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Enhancing Meaning in Learning: A Case Study of Adult Developmental Mathematics

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Abstract: *This case study, at the focal site of the Art Institute of San Francisco, involves a yearlong study of adult developmental mathematics courses influenced by vocational instructor feedback and meaningful learning theory. Learner surveys on learning outcomes show negative learning progress compared to a national database of similar developmental courses. This contradicts the general hypothesis that meaning in instruction and learning correlate with successful learning outcomes. It may be that due to a history of rote learning and mathematical frustration, some adult learners show signs of cognitive overload on constructivist tasks.*

Introduction

The goal of this study is to test if increasing meaning in a series of adult developmental mathematics courses can enhance positive learning outcomes. The objectives are to find what is relevant and meaningful to learners and instructors at the focal site. Then to apply these findings, together with relevant meaningful learning theory, to four sequential developmental math courses over the course of a year in 2009, and investigate if the courses do indeed produce positive learning outcomes. The focal site in this case is a corporation owned vocational college, the *Art Institute*.

Traditional mathematics teaching has been clearly influenced by the modernist work of Spearman and Binet (1906). From the age of scientism, the state has used mathematics as a type of intelligence test, a practical means of separating the numerically able from the numerically less able. Many argue that this may have seemed like a good idea in an earlier industrial and modernist era, when there was a need to place citizens into highly ordered and stratified organizations, but as society moves from an industrial age into a post-industrial, digital or symbol-based age, ideas on mathematics teaching must progress in tandem. The new digital world is more, yet differently mathematical than the old analog one. Digital information has revolutionized how the world deals with mathematics and thus has modified our definition of what mathematics is. However, in many classrooms, learning is still conceived of as a process in which learners passively absorb information and then store it in easily retrievable fragments as a result of repeated practice and reinforcement.

A democratic society needs an educated and informed electorate in an environment in which political and social decisions are based on increasingly complex technical issues. Current issues such as the environment, public medicine, spending and deficit involve many unrelated issues; their thoughtful resolution requires a sophisticated level of technological and mathematical reasoning. Moreover, a mathematically literate workforce is crucial because of advancing methods of production, especially the global introduction of computer-based tools such as *Photoshop*, *Illustrator* and *AutoCAD*. Recent studies indicate that people who study mathematics are predominantly white males and because women and minority learners study less mathematics, they are seriously underrepresented in technological and mathematical careers (American Association of University Women, 1992). As a result, their standard of living is often

lower and less secure. In such careers, mathematics has been a filter that often screens out women and minority groups. Thus, besides being an issue of social justice, the creation of a society where equal opportunity exists in access to mathematics has become an economic necessity.

Literature Review

The works of the seminal educational psychologists such as Ausubel (1962), Bruner (1968) and Gagné (1972) resonate with the idea that learning is a search for meaning; not a search to reveal or discover an objective or absolute reality but a construction of meaning that builds from within each one of us through a process of self organization and reflective analysis as we make sense of our experiences. Educators have started to challenge math learning that is based upon modernist assumptions of objectivity, absolutism, linearity and predictability.

In more recent times, mathematics education is resonating with a more systemic relationship constituted by the perspectives of constructivism (Cobb & Bauersfeld, 1995), “problem-centered learning” (Murray, Olivier & Human, 1998), “systems theory” (Capra, 1996), and “positive discipline” (Kohn, 1996; Nelsen, 1996).

Meaning in Mathematics Learning

Clearly influenced by the foundational philosophies of constructivism and cognitivism and incorporating elements of Knowles’(1980) concepts of adult centered learning, the *Standards* suggests all high school learners are capable of succeeding in mathematics, but courses must link-in and interweave the *Big Ideas* of mathematics. The *Big Ideas* include balance, number sense, proportional reasoning, variable, representation, measurement, relations and inductive and deductive reasoning. According to *The Standards*, these *Big Ideas* should be introduced as early as possible in the mathematics syllabus to allow learners to gain familiarity with these concepts of mathematics and ultimately to prepare the learners for subsequent and more advanced algebra courses.

Several assumptions shape the vision of *The Standards*. Firstly, mathematics is something a person does. Knowing mathematics means being able to use it in a purposeful way. To learn mathematics, learners must be engaged in exploring, conjecturing and thinking rather than the rote learning of rules and procedures. In other words, mathematics is not a spectator sport. When learners construct a personal knowledge derived from meaningful experiences, they are much more likely to retain what they have learned. This underlines the new role of the teacher in providing and explaining these experiences. Another assumption is that mathematics has a broad content encompassing many fields. Learners can benefit from exposure to a broad range of content that reveals the usefulness of mathematics. Through this exposure learners can build a foundation of relevance and meaning to their learning of mathematics. Another assumption of *The Standards* is that mathematics instruction can be improved through the appropriate use of evaluation. Evaluation should concentrate not only on assessing what the learners knows, but how they think and approach problems.

Another a seminal work in this area, *Crossroads* has established goals and standards for preparation for college- level mathematics. *Crossroads* is highly influenced by *The Standards*, but is yet another highly influential work in its own right, because it is primarily directed to adult developmental mathematics. *Crossroads* reflects many of the same principles found in *The*

Standards. These standards place emphasis on using technology as a tool and as an aid to instruction, developing general strategies for solving real-world problems, and being actively involved in the learning process. In particular, developmental math courses at the post-secondary level should include topics traditionally taught in developmental mathematics, but should also incorporate technology and project-based learning.

Research Methodology

The research draws from participatory action research methods, (Kemmis and McTaggart, 1988) which position the researcher simultaneously as a practitioner at the focal site where the study takes place, and also as a collaborator with the learners themselves with the aim of improving their own educational practices.

The design of this case study is based on a seminal work by Yin, in that a single case study is used to confirm or challenge a theory, or to represent a revelatory or extreme case (Yin, 1994). In this instance, the case study of the *Fundamentals of Math* course is ideal for a revelatory case study, as the observer has access to a phenomenon that was previously inaccessible. Many developmental mathematics courses occur in the space of public education and are devoid of context and relevance, but at the *Art Institute* developmental mathematics is studied simultaneously with the learner's vocational degree and as such is ideal for a revelatory case study of meaning in mathematics. Each individual case study consists of a whole study, in which facts are gathered from various sources and conclusions drawn on those facts. Consideration has been given to construct validity, both internal and external. Yin suggests using multiple sources of evidence as the way to ensure the construction of validity. He lists six sources of evidence for data collection in the case study protocol: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts.

The research analysis is based on three components. Firstly, the quantitative variable *Progress on Relevant Objectives* representing progress on learning outcomes, is derived from the survey instrument. Secondly, qualitative descriptive categories of meaningful mathematics learning is gathered from semi-structured interviews with learners and vocational instructors. Finally, artifacts such as learners' projects, observations and secondary quantitative data such as pass rates, retention and attendance, complete the data gathering.

Learner Surveys

Fundamentals of Math learners were surveyed on the learners' self-perceptions of progress on the *essential* learning objective of *Learning Fundamental Principles* and on their progress toward the *important* learning objective of *Learning to Apply Course Materials*. The primary quantitative variable and overall indicator of learning outcomes is the *Progress on Learning Objectives* measurement, which is a combination of the two *essential* and *important* learning objectives described above.

Semi-Structured Interviews

Focal-site informants were also interviewed on the general theme of mathematics in their education and, in the case of the instructors, their current instructional positions, in order to answer the research question; *What is meaningful to developmental mathematics learners?* Vocational instructors, in addition to learners, were chosen as interviewees from the focal site

because they provide an acute insight into the meaning and relevancy of mathematics in the learners' chosen careers.

The focal site informants are both learners participating in the *Fundamentals of Math* course, and vocational instructors at the focal site. Similar semi-structured interviews were arranged on the topic of meaning in mathematics with both groups of informants. The objectives of these interviews were twofold. Firstly, they were to inform the *Fundamentals of Math* course projects and class problems, reflecting the meaning and relevance to the learner's vocations and, secondly, to inform this study on the question of meaningful learning. The importance of the focal site for this research is that it can provide a possible link between vocational classes and developmental math classes, and similar schools can leverage these vocational assets for developmental math success.

The semi-structured interviews with instructors at the focal site yielded 13 digitally recorded interviews with interviewees representing various vocational categories such as Advertising, Animation, Fashion Design, Fashion Marketing, Interior Design, Culinary Arts, Graphic Design, Liberal Arts, Game Programming and Game Design. The outline of this study, the recruiting script and consent form for the instructor interviews were initially e-mailed to all the vocational instructors at the focal site. These initially yielded only 4 replies, indicating it would be extremely difficult to recruit instructors from all the vocations at the focal site using this scattershot approach. Further instructor interviewees were eventually selected by *snowball sampling*, which is a special non probability method used when the desired sample characteristic is rare. While this technique dramatically lowered search time, it comes at the expense of introducing bias because the technique itself reduces the likelihood that the sample will represent a random cross section from the population of vocational instructors. The interviews lasted approximately twenty minutes in length; they took place in the instructor's classroom during a break in class or in specialized interview rooms provided by the focal site. The interviews were digitally recorded for later transcription and analysis.

Recruitment of the *Fundamentals of Math* learners for interview required a different approach. On the last day of second *Fundamentals of Math* course, the study was introduced with a recruiting script and consent form and all the learners were invited to participate in an interview. Four learners responded to the request by returning the signed and dated consent form. These learners were then informed that they would receive an e-mail at the start of the next *Fundamentals of Math* course, letting them know that they were selected for an interview and setting up a time and place for the interview.

Conclusions

Over the course of one year, the self-assessment survey results from the *Fundamentals of Math* courses show *negative* progress compared to a national database of five thousand similar courses. This contradicts the general hypothesis that meaning in instruction and learning correlate with successful learning outcomes.

The learner surveys, interview results and anecdotal evidence indicate that developmental learners show signs of cognitive overload on certain cognitive and constructivist tasks. For some developmental learners in this study, constructivist approaches to many fundamental mathematics concepts often result in anxiety and confusion. These learners may have been previously accustomed to a traditional and rote approach to mathematics instruction. These developmental learners appear to derive more mathematical meaning from behaviorist tasks

involving step by step processes, the linking of previous concepts, and the repetition of key ideas are effective approaches.

From the contradictions between learner and instructor perspectives, we must conclude that mathematics meaning is *subjective* and *individual*. There is no given objective meaning which can be derived from mathematical structure. It appears that the *Crossroads* report inherited the principles of *The Standards* without modifying them for the specific needs of the developmental learner.

The instructor interviews suggest developmental mathematics programs should place strong emphasis on mathematics in the context of real applications, project based learning, technology and the meaning behind the *Big Ideas*. According to the interview themes, the *Big Ideas* of mathematics can be directly linked to relevant vocations, practices and ubiquitous software design tools such as *Illustrator*, *PhotoShop* and *AutoCAD*. These software tools appear to have increased the need for an understanding of constructivist, project based learning including visual, spatial and verbal representations of meaning (*Multiple Representations of Meaning*).

Also the repetition of the *Big Ideas* in various contexts is a common theme in the learners' interviews. Likewise, learners in the Confucian Heritage Countries (CHC) are known to practice memorizing and repetition, which, if one equates memorizing with surface learning, brings into question the amount of meaningful learning that takes place. However in CHC memorizing is not synonymous with rote learning (Biggs, 1996). Repetition is carried in order to understand, or as a contextual response to the critical need to pass exams. As far as the learner in the CHC is concerned, memorizing is a means of becoming thoroughly acquainted with the subject, to facilitate reflection and understanding (Marion et al., 1996).

Implications and Recommendations

This study has important implications for secondary and tertiary math instructors, academic directors, and principals. The resulting recommendation would be to limit cognitive load in developmental learners by utilizing carefully controlled and highly structured constructivist projects ensuring the concept or schema is in place before embarking on ambitious constructivist exercises and projects.

The learner survey and interview results show that an interactive, step by step, visual instructional approach, with each step logically linked to its predecessor may be a suitable approach to developmental mathematics. According to instructor interviews, developmental learners appear to derive mathematical meaning from visual and verbal approaches, which I have termed *Multiple Representations of Meaning*. This indicates a link to the theory of Multiple Intelligences (Gardner, 1983).

Another implication is that instructor training programs might shift the emphasis from teaching universal concepts of objective meaning to those of subjective meaning. Courses for prospective instructors should provide an awareness of what research reveals about project based learning, how we learn mathematics, models for effective learning, and an understanding of the power and limitations of the use of technology in the classroom.

Finally, another important consideration is in the use of textbooks. Textbooks have not gone the way of the scroll yet, but many educators believe that it will not be long before they are supplanted altogether by lessons assembled from the wealth of free courseware, educational

games, videos and projects on the internet, all catering to a new demand for non-traditional learning and instruction.

Over the last 5 years, the proportion of African-American, Latino and lower-income learners attending Art and Vocational Schools has exploded (Bolt, 2006). It appears that learners, especially African-American and Latino learners, are voting with their feet, rejecting the theoretical de-contextualized education provided by traditional curricula and jumping into the meaningful, relevant, practice based training provided for by the for-profit vocational schools. The proportion of African-American and Latino learners is higher in *Fundamentals of Math* than in the general *Art Institute* learner population, so the implications of this study disproportionately affect African-American and Latino learners. Some developmental learners from all demographics may have had a very traditional, rote-learning approach to mathematics learning, and some relearning in the cognitive and constructivist realm may be necessary.

Further research is necessary to understand what works specifically in developmental mathematics. In particular, we need to understand more precisely which approaches do promote positive learning outcomes. Is it because of the material covered, the instructional methods used, challenges outside of the classroom such as financial or family constraints, or some combination of all of these factors? This research of a single case can be expanded to multiple cases or extended over time with different instructors at the same focal site. These studies could then be scaled to multiple focal sites and multiple time lines.

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