Student Transformative Learning in Software Engineering and Design: discontinuity (pre)serves meaning

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Abstract

Reflective practice is considered to play an important role in transformative learning of educationally critical material, but students often respond in other, less productive ways. Transformative learning is used here as a lens to investigate reflectiveness: understanding the place of reflectiveness – and how defensiveness has no place – in transformative learning illuminates its operation and mechanism. The paper is written as part of an ongoing exploration into how to engender students' reflective response to difficult material, preparing a foundation on which to address that question directly. Previous preparation includes phenomenological analysis of reflectiveness and defensiveness, and a careful examination of the operation and mechanism of defensiveness, both based on Segal's explication of Heidegger's dynamic of rupture. Qualitative data for the investigation comes from an upper-level undergraduate software engineering and design course that students invariably find quite challenging. A grasp of concepts presented here should enable faculty to develop improved pedagogy and institutions to design more effective curricula for engendering students' reflective response to difficult material in computing – and other – education.

Keywords: defensiveness, reflectiveness, phenomenology, experiential learning, dynamic of rupture, pedagogy, curriculum, student feedback, confusion

1 Introduction

The real voyage of discovery consists not in seeing new landscapes but in having new eyes. – Marcel Proust

True learning begins as an encounter with the unknown and existentially unfamiliar, and therefore includes some interval of confusion that the student must navigate productively in order to reach knowing. Alternatively, if the student does not navigate that interval productively, an encounter with the unknown and existentially unfamiliar leads not to learning but to other, more problematic outcomes. In the former, the student is said to respond reflectively; in the latter, the student is said to respond defensively. This paper is written as part of an ongoing exploration into the operation and mechanisms involved in students' responding reflectively (to navigate the interval of confusion productively), and what is required to support it.

Preparation is required before addressing that question directly. The exploration began with a phenomenological investigation of reflectiveness and defensiveness, based on the literature. In particular, Segal's explication of Heidegger's dynamic of rupture provides a conceptual structure for analyzing students' experience: the sequence *rupture* → *explicitness* → *response* (either *reflective* or *defensive*) (Segal 1999). On that basis, the first paper contained careful definitions of reflectiveness and defensiveness, with some guidelines on recognizing instances of the dynamic of rupture among students and discriminating between the two possible responses (Schwartzman 2006). A subsequent paper analyzed the treatment of defensiveness by several classic sources (Segal alone – oriented in the gestalt of the dynamic – regards it as equally substantive with reflectiveness), and delineated more precisely its operation and mechanisms (Schwartzman 2007).

Qualitative data for the investigation comes from an upper-level undergraduate software engineering and design course that students invariably find quite challenging.

1.1 The Research Question

The ongoing exploration is motivated by the question most educationally productive, relevant to reflectiveness: how to engender a reflective response (which is required for transformative learning) among all students; or, among those students who do respond defensively, how to cultivate transition to reflectiveness. Building on considerations already addressed, the exploration continues here with an investigation into reflectiveness, viewed through the lens of transformative learning, to delineate more precisely its operation and mechanisms.

1.2 Pedagogy and Curriculum

An established profession or discipline is characterized by a body of esoteric knowledge that a prospective practitioner must master in order to become – and be recognized by the community as – a skilled professional (Johnson 2001). That esoteric knowledge includes difficult, counter-intuitive concepts so critical to

understanding the discipline that they permanently transform the practitioner's view of it. Making the transition from not-knowing to knowing that esoteric content, successfully navigating passage through the interval of confusion, depends on transformative learning. Such learning does not happen in a cumulative or linear fashion; it is often little understood and poorly supported in the formal education and training into a discipline. Understanding the role of reflectiveness (and the absence of defensiveness) in transformative learning should enable faculty to develop improved pedagogy and institutions to design more effective curricula for engendering students' reflective responses to difficult material in computing – and other – education

1.3 Organization of the Paper

Section 2 summarizes the literature background. Section 3 introduces transformative learning. Section 4 speaks to the role of reflectiveness in transformative learning. Section 5 holds a brief overview of software design course CSX, source of qualitative data for this paper. Section 6 contains data. Section 7 contains discussion of implications of this work. Section 8 holds conclusions and possibilities for future work.

2 Background Literature

This section contains a brief overview of reflectiveness and defensiveness, and an introduction to some classic literature sources on transformative learning.

2.1 The Dynamic of Rupture

Segal's analysis of reflectiveness and defensiveness uses Heidegger's dynamic of rupture as a conceptual framework (Segal 1999, citing Heidegger (1985)). For more information, see (Schwartzman 2007).

2.1.1 Overview

This dynamic can be explained by Segal's (1999) example from Dreyfus (1993), familiar to anyone who is traveling internationally for the first time, perhaps to attend a conference: Each of us 'knows' what particular distance to stand apart from an acquaintance when engaged in conversation. In general, we have no awareness of the specific distance, or even that we are doing it. This 'know-how' resides in the realm of the unseen taken-for-granted. However, when we encounter conference host country natives who use a different conversational distance, we experience them as standing uncomfortably close or uncomfortably far away, and we suddenly become aware that we have an accustomed distance. According to Segal – and it is borne out by the student data from CSX – this discomfort is experienced either productively (reflectively) or unproductively (defensively). Segal's explanation of distinct forms of differentness clarifies the two possibilities.

2.1.2 Distinct Forms of Differentness

Segal, citing Bauman (1990), distinguishes between two kinds of differentness or otherness: the oppositional (in shorthand, *enemy*) and the unknown (in shorthand, *stranger*). The oppositional is defined according to the same rules as we, but oppositely. Continuing the example of interpersonal conversational distance, the international traveler may respond: "These unrefined (host country) natives are standing the wrong distance away. I can't possibly carry on a civilized conversation under such conditions." Their differentness is thus defined in opposition: their 'wrong' vs. one's own 'correct' distance, 'unrefined' vs. 'refined' nature, 'uncivilized' vs. 'civilized' actions. Defining the other in opposition, as *enemy*, confirms one's view of the world. Questioning of one's own or the other's behavior has no place. *Enemies* oppose each other but have a common appreciation of the terms on which they meet; they *function in the space of the existentially familiar ...*

Alternatively, the unknown is defined by unknown rules, or perhaps not defined at all. The international traveler may respond, "What is happening here?", and eventually, "What does this mean? Do I have an accustomed distance? If so, how did I learn it, what length is it measured at? Do they have an accustomed distance? If so, how do I learn it, what length is it measured at, and how do I figure it out? How long will it take to learn, what will I do in the meantime? ..." Recognizing the other as unknown, as *stranger*, evinces the inadequacy of our worldview. Questions, but no real answers, abound.

Strangers have no common understanding of the terms on which they meet. *[They] give rise to the existentially unfamiliar ... [T]here are no ways of reading [such] a situation that can be taken for granted. ... The anxiety of strangeness is experienced not only in the face of the stranger but in the face of strange and unfamiliar situations – in any situation in which we cannot assume our familiar ways of doing things* (Segal 1999 p.76, citing and quoting Bauman (1990 pp.143-145)).

2.1.3 Reflectiveness and Defensiveness

In summary, rupture is required for explicitness; explicitness serves as pre-condition to both reflectiveness and defensiveness, which include significant affective components: unease and uncertainty are engendered by the shock of estrangement following rupture and explicitness. Defensiveness shields the responder from having to experience the estrangement, the unease, and the uncertainty: one disassociates from engendered uncertainty by recasting the unknown (strange) explicit as the known oppositional (enemy) explicit; one disowns engendered unease by projecting or displacing all responsibility for difficulty onto that recast source. In defensive response, one avoids the challenges of uncertainty and its affective components; for example, the first possible response attributed to the international traveler (2.1.2). In reflective response, one takes on those challenges; for example, the second possible response attributed to the traveler (2.1.2).

2.2 Transformative Learning

This paper draws from several classic literature sources on transformative learning, all speaking virtually of one

accord about reflectiveness, albeit from varying perspectives. Each organizes the information in a distinct way, using different vocabularies: *How We Think*, John Dewey's 1910 book on educating for reflective thought; *The Structure of Scientific Revolutions*, Thomas Kuhn's seminal book on the history and historiography of science; and *Transformative Dimensions of Adult Learning*, Jack Mezirow's study of adults' transformative learning. Dewey is interested in developing students' capacity for critical thought so that it becomes available for application to any content domain. He uses the study of various academic subjects as specific examples for the general habit of mind he wishes to inculcate: well-prepared reflectiveness (Dewey 1991). As a historian of science, Kuhn studies patterns of 'learning process' in communities of practice. He directs attention to the nature of *discovery*, whereby principles are reformulated and practice transformed. The process begins in anomaly, conflict between observed phenomena and a community's operative model for interpreting the world. Kuhn examines conditions under which that conflict gives rise to new models, tension generated by competition among models for dominance, and ways in which scientific communities navigate and ultimately resolve that tension (Kuhn 1996). Mezirow chaired the Department of Higher and Adult Education at Columbia University. In addition to reporting his own research, he draws on and cites a wide spectrum of scholarship related to transformation theory (Mezirow 1991).

The work of Aron Gurwitsch (1964) on the organization of fields of consciousness provides a rich framework for discussing various concepts relevant to the investigation.

Elements of striking symmetry connect Kuhn's work on the development of new scientific knowledge with that of Dewey on an individual's intellectual progress. The discovery process of an established research community encountering persistent anomalies appears almost as an isomorphic projection from the learning process of an individual encountering educationally critical, counter-intuitive concepts in an established body of knowledge.

3 About Transformative Learning

Introductions to components, a situating context, and well understood aspects, as well as definitions, follow.

3.1 Components of Transformative Learning

3.1.1 Meaning

Every source cited for this paper talks explicitly about the primacy of meaning. Mezirow defines meaning as *an interpretation, and to make meaning is to construe or interpret experience ... [done] both prelinguistically ... and through language ... [by] processes involving awareness. In other words, it gives coherence to experience* (Mezirow 1991 p.4). Dewey considers the absence of meaning an anomaly; he believes that the exercise of intelligence requires its existence, and to grasp it constitutes *the nerves of our intellectual life* (Dewey 1991 p.116). Meaning amounts to a coherent representation of experience, but cannot be arbitrarily imposed; it arises out of experience. *Saliency of a group of data so that this group emerges and segregates itself from the stream [of experience] is a feature not introduced into the stream, but yielded by the stream itself* (Gurwitsch 1964 p.31, citing James (1890)).

For Dewey, individual learning may be defined as making meaning; what one can interpret effectively, one understands both differentiated from and in relationship with its surrounding context (Dewey 1991 p.117).

3.1.2 Meaning Frames

Meaning making takes place under an orienting frame of reference, a *structure of assumptions within which one's past experience assimilates and transforms new experience, ... a habitual set of expectations.* Such structures embody the categories and rules that order new experience, shaping how we classify our encounters with the world: what we take in and how we act. They also dictate what we notice and what we ignore by *selectively determin[ing] the scope of our attention ... informed by an horizon of possibility, ... to simplify, organize, and delete what is not salient in sensory input ... and provide the basis for reducing complex inferential tasks to simple judgments.* Thus, they function as both *lions at the gate of awareness and the building blocks of cognition* (Mezirow 1991 pp.49,50).

Further, these structures define composite and prime elements (Kuhn 1996 p.129). A *composite* element can be decomposed to yield component parts relevant to meaning, a *prime* element cannot. For the reader seeking to understand an essay, its sentences (and their decomposition into constituent words) exemplify the former; constituent letters of those words exemplify the latter. For the calligrapher, in contrast, alphabetic letters (and their decomposition into keystrokes) represent composite elements (Simon 1996).

Note that sources for this paper use a variety of terms for these structures: *meaning schemes, meaning perspectives, frameworks of understanding*, *unconscious principles and assumptions, paradigms, schemas*, etcetera. Meaning frame is here used interchangeably with all of them.

Dewey states that *[e]xplicit thinking goes on within the limits of what is implied or understood*, and describes the role of these 'premises', the grounds or foundations, in reasoning: the premises contain the conclusions and the conclusions contain the premises. The importance of coherence as an organizing principle is embodied in that relationship (Dewey 1991 pp.81,215). Similarly, Kuhn describes operation under a paradigm as a fundamental principle of science, with both the structure and the constraints that imposes: *All research takes place within the context of a paradigm ... All observations are paradigm-based ... The commitments that govern normal science specify not only what sorts of entities the universe does contain, but also, by implication, those that it does not* (Kuhn 1996 pp.79,126).

Meaning frames operate below the level of awareness, as an *unconscious* system of ideas. They inhabit the realm of the unseen, taken-for-granted: *The old, the near, the*

*accustomed, is not that **to** which but that **with** which we attend* (Dewey 1991 p.222).

3.1.3 Awareness: organization of consciousness

Meaning frames refer to what one brings within oneself to engage in and interpret an encounter with the world. The work of Aron Gurwitsch enables reference to those aspects of the world that one takes in or one acts upon through the meaning frame. He asserts that every field of consciousness, regardless of content, exhibits a *universal, formal pattern of organization* comprising three domains or dimensions: the *thematic focus* or *theme*, upon which one's mental activity concentrates; the *thematic field*, aspects of the world co-present with the thematic focus and having relevance to it; and the *margin*, aspects of the world co-present with the thematic focus but irrelevant to it (Gurwitsch 1964 p.56).

Meaning frame operation and field of consciousness organization exist interdependently: meaning frame dictates what aspects of the world one's awareness encompasses at any given moment, which elements among them have direct significance (corresponding to what occupies the thematic focus), which have significance by association (corresponding to content of the thematic field), and which have little or no significance (corresponding to marginalia).

Booth summarizes Gurwitsch's work: The structure of awareness may be thought of as a dynamic relationship between oneself and the object of one's consciousness. One brings the totality of one's experience and awareness to the perception or consideration of some aspect of that object. The object is said to 'present' itself in that awareness; how it does so determines the thematic focus to emerge from it, and the attendant elements of relevance constituting the thematic field. A shift in one's awareness to another aspect of the object brings a corresponding shift in the thematic focus and thematic field. In contemplation of an object, one shifts one's awareness alternately among its different aspects. Each attendant shifting organization of the dimensions of one's consciousness may be enacted by delineation of a different element of the thematic field into thematic focus (Booth 1997 pp.141,146).

The more differentiated one's view of an object (the more aspects one can bring awareness to), the richer the set of elements in the thematic field associated with it and the more varied the set of elements that can serve as a thematic focus during contemplation of the object; thus, the deeper one's understanding. Consequently, a sparsely populated – or empty – thematic field leaves little possibility for deep understanding.

In the example of the traveler at the conference, conversation with host country natives was taken as the object of her consciousness, and standing distance between her and them became the thematic focus. Elements in the thematic field included observations and recollections. She observed host country natives talking with each other, host country natives talking with attendees from other countries, and attendees from other countries talking among themselves. She recalled standing distance in conversations at home with close friends or family, or with strangers, and how that distance varied depending on conversational content and the nature of the encounter.

3.2 An Embedding Context: learning

Transformative learning is situated within a larger context of learning generally.

3.2.1 Experiential Learning

All the classic sources on which this paper draws hold to a model of experiential learning. Sources speaking to it explicitly describe common underlying phenomena and a common process, although they may bring attention to different aspects. Those not speaking to it explicitly rely on the same phenomena and process as implicit model. According to the model, *learning is always grounded in prior experience, and any attempt to promote new learning must take into account that experience* (Boud 2001 p.11). Dewey thinks that, most often, *ordering of thought is attained through ordering of action*, and that tacit knowledge (required for acting effectively) precedes explicit knowledge (required for describing coherently): *[T]he development of an unconscious logical attitude and habit must come before [the conscious use of such an attitude]. ... [The conscious setting forth] is valuable only when a review of the method that achieved success in a given case will throw light upon a new, similar case* (Dewey 1991 p.41,132,113).

3.2.2 Meaning Frames: dynamic entities

In the normal course of our encounters with the world, meaning frames undergo endless refinement. Popper states: *We have been born with the task of developing a realistic set of expectations about the world based on the coded messages we receive from it. We can't even be sure of the code but must keep checking [constantly] on it.* (Berkson and Wettersten 1984 p.16). One's *selective and conceptualizing faculties are persistently at work* (Gurwitsch 1964 p.30). The *concept is always under construction* (Kuhn 1996 p.2). Encounters with the world also occur outside that normal course. As Dewey observes, any aspect of the world, no matter how well known, may suddenly present an unexpected and incomprehensible problem (Dewey 1991 p.120). When that occurs, refining the meaning frame does not suffice. Instead, a different kind of learning is required.

3.2.3 A Template for Learning

The factors enumerated above characterize CSX students' learning as well. The data illustrate that students learn the material – whether one homework's lesson or the overarching course objectives – only through experience (reinforced by discussion). For that reason, CSX homework assignments are structured to lead students through a series of experiences that bring their practice and (mis)understanding into awareness. Booth endorses this approach (Booth 1997 p.149).

Further, when new experience conforms to expectations grounded in students' extant frameworks of

understanding, learning happens cumulatively and with little additional thought. However, new experience violating expectations creates discontinuity; it leads either to a different kind of learning (when the student responds reflectively) – or to no learning (when the student responds defensively).

3.3 Initiation and Consequences

The classic sources concur in their comprehension and descriptions of these aspects of transformative learning.

3.3.1 In the Beginning: discontinuity

Discontinuity in knowing arises from a *conflict between what is known and what must be understood* (Mezirow 1991 p.163, citing Loder (1981)). This conflict, *anomaly,* is defined entirely in relation to one's meaning frame; it occurs as violation of the expectations carried therein. In the absence of an extant meaning frame, anomalies do not exist, by definition. A meaning frame is required to bring the anomalous nature of a phenomenon to light, but inadequate to resolve the problems raised by its existence (Kuhn 1996 p.122). In the example of the traveler, her meaning frame for conversational standing carried the habitual distance to which she'd been socialized; the phenomenon of host country natives' standing distance was defined as an anomaly in relation to it. *Troublesome knowledge* denotes an anomaly that cannot be avoided or ignored by the individual learner (corresponding to what Segal calls *rupture*). *Crisis* denotes the state induced in the relevant scientific community that cannot make an anomaly conform, avoid it, or ignore it (Kuhn 1996 p.ix).

Not all anomalies rise to a level of troublesome knowledge or crisis induction; at a minimum, persistence and significance are required. In the example of the international traveler, if the occasional host country native stands at an unaccustomed distance, the traveler can attribute it to that individual's eccentricities. But if virtually every host country native does so, the anomaly becomes an unavoidable phenomenon whose existential strangeness cannot be ignored.

3.3.2 Aftermath of a new meaning frame

Dewey describes the consequence of reformulation as clarity, illuminating *relations of interdependence between considerations previously unorganized and disconnected ... and* ***binding isolated items into a coherent single whole*** (Dewey 1991 p.80). With a new meaning frame, one is re-oriented in the world: the same collection of experience, organized along different principles, embodies a radically different set of relationships. Correspondingly, within a scientific community, *[a]lthough the world does not change with a change of paradigm, the scientist afterward works in a different world* (Kuhn 1996 p.121).

3.4 Definition(s)

Transformative learning arises from rupture in knowing. It is here defined in two ways. 1) Directly: through reformulation of meaning frame, transformative learning preserves meaning to effect coherence in transition across a discontinuity in knowing. 2) Indirectly: transformative learning is both differentiated from and related to deep learning, which occurs cumulatively, as described below.

3.4.1 Differentiation

At the level of individual intellectual progress, deep (cumulative) and transformative learning can be distinguished conceptually using Gurwitsch's fields of consciousness. As a result of deep learning, one switches dynamically – within the same field of consciousness – among thematic foci, with correspondent restructuring of thematic fields. The total set of elements in the field remains constant, while boundaries among the thematic focus, the thematic field, and the margin become fluid, and component elements shift between adjacent domains (Booth 1997 p.144). This corresponds to refinement and clarification of the extant meaning frame.

As a result of transformative learning, the field of consciousness changes: elements formerly not found in any domain of consciousness, possibly including component parts of elements formerly classified as prime, now occupy the thematic focus or reside in the thematic field, and some elements formerly found there are now relegated to the margin. This corresponds to formulation of a new meaning frame.

Kuhn makes an analogous distinction at the level of scientific development: In *normal science*, progress occurs cumulatively, an outgrowth of community practice dictated by and conforming to the reigning paradigm. A new theory (paradigm) doesn't originate via incremental change under these conditions. It begins with anomaly that rises to the level of crisis. *Extraordinary science,* the practice whereby crisis is resolved, requires that prior theory be reconstructed and prior fact be re-evaluated, an *intrinsically revolutionary process*. A new way of sense-making emerges: a way to organize, and then interpret and explain the world. This new paradigm in turn designates what constitutes the significant and what constitutes the irrelevant (Kuhn 1996 pp.7,76,128).

3.4.2 In Relation: cyclical alternation

The classic sources from which this paper draws all describe (albeit using different vocabulary) individual intellectual progress as an alternating rhythm of continuity and discontinuity, of consciousness (which *gives conviction and control*) and unconsciousness (which *gives spontaneity and freshness*) (Dewey 1991 p.217); that is, between deep and transformative learning. Similarly, scientific progress proceeds as alternation of *normal science* and *scientific revolution* (Kuhn 1996).

4 Transformative Learning and Reflectiveness

Next, I examine the transformative learning process. **Note**: 'operation' of a phenomenon refers to what occurs, 'mechanism' refers to how it occurs.

4.1 Transformative Learning: operational view

The classic sources give almost identical accounts of the operation and mechanism of transformative learning.

4.1.1 Individual Intellectual Progress

Dewey enumerates *five logically distinct steps common to all types of abstract thinking: i) a felt difficulty; ii) its location and definition; iii) suggestion of possible solution; iv) development by reasoning of the bearings of the suggestion; and v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief* (Dewey 1991 p.72).

Barer-Stein (and others cited by Mezirow) developed a five-phase sequence description, a phenomenological analysis of learning as a process of experiencing the unfamiliar: first, *being aware ... [characterized by the dominant question,] What is this?*; second, *observing ... How does this compare with what I know?*; third, *acting ... Shall I try it?*; fourth, *confronting ... Do I know this?*, and *Do I want to?*; fifth (if phase four questions are answered in the affirmative), *involving ... How did this come to be?, What are the possibilities, and which makes sense?, What [meaning] is relevant for me?* (Mezirow 1991 pp.84-85, quoting Barer-Stein (1987)).

4.1.2 Scientific (Community) Progress

Through the course of his book, Kuhn lays out the steps in the development of a *scientific revolution*. 1) *crisis*: observations of persistent anomaly, phenomena that violate the current paradigm with implications that cannot be ignored, and interrupt the practice of normal science (wherein the operative paradigm remains in the realm of the unseen, taken-for-granted); 2) *isolating the difficulty*: determining when, where, and what occurs, and precisely how it violates the current paradigm; 3) *proposal for a new paradigm*; 4) advocates who develop *a strongly reasoned argument in support of the new paradigm*; 5) ongoing debate and experimentation, enacting (for a successful paradigm) *rigorous evaluation*, *leading to gradual conversion of the relevant scientific community* (Kuhn 1996 pp.152,158).

4.1.3 Mechanism: the role of reflectiveness

Sequences enumerated in 4.1.1 define the operation of transformative learning. Reflectiveness is designated as *taking on the challenge of uncertainty and its affective components* (2.1.3), corresponding to steps 2, 3, and 4 in the sequence. That is, reflectiveness serves as the mechanism of transformative learning, and transformative learning is effected as a manifestation of reflectiveness.

To summarize the operational sequence: *discontinuity* → *reflectiveness* → *new meaning frame*. From CSX students' perspectives, it might be more accurately phrased as *confusion* → *struggle* → *knowing*.

4.2 Reflectiveness

From the source descriptions in section 4.1, one might construe reflectiveness (in the course of transformative learning) as an intentional process, with each step deliberately chosen in succession. However, as all the sources note, it happens as something other than either conscious choice or linear progression, and is *terminated by ... a relatively sudden ... unstructured event like the gestalt switch* (Kuhn 1996 p.122). Next, I examine both the operation and the mechanisms of reflectiveness.

4.2.1 Operational Sequence: the known

Segal, Dewey, and Mezirow (among others) describe the operation of reflectiveness as follows: When anomaly rises to a level of troublesome knowledge, it results in the need to re-evaluate one's meaning frame. One must determine the particular nature of the frame's inadequacies and reformulate it to correct them. Such re-evaluation begins with bringing the frame into one's conscious awareness. The incorporation of heretofore unseen, taken-for-granted elements into the thematic focus and thematic field(s) of one's consciousness is accompanied by much uncertainty and unease. If one can tolerate uncertainty and suspend judgment for long enough, one suddenly finds oneself encountering the world through a new meaning frame.

Using the example of the traveler: prior to the conference, her habitual standing distance resided in the realm of the taken-for-granted unseen. Early in the conference, the host country natives' unaccustomed standing distance could not be ignored or avoided. When she responded reflectively, their standing distance became an element of significance, perhaps intermittently even occupying the thematic focus of her consciousness as she attempted to manage the major distraction it posed. Her expectations were likely revised as follows: "I have been socialized to use a set of conversational standing distances particular to my culture. People in other cultures are socialized to the set of distances particular to their respective cultures. In any encounter with others, I can include within the field of my attention an awareness of our standing distance, adjusting it if necessary, for as long as it takes for us each to feel at ease." By conference end, she would be adjusting her standing distance without deliberate effort to accommodate the various culturally-related patterns – including her own – that she encounters.

4.2.2 Mechanism: value in the unknown

Under scrutiny, source descriptions are seen to leave much unexplained and to rely on ambiguous reasoning for describing reflectiveness. For example, Dewey simply states that because reflection originates in a problem, one must *at some points* consciously examine one's implicit assumptions (Dewey 1991 p.215). Further, details of the mechanism effecting reflectiveness, for example, the nature of interplay between conscious and unconscious forces involved, are left unspecified. This vagueness is well-founded; the mechanism of reflectiveness is not well understood, and remains *perhaps ... permanently inscrutable* (Kuhn 1996 p.90).

However, the literature has value; it assists in delineating more precisely what is known and what remains unclear about reflectiveness. In addition, the source descriptions provide a definition in progress for reflectiveness, and a way to approach and discuss what is not well understood.

5 CSX: the course, briefly

CSX, an upper-level undergraduate software engineering and design course, provides qualitative data for the paper. For more information, see Schwartzman (2006).

CSX is motivated by concerns about software quality as an ethical issue, and much of the course content is based on the work of David Parnas (2001). It is meant to teach software development fundamentals in a way that transcends software tools and languages, yet engages students in the actual practice of software, not just a theoretical or anecdotal exposition. Every one of the 15 class meetings during a semester includes substantive discussion on several aspects of software development other than code; translation to code (when mentioned) is treated as a small – and the easiest – step in the process. The first 12 of 13 assignments are to be done using pseudocode (for procedures) or English text (for documentation used as a design medium). A group project (assignments 10-13) is begun in class meeting 10. Assignments 10-12 are devoted to using documentation as a design medium, for both functionality and implementation; one half of assignment 12 requires pseudocode. Until assignment 13 (requiring use of a C++ compiler), students are strictly enjoined from coding.

6 Qualitative Data

6.1 Data Sources

Data for this paper derive from student project logs and end-of-term interviews. During the group project, students are assigned to keep logs (instituted for student accountability), a quantitative record of communication among group members, including participants, dates, times, and tasks accomplished. When students speak in (or outside) class of issues they're wrestling with or thinking deeply about, I invite them to record the material in their logs, promoting their more clarified thought and my more informed teaching. End-of-term interviews were devised for two purposes: they reveal the degree of students' overall knowledge of course material, enabling assessment of individual contribution to a group project; and they provide information about students' learning (or not) process. Initially, for the former purpose, I kept only occasional notes. I began recording interviews (by hand) for later analysis to serve the latter purpose: to better understand – and teach to improve – students' learning experience in the course. Sources are noted.

6.2 Methodology and Organization

6.2.1 Introduction to Methodology

Transformative learning occurs as a manifestation of reflectiveness. In this paper, I investigate the former – wherein meaning frames are reformulated – in order to better understand the operation and mechanism of the latter. The nature of a meaning frame is revealed through its operation; the encapsulated unconscious premises and expectations determine how one engages in and interprets encounters with the world. By definition, extant meaning frames elude conscious access, so they cannot be used directly to study student transformative learning. À la Proust's metaphor (*The real voyage of discovery consists ... in having new eyes)*: we cannot *see* our eyes (no one spontaneously speaks about the operation of her meaning frame), we can only see *through* our eyes. One does not have a point of view on one's point of view (Sartre 1966). Instead, internal change is projected onto the world, as indicated by CSX feedback data. Students' statements found in 6.3 make clear they know that – and somewhat how – (their relationship to) relevant aspects of the world have radically changed.

Transformative learning brings into awareness one's former (and formerly taken-for-granted, unseen) meaning frame, experienced – and described – as perceptions of (one's relationship to) relevant aspects of the world. End-of-term accounts often include some variant on the statement "Before, I only knew or did … as a way to write code; now I know a process that … as a way to develop software." These accounts present information about transformative learning (or not) by describing – and contrasting – 'before' and 'after' states of practice and points of view. In order for a study of student learning to use that state information, it must be represented in a form that is correlated with the salient features of transformative learning, and that allows comparisons among accounts. In other words, a representation scheme for that information must meet two conditions: well-defined correspondence to meaning frame operation, and standardized form.

Gurwitsch's framework satisfies the two conditions. His *universal formal pattern* for the organization of fields of consciousness comprises a standardized form, with well-defined correspondence to meaning frames (3.1.3). A characterization of student accounts as the contents of the three dimensions in a field of consciousness can act as a stand-in for the operation of a meaning frame, and thereby enable study of student transformative learning. Student experience of radically changed views and practice would be characterized as radically different 'before' and 'after' field of consciousness contents – most notably the presence in the 'after' field of elements unknown in the 'before' field – corresponding to the reformulated meaning frame of transformative learning.

Aside: Some computing education research evaluating how students understand software or systems depends on eliciting their mental and conceptual models (Ben-Ari *et al*. 2004). Meaning frame operation delineates what the models can – and cannot – encompass. Access to that operation (via fields of consciousness as stand-in representation) may support more informed elicitation.

6.2.2 Introduction to Data Analysis

Data analysis proceeded in three steps:

1. characterization, in Gurwitsch's framework, of students' descriptions of (their relationship to) software and software development (a phenomenological analysis of student accounts, essentially);
2. comparison of 'before' and 'after' states characterized in step 1, to identify and evaluate occurrences of transformative learning (or not);

3. preliminary classification of results from step 2, based on patterns of similarity and difference, to determine and categorize types of transformative learning that occurred.

Combined results of steps 1 and 2 are found in 6.4 and 6.5. Step 3 was conceived as an initial, broadly defined classification of step 2 results, from which would proceed a comprehensive phenomenographic analysis (Booth 1997 p.138) of student experience according to the extent and nature of their transformative learning. Due to space constraints, this coarse partitioning was interrupted. A glimpse of in-process results is found in 6.6.

6.3 Transformative Learning: evidentiary data

Data in this section indicates the occurrence – in various ways – of transformative learning among CSX students.

6.3.1 Operational Sequence

This student's account, excerpted from an end-of-term interview, closely matches Dewey's (4.2.1) operational sequence for *abstract thinking* / transformative learning.

(S_m107): (prior expectations: … *In this project, I'd thought the main focus was code*.)

i) a felt difficulty: *When we sat in the lab coding, and it wasn't working,*

ii) its location and definition: *I thought: there must be something to that module design document (I just happened to look at it while sitting in the lab). It said 'this invokes that' and we weren't doing it that way, and we were more focused on getting the code done.*

iii) suggestion of possible solution: *And I thought why did [the instructor] give us [these three weeks of other assignments] before code, if it's all about coding? I don't think you'd [the instructor] have given us all that time for other assignments [if it was all about coding]. … Maybe it's not all about the code. …*

iv) development by reasoning of the bearings of the suggestion: *It started giving meaning to me two weekends ago. The way I've always thought to do coding: … I'd try this way; if that didn't work, I'd try that way. And if I created a wonderful piece of software in a course, and today I wanted to write it in another language, I couldn't do it. …*

v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief: *With the [design in documentation already done], you just have to worry about the final step of coding it in [any] language.*

6.3.2 Eureka

These two student accounts, excerpted from end-of-term journals, are written from a perspective of reformulated meaning frames, the aftermath of transformative learning.

(S_m201): During this week, I have written the code based on the pseudo code and prior documents. It was amazing how quickly I was able to generate the code [1/2 hour] and how well it worked on the first run... Many modules, including the infrastructure module (which initially seemed to be the most complex) ran flawlessly on the first run. … I have really come to relate to [Parnas's] concept of faking the design process. … [In the past, when] I'd work with a team, we'd develop documentation, and find later on [w]hat we forgot to anticipate, [and] I'd throw up my hands and jump into the code. [Later, the student explained that s/he would now return to the documentation as a design medium, to think through the new, unanticipated, issues, before beginning to code.]

(S_m202): I was afraid the pseudocode would take me all week to do, so I started it on Monday of last week. It surprised me that I actually did the entire thing during Monday Night Football in about two hours, then revised it early on this week. [This student had remained skeptical of Parnas's approach throughout the semester. Her / his large programming project in another course was plagued with problems despite a month's hard work. Following that Monday night football game – one week before finals – s/he began the other project again, using an approach based on Parnas's work.]

6.3.3 Inside the Experience

Accounts from end-of-term interviews, one succinct, one expansive, document almost textbook examples of student experience as confusion → struggle → knowing.

Q: If you could change anything about this course, what would you change?
(S_v101): See, I don't know if I'd change anything; because I know, looking back on it, it sucked when you had to go through it. But looking back on it now, I can see why we did all the stuff that we did and the reasoning behind it.
Q: If I'd asked you this question early in the semester, what would you have said [to change]?
Everything

Q: Looking back over the course, does it appear different to you at the end of the semester than at the beginning or middle? If so, how?
(S_v102): Very different … [at the beginning of the semester,] it seemed like a piece of cake, no problem: read a book, write a program, and you're done, pretty much like any other programming class. … At the middle [just before beginning the group project], I was kind of torn between two worlds - I still wanted to jump right into coding, but I had to force myself not to. … You [the instructor] were pretty adamant about staying away from the computer and the compiler; Parnas was adamant too. … I had to think about what we did earlier in the semester and really implement what we learned. … I don't know how to say it; very much halfway between where I was at the beginning and where I was at the end. One side of me was saying 'Code', one side of me was saying 'Don't code'. I could see the point, but I didn't understand the picture. I understood each little point, but I didn't see how they fit together, until we started the project - or even the end of the project. At the end, that's when everything made sense, the big picture [came] at the end. It's important for future students [to know] … 'Do not get discouraged; keep with it, it will make sense'. I wish I could just stand in front of people thinking about

taking this class and say, 'Stick with it, it's tough but there's light at the end of the tunnel'. At the end now, looking back, I can say, 'Ah, now I see what [the instructor] was trying to teach us', but throughout the semester, that's not easy to see.

6.4 Analysis 'Before' and 'During': only coding

As noted in section 5, students are strictly enjoined from coding until week 13. End-of-term interviews illustrate that virtually all students found it extremely challenging – if not impossible – to begin the project without coding.

Q: What did you find most difficult in the project?
(S_m107): Trying to change my way of thinking about approaching a software development project; it was difficult not sitting at a computer, I want to sit at a computer right away and code. You're doing something different than you've done in all your other courses.

(S_m104): The coding [laughter] …
Q: Because you went to the coding right away?
Yes …

Q: Did your ideas about the contents of the four [group project] assignments change over the course of the project? If so, how?
(S_v102): Yes, most definitely. … We probably should have spent a lot of time on the documents, and then needed only a little time on coding. Instead, we spent a little time on documents, and a lot of time on coding. … We all had a great, big headache on Monday night; we were so stressed out, we barely looked at the earlier documents … Basically, what we've done in other classes: we've sat there, looked at the code, and given ourselves and each other headaches.

Any one student's consistent behavior of this kind indicates his / her inability to hear instructions specifying non-coding approaches. Such 'deafness' evidences the power of an established meaning frame to effect selective awareness. Virtually every student in CSX behaves this way, signifying a virtually universal 'before' meaning frame: *It's all about code.* Analyzed from the perspective of Gurwitsch's work, feedback data demonstrates a pre-existing field of consciousness comprising the following content among its three domains:

- code occupies the thematic focus
- the thematic field is sparsely – if at all – populated
- all else within awareness is relegated to the margin

6.5 Analysis 'After': motivation, alternatives

Two factors appear to play a major role in transforming students' practice from that described above: an enveloping context of quality (and the problematic consequences of poor quality software) as an ethical issue; and the capability to decompose the software development process in a way that manages complexity. The former enables them to see the problematic nature of an 'only coding' approach, and motivates them to consider other approaches. The latter makes alternative approaches possible. For many students, the two factors are deeply intertwined, with the acknowledgement (often explicitly stated) that what they knew – 'only coding' – does not work. Therefore, one set of feedback data, containing references to both factors, is presented here.

Q: Looking back over the course, does it appear different to you at the end of the semester than at the beginning or middle? If so, how?
(S_v103): Yeah, it's different from beginning to end; I guess the difference really comes in a fuller comprehension of the material or the subject matter. … To be honest, I wasn't impressed [at the beginning], I was skeptical of … [Parnas's] messages. At the midpoint, I started to realize there was truly some reality … in the papers and in developing good quality software. … [For example,] I gave some reasons on homework about why we could use [SDI] without a full nuclear war. But the more I think about it [Parnas's work], the more it just made sense, the more I believed it, the more I saw it in my mind's eye. … Initially, [I believed that] anything can be done. If we get the job, it can be done. But thinking about Parnas's papers, why it can't be done … [With a problem at work, I see such a difference between a] band-aid and fixing the real problem. … [Before,] I thought [the best approach to take] was sheer persistence … [After this semester,] I don't think it's the best way …

(S_v102): Much different. It seems like software design is actually a task that can be accomplished if you do it the right way. … and it's definitely more about the process than the coding.

Q: What will you take away … from the course?
(S_v101) … one thing I did learn in the course that I never even thought of before was that there were ethics behind computer science, and I didn't realize how many people out there abuse it. … It just makes it so easy to deceive people sometimes, especially with the attitude people have now that technology can do everything. … It can do a lot of cool stuff, but it can't do everything. …
Q: You've talked about the big role of documents, [However,] you spent [only] 4-5 hours on them, but 20-25 hours (total as a group) on code.
*If I'd not done the documents, started right away on the code without documents, it would have taken me a **lot more time**. That's because even though we weren't actually sitting down and writing the code, it was just like, as we did the documents, the picture of that code that I had in my head got more and more defined as we went down the chain. And then when we actually wrote the code, it's like my brain just dumped it all down on paper. I didn't even have to think about it;… I didn't … hit backspace, … knew exactly [how] I wanted it to look.*
Q: That's unusual for you?
***Oh, yeah**. Normally I'm … going back, rewriting what I did before; and [the difference] was all thanks to the modularization. … The reason it helped is that I knew where everything was and how it fit together. That's the hardest part of software development.*

To summarize the shift in content of students' three dimensions of the field of consciousness: Before, no possibility of managing complexity is found in any dimension; for some students, quality is not found in any dimension, and for the others, quality is relegated to the margin. Furthermore, the students had no sense of a development process; coding occupied the thematic focus as a prime element, to be addressed only by relentless effort, not decomposition and forethought.

After, both quality and conceptual approaches for managing complexity loom large in the (now well-populated) thematic field, each intermittently occupying the thematic focus. For students who fully completed group project assignments 10, 11, and 12 (before coding in assignment 13), code was relegated to the margin; for those who did not fully complete them, code resides as one element among others in this rich thematic field.

6.6 Glimpses: a long shadow

Implications of two almost identical puzzling statements preview a proposed comprehensive phenomenographic analysis of student transformative learning.

(S_v103): It just ... drove home to me how difficult it is to really develop robust software. [I didn't know it before].

*(S_v102): The reason [this course] is so tough is because it is **not easy** to develop good quality software. That's [a] huge [realization].*

How could they not have known the serious difficulty posed by software development? Neither could explain further. Review of the data with that question in mind strongly suggests that complexity was not to be found in any student's 'before' field of consciousness; it resided outside awareness. For these two, and others speaking more obliquely, transformative learning led to their becoming explicitly aware of it; it became the thematic focus of 'after' consciousness. I interpret that awareness as epistemologically prior to integrating into their practice Parnas's approaches to managing complexity. (Without awareness of a problem, its solution has no meaning.)

Based on the virtually universal relief, enthusiasm, and transformed practice among students when they begin to grasp Parnas's approach, I speculate that most of them experience a similar learning. Complexity appears to cast a long shadow, just below the level of their awareness, from early in students' practice of developing software.

7 Discussion

Three points informing the paper are viewed through a dual lens of transformative learning and software quality: rupture / crisis, uncertainty, and complexity.

7.1 Benefits of Rupture and Crisis

Rupture (for an individual) and crisis (for the community) play critical roles in intellectual development. Segal's explication of Heidegger's dynamic of rupture captures the nature and structure of discontinuity inherent in an individual's transformative learning. He describes *[e]xplicitness through rupture [as] the logic of the development of intuitions into publicly communicable forms ... Making explicit presupposes the ability to bring the shock of the not yet said but strongly felt into an explicit form.* (Note the 'long shadow' in section 6.6.) *To learn how to make our own and our students' practices explicit is therefore an essential part of the educational process* (Segal 1999 p.88).

Kuhn writes about *crises* as *necessary pre-conditions for the emergence of novel theories. ... [By] proliferating versions of the paradigm, crisis loosens the rules of normal puzzle-solving in ways that ultimately permit a new paradigm to emerge* (Kuhn 1996 pp.77,80).

7.2 Implications for Pedagogy

7.2.1 Experiential Learning

The power of a meaning frame to render aspects of the world unseen and to construe experience has significant implications for pedagogy. The classic sources express unanimity of opinion on how transformative learning happens: the meaning frame is reformulated only as a response to encounters with the world that result in persistent, significant observations that violate the frame; experiential learning is required.

7.2.2 Cultivate Well-Founded Uncertainty

Reflectiveness *depends most upon the capacity to suspend judgment and tolerate uncertainty: one must carefully determine the exact nature of the problem before proceeding to devise a solution* (Dewey 1991 pp.73-74). In computing education, courses are often taught as if every problem had a well-defined, known-in-advance solution. Since these conditions do not characterize software development, students cannot learn how to really develop software in such courses. As part of our responsibility as educators, we should allow students to enter – even choreograph their entry into – situations of uncertainty, and support them to find their way through it, while cultivating skills for reflectiveness.

Dewey advocated this position 100 years ago: *The difficulties that present themselves within the development of an experience are, however, to be cherished by the educator, not minimized, for they are the natural stimuli to reflective inquiry. Freedom does not consist in keeping up uninterrupted and unimpeded external activity, but is something achieved through conquering, by personal reflection, a way out of the difficulties that prevent ... spontaneous success* (Dewey 1991 pp.64,65). Booth, a contemporary scholar of computing education, agrees: *[P]roduction of working programs is no sign of an adequate understanding*. Rather than assignments that can be solved by *template programs*, teachers should *pose problems that allow interpretation* (Booth 1997 p.155).

7.2.3 Engagement and Stimulus, not Formula

Authentic reflective practice involves becoming aware of one's habitual behavior. It must come from a student's internal process, wherein questions arise out of dynamic engagement with the content. If self-observation is done by rote, it leads to confusion rather than insight: *[D]ogmatic commitment to observation produces a disengaged and decontextualised relationship to one's practice* (Segal 1999 p.75).

Similarly, the teacher's role cannot be specified in advance as a formulaic series of steps. Booth notes that imposing a pre-existing set of questions leads to

disastrous results (Booth, 1997 p.145). Dewey comments on information or observations communicated by the teacher to the student: It should include only content that the student could not readily acquire by personal observation; it should be offered in the form of a suggestion, a *stimulus, not with dogmatic finality and rigidity*; it should be made available only when it has relevance to the student's process. If done formulaically, it is not brought into a reflective process: *[Lying useless in the mind like] debris, it is ... an obstruction to effective thinking ...* (Dewey 1991 pp.198,199).

7.3 Implications for Curriculum Design

7.3.1 Received Meaning

Curriculum may be said to transmit a field of consciousness: Until one has developed a meaning frame for a particular content domain, one's received 'organization of consciousness' (the designation of significant elements and irrelevant elements with regard to that content domain) dictates how one navigates it. For the novice in an academic field, the curriculum dictates the element(s) to which one should direct attention (the thematic focus), and the elements that are noticed but deemed irrelevant to the point(s) of attention (the margin). The thematic field is defined as noticed aspects of the world relevant to the elements(s) being attended to. I speculate that when elements(s) being directly attended to are presented within a situating context, that context forms the content of the novice's thematic field. Without context, the novice's thematic field remains empty – and learning remains surface. Not least, curriculum dictates what is not to be noticed, what no one talks about.

This received field of consciousness in turn sets up the novice's meaning frame and approach to the topic from then forward (unless and until the frame is reformulated). Therefore, one can learn a great deal about a curriculum by examining students' meaning frames in the collective. Data in section 6 indicate that CSX students' pre-existing meaning frames had no place for either quality concerns or taking on complexity. One wonders if the curriculum to which these students had been exposed had no place for them either.

7.3.2 Challenge and Responsibility

While complexity – and the possibility of procedures to manage it – appear not to be found in any dimension of students' 'before' consciousness, they loom large in their 'after' understanding. I speculate that, lacking a widespread, established paradigm to manage complexity effectively, most educators don't address it directly. In developing software, the central challenge involves managing complexity (Peter (Naur 2007) described the core of computer science as *the scholarship of coherent description*); and the central responsibility involves formulating – and meeting – quality standards. I propose enlarging the discourse among educators and practitioners regarding these two critical areas, and building on that discussion to make them designated curriculum topics.

7.3.3 Parnas as Resource: confront complexity

CSX course content is based on work by David Parnas. Results from the course make clear that his work offers a strong foundation for addressing both the challenge of complexity and the responsibility of ethical concerns. Regarding the former, students develop new conceptual categories directly related to managing complexity; for example, (how) to use documentation as a real design medium. Regarding the latter, Parnas's explanation for resigning from the SDI Advisory Board (whether or not one agrees with his conclusion) offers a model of careful, professionally informed reasoning motivated by a sense of ethical responsibility and based on technical analysis.

8 Summary, Conclusions, and Future Work

8.1 Summary and Conclusions

This paper is written as part of an ongoing exploration into the operation and mechanisms of student reflective response (productively navigating the confusion created by an encounter with the unknown) – or not – and what is required to support it. Findings refine and accrue to previous results, expand the foundation on which future work will rest, and inform that work. I've investigated transformative learning so as to more clearly articulate the operation and mechanism of reflectiveness (itself the mechanism of transformative learning).

- Meaning frames *determine the essential conditions for construing meaning for an experience* (Mezirow 1991 p.44), and must satisfy (at least) two conditions to remain useful: 1) accuracy, correctly representing all aspects of the world considered relevant; and 2) availability below the level of awareness (thus inaccessible at a conscious level), internalized sufficiently to become operative (made manifest) without deliberate initiation. Student feedback data in 6.4 illustrates the power of an established meaning frame to effect selective awareness.

- In case of a rupture in knowing, transformative learning effects coherence in transition across that discontinuity; a reformulated meaning frame preserves meaning.

- In cumulative learning, old meaning is imposed upon new experience: pre-existing expectations are applied to interpret new experience. From transformative learning, new meaning arises, to be imposed upon new and old experience (Mezirow 1991 p.11). Experience anomalous to extant expectations (confusion) leads to reformulation of expectations (struggle); in turn, these direct interpretation of new and old experience (knowing).

- Kuhn's work in the history of science illuminates an analogous process (at community level) in developing esoteric bodies of discipline- or profession-specific knowledge. Terms for individual learning / *scientific group progress* correspond as follows: meaning frame / *paradigm*; cumulative learning / *normal science*; troublesome knowledge / *crisis*; transformative learning / *revolution*; reflectiveness / *extraordinary science*.

- Gurwitsch's work on the organization of consciousness offers indirect access to the operation of meaning frames, and clarifies distinctions among surface, cumulative, and

transformative learning. His description of awareness illuminates the role of context (as correspondent to a richly populated thematic field) in deep understanding.

In conclusion, the papers written thus far have introduced, investigated, and shown relevance of the literature to student experience of reflectiveness and defensiveness. Analysis of feedback data reveals students' 'before' states as lacking any real concept of software design process: no process, no design, no software, just bricolage and code; all the result of *surface learning* (Booth 1997 p.145). Consequences to software quality argue for designing curricula (perhaps, as in CSX, based on David Parnas's approach) that explicitly take on complexity, and for developing pedagogies aimed at both transformative and deep learning. The learner must be supported to discover for herself the *elusive obvious* (Feldenkrais 1981).

8.2 Future Work

Several possibilities exist for investigation: where in a course students collectively experience the dynamic of rupture; the learning of those few students who do not experience the dynamic (Heidegger's 'obliviousness'); the source of heightened affect during reflectiveness or transformative learning; a full phenomenographic analysis of CSX student feedback data for categories of transformative learning and 'before' / 'after' states.

Further, Kuhn's history of science strongly suggests that the discipline of computing remains in a pre-paradigmatic state. Investigation is merited into that possibility and (if true) what is required to mature the discipline beyond it.

9 Acknowledgements

I thank Raymond Lister for his thoughtful comments and intellectual generosity, Simon for formatting assistance, and the anonymous reviewers for their suggestions.

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