dotted 'flow-line' represents the ideal flow condition of challenge = skill.

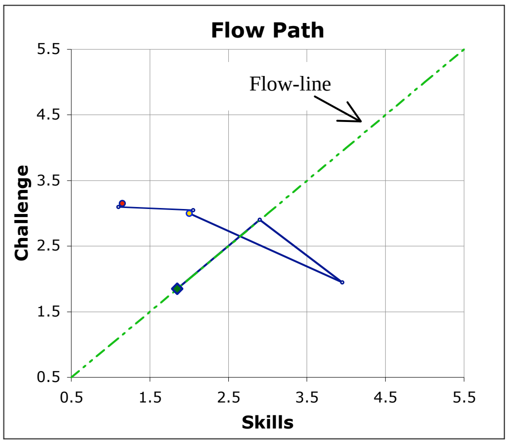

**Fig. 2.** Flow path for a student. The path commences on the 'flow-line' at the lower left and progresses initially upwards, in the end representing relatively high challenge but low skills.

This particular plot shows the 'flow-path', in challenge-skill space, of a student who performed very well on the exercise in terms of learning outcomes. It tells the story of her progress through the seven activities of the learning task. She began the task with relatively low skills and perceived the first activity to be relatively low challenge (bottom-left of path). The second activity she found more challenging but she also rated her skills as having increased to meet the challenge. The third activity presented less of a challenge and she still perceived her skills as increasing. The final two activities presented more challenge and she felt her skills were becoming increasingly less adequate for the requirements of the task.

This student's plot has some consistency with a flow model of learning: the student's perceived challenges and skills grew together through the first part of the learning exercise. However, for her, the final activities were difficult and she completed the activity sequence in a state of some anxiety.

Inspecting such plots for the cohort of 59 students does not show any clear pattern linking these diverse flow-paths to the post-survey flow measures. Students moved frequently between states during the exercise indicating that flow is a more complex concept than can be represented by a singular measure. Rather than relying on a single flow measure, or *state*, recorded at the end of the session, we need to regard flow as a *process* that changes throughout the activity. We developed a new visualization of this process in order to obtain a better understanding of what was occurring.

**Flow as a *process* versus flow as a *state*.** The experiment provided data on flow both from the students' reflections at the end of the learning activity, 'final-flow', as well as from data gathered throughout the activity. The question arises as to how these two different views of flow are related. The former provided us data on flow as a state, giving us insight into a student's retrospective view of what happened during the whole activity. A student might indicate an average high or low level of flow throughout the activity, but such a blunt instrument cannot describe the changing states as the activity progresses. Students' responses might also be biased by specific events that dominated their experience.

The data gathered throughout the activity provided us with a view of the twists and turns that occurred as the students grappled with the (complex) learning tasks. It enabled us to form a finer-grained picture of how the different challenges presented resulted in a perception of increasing skills by students who were coping, or in frustration and anxiety by students who had not yet grasped the necessary concepts. In applying flow theory to learning in this manner we expect to observe such variations as students show their individual learning differences in response to the materials and the concepts they were expected to master. The value of this process view is in the light it sheds on how different students react to different aspects of the activities, and how the activity design needs to recognize these differences and adapt to maintain an optimal challenge-skill balance.

To make a comparison between these two measures of flow we defined the quantity 'from-flow-distance' as a measure of how far an individual's challenge-skill ratio is from the flow-line (challenge/skill = 1) on the flow-path plot (see Figure 2). The expression for this quantity is derived from the geometry of the 5x5 challenge-skill space of the plot and is as follows:

$$\textit{from-flow-distance} = 0.25 \times (\textit{skill} - \textit{challenge})$$

We calculated a value of from-flow-distance for each student for each of their seven activities as well an average value from their whole experience. We looked for a relationship between the flow recorded during the activity and the flow recorded at the end ('final-flow') in three ways. The first way was a visual examination of the flow-path plots looking for patterns of flow-like behavior correlating with final-flow ratings. We detected no discernable patterns that linked measures of flow recorded during the activity with the final reflective value that the students recorded through their questionnaires. Next we explored a statistical correlation between the from-flow-distances and the final-flow values for the cohort of students. This also showed no correlation between these two methods for measuring an overall value of flow.

Finally, we performed a statistical correlation between each student's seven activities' from-flow-distances and their final-flow value. In this third analysis we observed an interesting result. This is shown in Figure 3 as a plot of from-flow-distance versus final-flow for each of the seven pages of the exercise. Pages 2, 5, 7 and 8 resulted in correlations above the critical value ($r_{crit} = 0.322$, $p<0.02$).

The graph shows strong primacy and recency effects on pages 2 and 8 respectively (page 2 contained the first learning activity, page 8 the last activity). This suggests that the final-flow value measured by the survey may be dominated by the students' interactions on the first or final page of the activity. The spike on page 5 is interesting. The task on that page introduced a physics situation that many of the students found confronting, namely, that the cart was moving in one direction while it was accelerating in the opposite direction. This page also produced the highest average challenge score for all students. The suggestion here is that this particular challenging activity captured the students' interest in a way that influenced their final affective rating of the task as a whole.

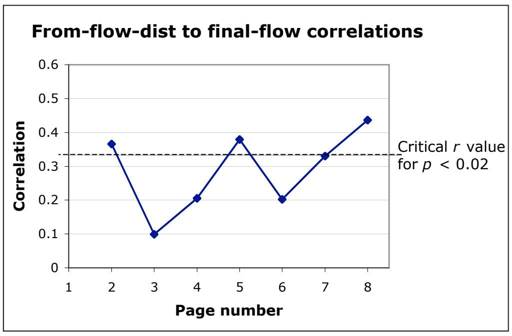

**Fig. 3.** Correlations of from-flow-dist to final-flow for the entire cohort for each page of the exercise.

The interesting outcome from the above analyses is the lack of a clear mapping between the students' responses during the exercise and their reflections at the end. Even students who indicated strong engagement, enjoyment and control in the final survey did not exhibit consistent flow patterns in their flow-paths. Students experienced a variety of ups and downs in their perceptions of challenges and skills that did not necessarily relate to their final-flow values. This suggests that we should not focus too strongly on a reflective measure of an extended 'flow experience' but rather should look at the process through which students pass during the exercise.

We have seen that the flow process can be a convoluted one and reflects the complexity of the interactions that the students undertook. However, due to the poor correlation with post-survey flow measures, this analysis also raised the interesting question of "what is being represented by this process?". To answer that question we interviewed several students about their experience during the exercise as discussed in the next section.

## 4 Distinguishing task from artefact

The post-interviews with the eight students aimed to explore the various elements that comprised a flow experience. We aimed to gain a richer understanding of how flow manifested itself in this online learning context as well as how this might relate to learning. In particular, we wanted to gain a better understanding of the challenge-skill plot information provided by the students' experiences during interaction with the learning environment.

It readily became apparent that a simple challenge-skill measure was not an adequate technique for indicating the complex behavior during a learning session.

Many times during the interviews students made clear distinctions between when they were focusing on the task (in this case a *learning activity)* and when they were focusing on the technological artefact (a *screen-based simulation).* This distinction between task and artefact has rarely been acknowledged in the flow literature [15, 16]. It strongly influenced the students' interpretation of both challenge and skills as their minds moved between one and the other. This was strikingly put by one student:

> *"the simulation wasn't challenging but the concept that I got from the simulation was challenging."*

Without knowing what the student's mind is focussing on at any moment, we cannot know how to interpret the challenge-skill plots in terms of flow.

Similar consideration must be given to how the students described their experience of some of the attributes of flow. For example, control and feedback, both essential elements of flow, were also interpreted as relating to either the task or the artefact. This leads to important considerations of the meaning of such terms when evaluating software involving interactive elements and a complex task.

Feedback is particularly important in an online learning environment. It is ambiguous to simply ask whether feedback is adequate. The feedback from the *artefact* (a simulation, in this case) might be quite clear: dragging and dropping an object on the screen might give clear feedback as to what had been achieved with the software. However, at the same time, feedback from the *task* might be quite confusing: the resulting output from the simulation might not assist the user in constructing the desired concepts.

Our conclusion from these experiments is that, whilst the system provided the same feedback to all students, those with better domain knowledge were able to interpret it more effectively than those with poorer knowledge. This is critical information for the design of engaging learning systems: the feedback essential for flow must take into account the individual's prior learning or domain knowledge. Whilst students could focus their minds on the artefact, or the task, or both, when the concepts were demanding it was the task that tended to dominate this concentration. Feedback is not simply an attribute of the software, but a consequence of the user's interaction with the system and how well its output fits their mental schema.

## 5 Implications for design

Others have written about considering flow in Web design and the benefits of doing this are becoming more commonly accepted (see, for example, [17, 18]. The contribution from this research is to consider how the learning gained from understanding flow in an online interactive learning environment can be applied to the design of such an environment.

The general benefits of, and requirements for, flow are quite well understood. However, these are often considered for tasks that are either not well specified (e.g. 'using the Web') or are rather simple and confined (e.g. selecting a product from a list in an on-line shopping site). When the task itself is *complex* and the artefact also has a degree of complexity, then we may observe competition between task and artefact for the attention of the user.

The consequence of this is particularly important in designing for an appropriate level of *challenge* that will be perceived by the user. The challenges will vary from user to user but they should lead the user to focus on the *task*, not the artefact. This means that the artefact (Web page, simulation, etc.) must be sufficiently engaging without becoming a distraction to the user's attention. It should be transparent and allow the user to focus on the higher order task. This is hard to achieve since it relies on some knowledge of the user's skills both with the artefact and within the domain of the task. These are likely to vary considerably from user to user in a learning environment.

Similarly, the feedback presented to the user from the artefact should not distract the user from engaging with the task. The user needs to experience a sense of 'direct engagement' [19] when using the artefact so that challenges from the task can be addressed and explored. Through this the user needs to derive a sense of control over both artefact and task.

To measure how successful one has been in obtaining flow with a user in a learning context, a challenge-skill measure is useful but it needs to be carefully focused on the task. Whereas flow might be experienced by a user focusing on the artefact alone (having a fun time playing with a simulation, but learning little; we call this 'artefact flow'), our aim is to move the user's flow into the realm of the task and to engage her there ('task flow') and to focus her mind on learning about specific concepts, rather than merely playing with the software artefact. Flow could have a negative impact if it engages and distracts a student *away* from the learning task. Given the intrinsic enjoyment offered by many online activities, and the difficulty of many learning tasks, this can be a real danger.

## 6 Conclusion

Flow is an important consideration in designing for the Web in many contexts. The learning context presents challenges in terms of producing highly motivational materials in order to encourage students to use them and learn from them. In the research reported here we took a fine-grained approach to observing flow by monitoring challenge and skills throughout an activity and comparing this to other traditional measures of flow. This comparison suggested that flow is better viewed as a process rather than a state.

For flow to be a useful measure in this context, we need to ensure that we distinguish between measurements of 'task flow' and 'artefact flow'. Whilst the former has potential to enhance learning, the latter may actually distract the student from engaging with the concepts being presented.

The research prompts further questions about the relationship between flow and learning and the nature of an interactive environment that might encourage flow. These issues are currently being addressed by the researchers.

## References

1. Csikszentmihalyi, M., Beyond Boredom and Anxiety. 1975, San Francisco: Jossey-Bass Publishers.
2. Bentley, T., L. Johnston, and K.v. Baggo. Affect: Physiological Responses During Computer Use. in 2003 Australasian Computer Human Interaction Conference, OzCHI 2003. 2003. University of Queensland.
3. Chen, H. and M. Nilan. An Exploration of Web Users' Internal Experiences: Application of the Experience Sampling Method to the Web Environment. in WebNet 98 World Conference. 1998. Orlando, Florida.
4. Novak, T.P., D.L. Hoffman, and Y.-F. Yung, Measuring the Flow Construct in Online Environments: A Structural Modeling Approach. Marketing Science, 2000. Winter.
5. Csikszentmihalyi, M., Finding flow: the psychology of engagement with everyday life. 1st ed. MasterMinds. 1997, New York: Basic Books. ix, 181.
6. Ghani, J.A., R. Supnick, and P. Rooney. The Experience of Flow in Computer-Mediated and in Face-to-Face Groups. in Proceedings of the Twelfth International Conference on Information Systems. 1991. New York.
7. Agarwal, R. and E. Karahanna, Time flies when you're having fun: cognitive absorption and beliefs about information technology usage. MIS Quarterly, 2000. 24(4): p. 665 - 694.
8. Webster, J., L.K. Trevino, and L. Ryan, The Dimensionality and Correlates of Flow in Human-Computer Interactions. Computers in Human Behavior, 1993. 9(4): p. 411-426.
9. Chan, T.S. and T.C. Ahern, Targeting Motivation - Adapting Flow Theory to Instructional Design. Journal of Educational Computing Research, 1999. 21(2): p. 151-163.
10. Konradt, U., R. Filip, and S. Hoffmann, Flow experience and positive affect during hypermedia learning. British Journal of Educational Technology, 2003. 34(1).
11. Draper, S., Analysing fun as a candidate software requirement. http://www.psy.gla.ac.uk/~steve/fun.html. 2000.
12. Ghani, J.A., Flow in human-computer interactions: test of a model, in Human Factors in Information Systems: Emerging Theoretical Bases, J. Carey, Editor. 1991, Ablex Publishing Corp.: New Jersey.
13. Massimini, F. and M. Carli, The systematic assessment of flow in daily experience, in Optimal experience : psychological studies of flow in consciousness, M. Csikszentmihalyi and I.S. Csikszentmihalyi, Editors. 1988, Cambridge University Press: Cambridge ; New York. p. 266-287.
14. Novak, T.P. and D.L. Hoffman, Measuring the Flow Experience Among Web Users. 1997, Paper presented at the Interval Research Corporation.
15. Finneran, C. and P. Zhang, A Person-Artifact-Task (PAT) Model of Flow Antecedents in Computer-Mediated Environments. International Journal of Human-Computer Studies, Special Issue on HCI and MIS, 2003. 59(4): p. 397-402.
16. Finneran, C.M. and P. Zhang. The challenges of studying flow within a computer-mediated environment. in Eighth Americas Conference on Information Systems. 2002.
17. King, A.B., Speed up your site: Web site optimization. 2003: New Riders.
18. Novak, T.P., D.L. Hoffman, and Y.F. Yung, Measuring the Customer Experience in Online Environments: A Structured Modelling Approach. 1999.
19. Hutchins, E.L., J.D. Hollan, and D.A. Norman, Direct Manipulation Interfaces, in User Centered System Design, D.A. Norman and S.W. Draper, Editors. 1986, Lawrence Erlbaum: Hillsdale NJ. p. 87-124.