Breaking the Flow
Examining the Link between Flow and Learning in Computer-Mediated Learning Environments

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Abstract: In the context of research concerning computer-mediated learning environments (CMLEs), the construct of flow, or optimal experience, has been positively linked with students' learning outcomes, such as affective and cognitive perceptions of learning and the development of academic skills. However, this linkage is compromised by inconsistent characterizations of flow across studies and divergent measures of when flow may have occurred during learning. Further, characterizations of learning have differed across studies (i.e. self-reported attitudes about one's learning experience or one's academic achievement). In this paper, we review these inconsistencies and discuss how meta-analysis may be one means by which we can examine whether flow does impact learning within CMLEs, given the differing operationalizations of flow and learning that are found within the extant literature.

1 INTRODUCTION

The concept of flow, or optimal experience, as first introduced by Mihalyi Csikszentmihalyi (Csikszentmihalyi, 1990), has been examined in the context of diverse activities such as sports, classroom learning, and more recently online and computer-mediated learning environments (de Freitas and Neumann, 2009; Liao, 2006; Shin, 2006; Voiskounsky, 2008). Flow can be characterized as a state in which individuals are "in the zone" or immersed in the task at hand, such that concerns about performance become less salient. Further, Csikszentmihalyi (1990) has likened flow to optimal performance, positive feelings of well-being, and enjoyment. In the academic realm, flow has been associated with enhanced academic performance, particularly in traditional classroom settings. For example, high school students who reported experiencing flow while writing English essays submitted better work and were more engaged in the activity than students who did not report as such (Larson, 1988). In the online learning realm, Liao (2006) found that college students who reported being in flow during their online courses were more likely to engage in online course activities than those who were not in flow.

The linkage between factors such as flow and learning has garnered much research attention particularly in computer-mediated learning contexts (Konradt, Filip, and Hoffman, 2003; Liao, 2006; Shin, 2006), which includes learning via mobile device applications and online learning modules. These contexts are becoming increasingly ubiquitous in higher education (Allen and Seaman, 2010). Online learning in this context refers to courses whereby all or a significant portion of the instruction and learning activities are presented via the Internet. Findings show that learning outcomes in online courses are comparable to, or in some cases, superior to learning in traditional classroom environments (Allen, Mabry, Mattrey, Bourhis, Titsworth and Burrell, 2004). One contributing factor to enhanced academic performance in online learning environments is the engagement they evoke (Arbaugh, 2010). In fact, some researchers contend that online learning environments or computer-mediated environments (CMEs) in general promote flow (Chen, Wigand, and Nilan, 1998; Hoffman and Novak, 1996; Liao, 2006). One striking issue that has plagued this work, however, is the diversity of operationalizations and measurements of flow. This situation compromises conclusions that can be

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drawn about how flow may impact learning in these environments.

Initial characterizations of flow in CMEs were drawn from Hoffman and Novak (1996) whose characterization of the components of flow as experienced during web browsing were adapted by other researchers. Hoffman and Novak's model of flow replicated much of Csikszentmihalyi's original formulation (as discussed below) and constructs derived from the media literature including interactivity and telepresence. Researchers (Chen, et al., 1998; Choi, Kim and Kim, 2007; Novak, Hoffman and Yung 2000) then modified Hoffman and Novak's (1996) framework to investigate flow in CMEs often with far less extensive characterizations of flow that fell far short of Csikszentmihalyi's original formulation (Liu, et al., 2011). Thus, diverse characterizations of flow have been reflected in the CME literature, which includes similarly diverse means of measuring flow. For example, researchers have assessed flow experiences via surveys that span diverse time frames in which individuals may attain and lose the flow state (Choi, et al., 2007; Konradt, et al., 2003; Liao, 2006; Liu, et al., 2011; Shin, 2006) or may follow by several months after a given activity has occurred (Choi, et al., 2007; Liao, 2006). This situation limits conclusions about whether flow does influence learning in CMEs.

The fundamental question remains whether flow is experienced during CMEs generally and CMLEs (computer mediated learning environments) more specifically, and how the experience of flow may affect learning. Given the lack of consensus about how flow occurs in CMLEs, conclusions about whether CMLEs allow for flow or at minimum, learner engagement, are not readily drawn. Further, the body of literature concerning CMLEs and flow spans diverse disciplines that tend to perpetuate, within discipline, a particular conceptualization of the flow construct. In this paper, we review these issues and make suggestions for clarifying the flow construct as linked to learning outcomes within CMLEs.

2 FLOW AND ITS CHARACTERIZATION

Flow refers to a state of optimal performance whereby individuals feel in control of their behavior while engaged in motivating activities, and report extreme enjoyment or self-transcendence (Csikszentmihalyi, 1988). According to Csikszentmihalyi (1988), flow is experienced across diverse domains and activities, is all-absorbing, and seemingly automatic despite occurring during cognitively demanding tasks (Csikszentmihalyi, 1988). He further noted that those experiencing flow were more likely to re-experience it. Therefore, flow is best characterized as cyclical, whereby its attainment is positively correlated with the desire and likelihood of re-attaining it.

According to Csikszentmihalyi (1988; 1990), flow is comprised of nine major components reflecting the general categories of *antecedents*, *experiences*, and *effects or consequences*. One antecedent includes a balance between perceived skills required to complete an activity and optimal challenge whereby the activity is neither too easy nor too difficult. When one's skills are low and challenges posed by the task are too easy, an individual may experience apathy. If one's skills are high, but challenges posed by the task are too easy, an individual may experience boredom. Similarly, when one perceives one's skills as insufficient given the demands of the tasks, the individual may experience anxiety and abandon the task. Accordingly, ideal flow situations are those in which the challenges become progressively difficult as one's skills improve. Two further antecedents include a clear, attainable goal and unequivocal feedback from the situation.

Aspects of the flow experience entail the merging of action and awareness, which is accompanied by focused concentration that culminates in the paradox of control (Csikszentmihalyi, 1988). Here, the individual feels in control of his actions during a task, despite a seeming automaticity and effortlessness to his behaviors. The three flow effects include the loss of self-consciousness, the transformation or distortion of time, and a resulting enjoyable experience.

Csikszentmihalyi first examined flow within the context of athletic performance (Csikszentmihalyi, 1988; Csikszentmihalyi, 1990). For example, while interviewing high-achieving athletes about their performance in their respective sports, Csikszentmihalyi (1988, 1990) noticed that each described key accomplishments in similar ways: the loss of self-consciousness, the sensation of being carried or flowing on a current, and the feeling of being present in the moment despite exposing their bodies to stressful physical circumstances. Participants also reported feeling compelled to re-engage in these activities when they accomplished their goals, if only for the opportunity to achieve new goals and the self-fulfillment that accompanied their success. For example, Sato (1988) found that Japanese adolescents' motorcycle riding produced positive feelings of well-being among those engaged in the activity, a sense of community with fellow riders, and pride from applying their skills to the challenges of the rides.

3 MEASUREMENT OF FLOW

Since the late 1970s, the standard technique for measuring flow had been the Experience Sampling Method (ESM). This tool, first used by Csikszentmihalyi and colleagues (Csikszentmihalyi and Larson, 1987; Csikszentmihalyi, Larson, and Prescott, 1977), was designed to allow real-time measurement of flow experiences. Specifically, individuals were given paging devices that randomly "beeped" during a given interval of time. When the devices beeped, participants were to stop what they were doing and answer questions about the activity in which they were currently engaged. For example, participants were asked what they were doing, where they were doing it, their emotional state, involvement in the activity, perceptions of activity challenges, perceptions of their skills to meet these challenges, interest and motivation to engage in the activity, concentration levels, their sense of self-consciousness, and control. Csikszentmihalyi and LeFevre (1989) found, via this technique, that individuals tended to report experiencing flow more often while on the job than during leisure activities despite their greater motivation to engage in leisure activities. Notably, those who were more engaged in a given activity when they were beeped reported happier feelings, greater creativity, concentration, and satisfaction than those who were less engaged. Other researchers using ESM and its derivations have since documented flow in diverse activities across cultures including daily labor, educational settings, web navigation, electronic gameplay, and computerized simulations (Carli, Delle Fave and Massimini, 1988; Chen, et al., 1998; Csikszentmihalyi and Csikszentmihalyi, 1988; Csikszentmihalyi, 1990; Larson, 1988; O'Broin and Clarke, 2006; Shernoff et al., 2003).

4 FLOW IN TRADITIONAL LEARNING ENVIRONMENTS

Flow also has been studied in diverse educational contexts. For example, Shernoff, et al. (2003) examined flow in the context of student engagement in classroom activities using data from a three-year longitudinal study of 526 10th and 12th graders. These students participated in discussions that were either teacher-led or student-led and required skills and challenge levels that varied from low to high. Participants then completed surveys concerning aspects of flow such as engagement, attention, motivation, and enjoyment, with regard to the activities completed in class and their perceived performance in these activities. Students' perceptions of high challenge and skill levels were associated with greater engagement in their coursework than when they perceived lower challenge levels. When experiencing flow, students reported greater interest, concentration, and enjoyment than those not experiencing flow (Shernoff, et al., 2003).

Larson (1988) also found that characteristics of flow correlated with better research papers produced by high school students for their junior-year English class than when these characteristics were absent. In his study, students were to write 10-page papers over the term, and to review and to revise their work based on teacher feedback before submitting final drafts. Larson (1988) compared students' survey responses about their emotional states while writing their essays with their essay grades to determine how flow characteristics predicted their performance. Students who demonstrated aspects of flow, as reflected by enjoyment in the activity, also demonstrated effective self-regulation strategies to stay on task, and achieved their goal of writing well-structured and well-researched papers according to their teachers. Students who experienced flow, regardless of time spent on the task, were more creative, more efficient and received higher grades than peers who did not cite flow. Further, those who did not demonstrate aspects of flow set expectations that were unrealistically high, were more anxious about their goals for completing their papers, and received poorer grades than their counterparts who reported flow.

Collectively, these findings show that in traditional learning environments students who achieve flow as opposed to those who do not, are more engaged in and attentive during their schoolwork (Shernoff, et al., 2003), more successful at achieving their academic goals (Larson, 1988), better at employing self-regulation strategies (Larson, 1988), more likely to show gains in self-esteem following the activity (Shernoff, et al., 2003), experience greater enjoyment (Shernoff, et al., 2003), and report less anxiety about their schoolwork (Larson, 1988). Studies eliciting these findings, however, are not grounded in all original nine variables that Csikszentmihalyi cited as requisite for the flow experience. This situation reflected a situation whereby researchers made selective choices about which variables to include in their investigations of the flow experience. Among the variables selected most often were the balance of perceived skills to perceived challenges and perceived control. Among the variables most often excluded were feedback, time distortion and loss of self-consciousness. The selective addition and deletion of components of Czikszentmihalyi's model was notably evident in the literature concerning flow in the context of CMLEs as discussed below.

5 EXAMINATION OF FLOW IN CMLES

Given educators' increasing interest in online learning, research examining flow in the context of CMLEs (Chen, et al., 1998; Ghani, 1995; Voiskounsky, 2008; Webster, Trevino and Ryan, 1993) has become more salient. Across this growing body of work, very clear distinctions in the operationalization of flow, the timing of its assessment, and the characterization of learning have emerged. Specifically, flow has been described via characterizations that reflected all, some, or none of Csikszentmihalyi's original formulation (1988; 1990). Second, flow has been assessed at variable times intervals such as during learning activity sessions (consistent with Csikszentmihalyi's ESM approach) or after, sometimes with significant delays. Finally, although researchers have often claimed to have measured learning via content or skills acquired after a given activity (reflecting a direct learning measure), in most if not all studies as reviewed below, learning has been assessed via attitudes about the activity or one's skills (reflecting an indirect learning measure). These discrepancies have ramifications for understanding the linkage between flow and learning within CMLEs and begin with defining the flow construct.

5.1 Divergence in the Operationalization of Flow

Researchers who first studied flow in the context of CMLEs did not see Csikszentmihalyi's (1988; 1990) original formulation as applicable. For example, Hoffman and Novak (1996) built a model to examine flow in the navigation of consumer web sites that started with Csikszentmihalyi's nine characteristics and then also incorporated extrinsic motivation, as demonstrated by goal-directed search (where search referred to those conducted while navigating a given website); intrinsic motivation, or non-directed search; users' level of involvement in the task at hand, interactivity of the medium, vividness of the site, and telepresence or the "mediated perception of an environment" (see Steuer, 1991, p. 76). According to Hoffman and Novak, the attainment of flow was linked to increased learning, perceived behavioral control, willingness to explore (in their case, websites), and positive subjective experiences. They demonstrated this in studies examining participants' exploration of a consumer website (Novak, et al., 2000), whereby reported experiences of flow were significantly, positively correlated to respondents' perceived skills, perceived challenges of browsing the web site, telepresence, and to the interactive speed of the web site.

Despite only a few variables being shown to link directly to flow, researchers would continue to draw from and test the work of Hoffman, Novak and colleagues (Hoffman and Novak, 1996; Novak, et al., 2000). Some of these researchers who drew on Hoffman and Novak's (1996) work used predictors that seemed unique to CMEs, such as interactivity (Liao, 2006) and telepresence (Shin, 2006). For example, Liao (2006) found that within a distance learning course, interactivity was more predictive of flow than undergraduate participants' assessment of the balance of skills to perceived challenges; a finding that contradicted the accepted notion that the balance of skills and challenges is the best predictor of flow (Chen et al., 1998; Konradt, et al., 2003; Massimini and Carli, 1988; Pearce, Ainley, and Howard, 2005). Shin (2006) incorporated telepresence into a factor analysis to clarify how the flow antecedents of perceived skills, perceived challenges, and clearly defined goals, contributed to the flow experiences of enjoyment, telepresence, focused attention, engagement and time distortion within online coursework. The findings showed that these five experience factors accounted for nearly 60% of the variance in explaining flow. Further, flow was significantly positively correlated with the balance of skills and challenges and overall satisfaction with online courses.

Others would omit variables, such as the perceived balance of skills and challenges that were common in flow studies and instead examined the appeal of the activities themselves. For example, Ryu and Parsons (2012) assessed the link between flow and learning using a mobile device application via a seven-question Likert scale drawing on two variables from Csikszentmihalyi (1990) to predict flow, which were cognitive curiosity, and intrinsic interest, and added risk-taking behavior, or attempts to explore aspects of the learning environment not required by the task instructions. Flow was indirectly linked to learning through each of these three predictors demonstrating participants' voluntary willingness to explore the environment further, greater importance given to the activity, and more motivation to learn.

Still other researchers examined flow with respect to only one of Csikszentmihalyi's (1988; 1990) original nine predictors of flow; the balance of perceived skills and perceived challenges (Csikszentmihalyi and LeFevre, 1989; Konradt, et al., 2003; Liu, et al., 2011; Pearce, et al., 2005). For example, Liu, et al., (2011) examined flow and learning through use and acquisition of problem-solving strategies among 110 first-year university computer science students constructing railway system simulations follow lecture or lab activities. The authors hypothesized that students in flow would show better problem-solving strategies than students who were anxious or bored; essentially, the antithesis of flow. Findings indicated that flow was more likely to occur when the students were actively engaged in building simulations than passively involved in the lectures. Specifically, when building simulations, over 55% of students achieved flow; 21% of students achieved flow when attending lectures. Liu, et al., (2011) offered a unique contribution to the literature in that they demonstrated that flow was correlated to a direct learning outcome, namely that participants in flow appropriately transferred successful problem-solving strategies to new situations more often than those who did not achieve flow. However, this finding was only marginally significant.

Choi, et al., (2007) assessed flow using participants' self-report of whether they had experienced it, their ratings of its frequency, and its intensity. Participants were asked to answer survey questions two to three months following the end of the course to determine whether flow impacted individuals' self-efficacy with technology while using an e-learning system. Students' self-reports of flow were significantly, positively correlated with their attitudes towards or satisfaction with e-learning and with technology self-efficacy.

Notably, one set of researchers (Pearce, et al., 2005) evaluated flow in two ways; the first entailed a situated measurement that assessed flow immediately after each of seven learning activities by asking participants to rate their perceived skills to meet the perceived challenges (Massimini and Carli, 1988; Konradt, et al., 2003). From these seven skill/challenge ratios the researchers tallied a final, in-situ score for flow. Pearce et al., (2005) also assessed flow a second way using a post-hoc questionnaire following all seven activities. Flow was operationalized by the variables of control, enjoyment and engagement. Surprisingly, the post-hoc measure of flow did not correlate with the in-situ measure of students' flow states. This finding was perplexing as the balance of perceived skills to perceived challenges as used in the in situ measure, and control, enjoyment, and engagement from the post-hoc measure are all variables that have been established as predictors of flow and should have yielded a positive correlation. Therefore, the authors re-examined participants' post hoc reports of flow and found that they were correlated with the most memorable of the seven activities that participants had just experienced. When the researchers were comparing the post-hoc measure to a summed total of the seven distinct in situ measures they had conflated flow and non-flow moments. Thus, the predictors of flow were less important than the timing of the flow assessment to the supposedly flow-inducing activities.

5.2 Measurement and Timing of Flow within CMLEs

The timing of flow measurement is critical to the accuracy of individuals' self-report. If it is too delayed, memories fade leaving reports of the experience in doubt. In ESM, participants' perceptions of flow states are assessed as soon as they receive the alert to report on their state. However, ESM has been criticized because it removes participants from the state to be assessed (Weber, et al., 2009). A survey of the literature indicates that researchers have assessed flow using both in-situ and post-hoc measures. For example, Pearce, et al., 2005 examined flow in-situ, following each of the seven potentially-flow inducing activities, and after the entire set of seven learning activities. Other researchers have assessed flow in non-situated ways and with significant time delays. In fact, Ryu and Parsons (2012) assessed flow days after the flow-inducing activities occurred and Choi, et al. (2007) and Liao (2006) did so months after these activities ended.

Variants in the timing of flow may be an artifact of researchers' efforts to adapt measurement of flow to web-based environments. For example, Chen et al, (1998) adapted ESM for the web such that a survey assessing flow would appear directly on the screen on which the respondents already were viewing. In their study, their flow conceptualization was consistent with that offered by Csikszentmihalyi. As part of their investigation, they designed a questionnaire to "pop up" randomly and frequently during web browsing sessions as participants navigated different sites. The researchers found evidence of flow in users' experiences, particularly, when the users perceived themselves as able to navigate a given site.

Researchers also have adapted ESM for use within learning activities occurring on computers or within CMLEs. For example, O'Broin and Clarke (2006) adapted the Chen, et al. (1998) pop-up web survey to design a computer-based and mobile application which recorded students' assessment of their perceived skills, perceived challenges; clarity of the activity's goals; understanding of feedback; meaningfulness of the activity; amounts of concentration; and feelings of control. Findings showed that participants were in flow 81% of the time when engaged in a given task.

Capturing the flow state as close in time to when it likely occurred is the goal of many studying flow (Chen et al, 1998; Csikszentmihalyi and Lefevre, 1989). Conceivably, this is because measurement accuracy should be higher when more closely situated to the flow experience. For example, Pearce et al. (2005), in the study described above, noticed that participants who did well on the learning activities demonstrated skill growth as the scaffolded challenges increased. Specifically, the skill/challenge ratios following the first activity, the fourth activity (which was highly-challenging and thus, presumably memorable), and the sixth and seventh activities significantly correlated with the post-hoc measure of flow. The authors concluded that primacy effects, recency effects, and highly salient events, such as greatly challenging tasks, predominated participants' overall assessment of their experiences reporting their flow states after all activities had been completed. This conclusion highlights the importance of contextualizing flow measurement to particular moments in time and not generally as flow may vary during the course of an activity or over the course of a set of related activities.

Additional criticisms of flow measurement include assessing flow as related to an activity in general and not to a specific moment when flow may have occurred (Weber, et al., 2009). For example, Shin (2006) and Liao (2006) assessed students' flow states as related to perceptions of their online coursework overall rather than specific activities where they may or may not have been in flow. The use of ESM and adapted ESM techniques has greatly improved flow measurement by allowing researchers to assess flow immediately after having experienced it (Csikszentmihalyi and Larson, 1987; Csikszentmihalyi and LeFevre, 1989). However, studies that utilized adapted ESM techniques did not examine flow's link to learning (O'Broin and Clarke, 2006) and studies that utilized other forms of in situ measurement of flow did not establish links to direct learning outcomes (Pearce, et al., 2005). There is inconsistency about what flow is and despite clear recommendations in the research specifying that flow should be measured as close in time to the supposedly flow-inducing moments, researchers measure flow in non-situated ways and with significant delays following the activities. Therefore, conclusions about flow's linkage to learning are dubious.

5.3 Flow Linkages to Learning Outcomes within CMLEs

Findings that examine the linkage between flow and learning outcomes, especially direct learning outcomes, are limited. For example, Liu, et al., (2011) as noted above, demonstrated flow's link to successful use of problem-solving strategies. However, these researchers assessed students' perceptions of flow following a six-week lecture period, and later following a two-week period of building simulations thereby conflating flow and non-flow moments within each assessment and neglecting appropriate measurement of the construct. Therefore, this situation compromises conclusions about whether it was flow that was linked to learning, or another aspect of the instructional situation unrelated to participant's flow levels.

Far greater evidence of flow's linkage to indirect than direct learning outcomes is reflected in the literature. For example, flow has been shown to yield greater satisfaction with learning (Choi, et al., 2007; Liao, 2006; Shin, 2006), self-efficacy within the medium (Choi, et al., 2007), intentions to engage in the learning environment again in the future (Liao, 2006), exploratory use of the environment (Liao, 2006; Ryu and Parson, 2012), and motivation to learn and involve oneself in the activity (Ryu and

Parsons, 2012). Compromising the linkage between flow and indirect learning in these situations is that flow was assessed either independent of a given learning activity (Liao, 2006; Shin, 2006) or long after the activity concluded (Liao, 2006; Ryu and Parsons). A consistent definition of flow and a situated and timely measurement of flow's impact on learning outcomes would reduce doubts about claims of flow's linkages to learning,

6 CONCLUSIONS

The fundamental set of questions that emerges from the literature is whether flow occurs within CMLEs, and if so, how best to measure it and facilitate it so as to impact learning. The promise of flow is that it is all-absorbing engagement in a task and it motivates individuals to engage in an activity, to exceed their current skills, and to continually increase their expertise in this domain. This situation is desirable in both formal and informal education contexts.

However, characterizations of flow in CMEs and CMLEs have been inconsistent. Similarly, researchers' measurement of flow have deviated widely from Csikszentmihalyi and colleagues' (Csikszentmihalyi and Larson, 1987; Csikszentmihalyi, et al., 1977) goal to capture the flow experience as close in time to its occurrence. As noted above, many researchers have assessed flow long after its occurrence has passed.

As part of our efforts to clearly identify trends in these differing definitions of flow and its measurement as linked to learning within CMLEs, we suggest the use of meta-analysis, as currently being undertaken in our work. The goal of our meta-analysis is to extensively examine the pool of relevant studies to determine if the divergent methods of defining and measuring flow demonstrate consistent impact on direct or indirect learning outcomes. It is anticipated that given the diversity of flow characterizations and measurement that a homogeneous effect, which would signify one universal impact of flow on learning across all studies, is highly unlikely. More likely, the overall meta-analytic effect size will demonstrate heterogeneity, whereby some flow characteristics might demonstrate stronger links to direct and indirect learning outcomes as compared to other flow characteristics that demonstrate weaker links to learning.

Given that learning might be influenced more by a small number of flow characteristics, such as the balance of skills to challenges and the interactivity of the CMLE, the meta-analysis would recommend flow characteristics and combinations of those characteristics that demonstrate the kinds of learning gains that are possible when learners actually achieve the flow state. Further, certain situated measurements of flow might demonstrate greater occurrence of flow, or increase the certainty that flow actually occurred as compared to significantly delayed measurements of flow that might produce further doubts to flow's association with learning. Since flow is difficult to capture the more time has elapsed and the more general the measurement is to flow moments, even without the benefit of our meta-analysis, one may conclude that researchers should avoid non-situated and delayed measures of flow.

By offering an operationalization of flow that demonstrates its ability to impact learning within CMLEs and situating its measurement close in time to its occurrence, this meta-analysis would offer a starting point for more consistency in this area of the literature. Thus, examining flow's link to learning outcomes within CMLEs could be more easily compared across studies because when flow is discussed it is certain that there is a consistent definition and reliable measure of flow.

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