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TOWARDS A THEORY-BASED DESIGN FRAMEWORK FOR AN EFFECTIVE E-LEARNING COMPUTER PROGRAMMING COURSE

Ian S. McGowan
University of Technology, Jamaica

ABSTRACT

Built on Dabbagh (2005), this paper presents a four component theory-based design framework for an e-learning session in introductory computer programming. The framework, driven by a body of exemplars component, emphasizes the transformative interaction between the knowledge building community (KBC) pedagogical model, a mixed instructional strategy of student collaboration and scaffolding, and learning technologies that supports the community. The foundation knowledge perspective of situated cognition derived the KBC model. Specific examples of how to apply this framework over computer programming sessions in e-learning context are provided.

KEYWORDS

e-Learning; Pedagogy; Learning theories; Computer Programming and Algorithm

1. INTRODUCTION

Computer Programming (CP) is a very useful skill and can be a rewarding career. In recent years, the demand for programmers and student interest in the area have grown rapidly. Introductory CP courses at the university level have become increasingly popular as a result. Learning to program is hard however. Student programmers suffer from a wide range of difficulties and deficits. These courses are generally regarded as difficult, and often have the highest dropout rates (Robins et al 2003). CP seems to demand complex cognitive skills such as procedural and conditional reasoning, planning, and analogical reasoning (Kurland et al, 1986). Instructors in the subject, generally agree that CP is a difficult matter, because it's more of an art than a body of knowledge (Hadjerrout, 2008). Knuth (1974) says preparing a computer program to solve a problem, feels like composing poetry or music. Hence Knuth further emphasized that in crafting a computer program, there is no "best" style in approach; everyone has his or her own preference of style, and it's a mistake to try to force learners of CP into an unnatural mold in this regard.

Pedagogical approaches, which take advantage of learning theories and information technology, have been proposed in the research literature to tackle the learning problems associated with CP. However, there are very few evidence-based research, and the difficulties of learning CP remain to be researched (Bank et al, 2006).

Research on the instructional uses of technology, however, has revealed that instructors in higher education often lack the knowledge to successfully integrate technology in their teaching and their attempts tend to be limited in scope, depth and variety (Kochler, 2013).

With recent advances in internet and web-based technologies that have redefined the boundaries and pedagogies of distance learning by stretching it scope and interconnectedness (Dabbagh, 2005), computer science departments now have the ability to explore an additional delivery environment for CP in the form of e-learning.

Generally a grand unifying theory of e-learning remains elusive and e-learning practitioners continue to operate largely on the basis of trial and error (Chin et al, 2006). E-learning thus, like all instructional delivery environments, must be rooted in epistemological frameworks to be effective for teaching and learning (Dabbagh, 2005). In other words, describing learning of and designing instructions for e-learning CP, must include appropriate e-learning instructional systems and the use of suitable learning technologies or tools to facilitate student learning.

Building on Dabbagh (2005)'s three component theory-based framework (Figure 1) for designing an e-learning course, this paper aims to present a four-component theory-based framework (Figure 2) for designing an e-learning CP session delivery that capitalizes on a pedagogical model, a body of examplars, instructional strategies and learning technologies to facilitate meaningful learning of proper CP practices and knowledge building. Dabbagh (2005) framework is based on Coleman et al's (1997) work on specifications of pedagogical models and strategies resulting from situated cognition and constructivist views of learning, and Hannafin (1992)'s work on tasking the learner with constructing representations of individual meaning.

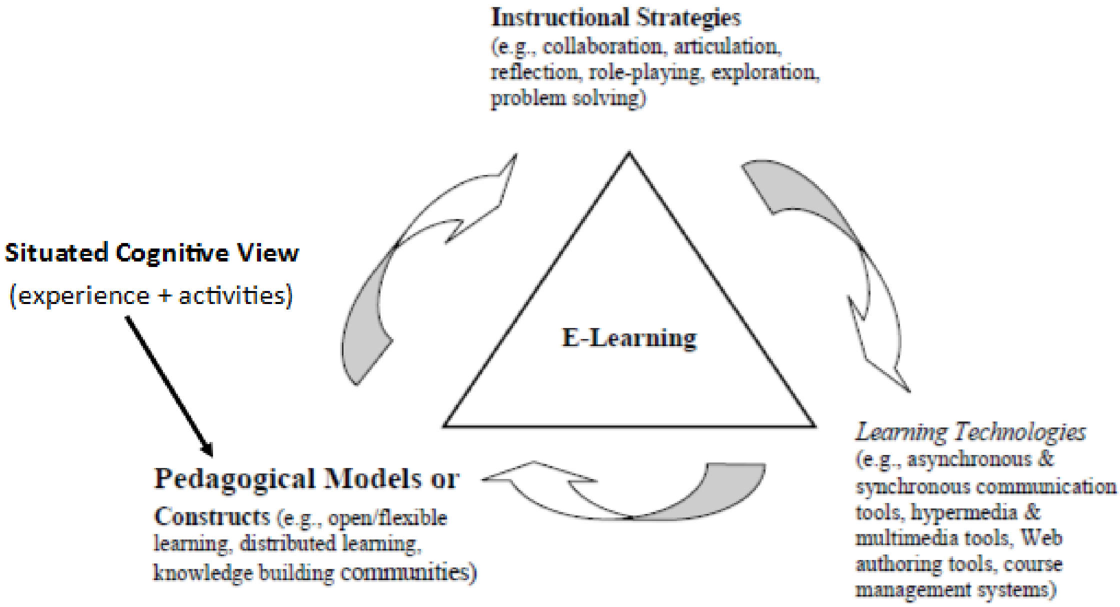

Figure 1. Theory-Based Design Pedagogical Framework for an E-Learning course (Dabbagh, 2005)

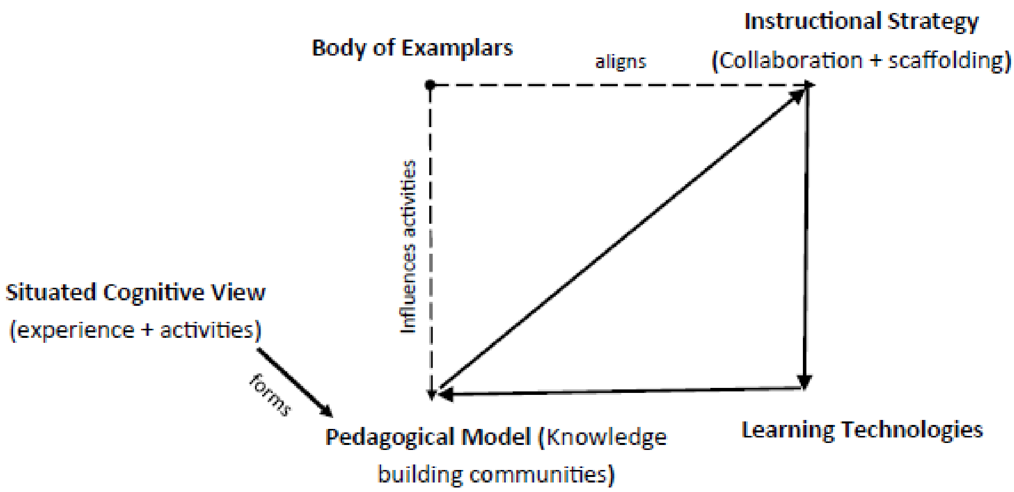

Figure 2. Proposed four-component Theory-Based Design Pedagogical Framework for E-Learning CP course (Built on Dabbagh, 2005)

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This paper is a reflection of some of my observations into the current teaching practices, and learning habits of first-year students in relation to the subject of CP in recent years at a higher education institute in the Caribbean where I work as a CP instructor. With failure rates in excess of sixty-five percent year after year in first year, the subject, and by extension, the academic department, have been receiving negative attention consistently from the school's academic administration. As the institution begins to consider an e-learning route for CP and investing large sums of money on this e-learning initiative as a possible reaction to this crisis in the department, this review is aimed at generating a fresh pedagogical framework on which CP instructors could consider and build on to improve on the student learning outcome.

2. GROUNDING ASSUMPTIONS FOR AN E-LEARNING COMPUTER PROGRAMMING COURSE

2.1 Defining a Theory-Based Framework

CP, a first year subject in the curriculum of the bachelor's degree in Information Technology, in the department of Information Technology at the University of Technology, Jamaica, is basic knowledge of designing algorithms. Only studying CP in a normal class is most times never sufficient (Rodmunkong, 2015). As CP is more of a practiced based course, confidence will need to be transferred to the learner from early in the course. A high level of confidence provides a sense of security for the learner in both the ability of the instructor to provide the correct guidance as is required in the providing of CP instructions, and the learner's own ability to work without guidance.

Mayes et al (2005) emphasizes that in designing instructions for the learner, knowing why you (the instructor) do what you do is essential in generating instructor confidence. Learning theories, according to Mayes et al (2005), are empirically based accounts of the variables which:

- influence the learning process
- lend coherence and consistency in instructional design planning

A theory-based framework thus uses one or a mix of learning theories to explain views about cognition and how knowledge was constructed. These views then form the pedagogical model or the starting of the pedagogical framework.

2.2 Pedagogical Framework

A well understood pedagogical framework is essential for a good pedagogical design in higher education/further education (HE/FE) contexts (Mayes, 2013; Biggs, 1999). Pedagogical frameworks describe the broad principles through which theory is applied to learning and teaching practice. Narrowing Mayes's definition to include technology, Hadjerrouit (2008) explains a pedagogical framework to an understanding of the relationships among learning theory, information technology, educational practice, and more specifically to an academic subject. Ivala (2013) argues that a pedagogical framework offers instructional designers an effective means of embedding a subject's pedagogical model into the e-learning environment. Dabbagh (2005) appears best to have strengthened Ivala's definition, in that the relationships among the pedagogical components are iterative (Fig 1). An iterative relationship embedded in a pedagogical framework would be more adaptive in an e-learning environment as learning technologies become ubiquitous, and continue to evolve school year to school year in any computer science department in a HE/FE.

2.3 Situated Cognition Views

Situated cognition (SC) emerged at the end of the 1980s as a new way of theorizing human performance. Roth et al (2013) describe the central aspect of the SC hypothesis is that intelligent behavior (perceiving, remembering, reasoning and problem solving), arise from the dynamic coupling between intelligent subject and its environment, rather than only from the agent's mind (brain and control system) itself.

Roth argued that the shift to SC hypothesis in cognitive science, adopted to the perspective that information does not exist prior, but emerges from, and is a function of the organism-environment relation (coupling). Environments include physical and social (communities, social networks and society). Roth explained further, that the cognition in a subject is enacted, and that human behavior is characterized by relations of reference to the surrounding world. For example, from the SC hypothesis, the rules in a spoken language are not considered formal symbolic relations stored in the mind that a subject use to generate a phase. Spoken language is learned by participating in societal relations.

Wilson (2002) uses a different terminology than that of Roth in the push to understand the mind in the context if its relationship to the physical body that interacts with the world: *embodied cognition*. Wilson agrees with Roth that cognition inherently involves perception and action, and takes place in the real world environment. Wilson went on further to argue that because human cognitive work is limited, it off-loads the work on to the environment. We make the environment hold or even manipulate information for us. We then harvest the information only on a need-to-know basis. Wilson's definition of SC narrows the content to task related. That is, cognition that takes place in the context of task-relevant inputs and outputs. While a cognitive process is being carried out, perceptual information continues to come in that affects processing. Motor activities are then executed that affects the environment in task-relevant ways. For example walking down an isle in a supermarket, holding a conversation with a neighbor, and moving around a used-car lot as you imagine how you would look in that car as you pass it, are all cognitive activities that are situated in this sense. With this definition, any cognitive activity that takes place in the absence of task relevant input and output or "off-line", is not *situated*. Examples include planning, remembering, and day-dreaming.

Dabbagh's (2005) situated cognitive view is consistent with the epistemological assumptions of constructivism, which stipulate that meaning is a function of how the individual creates meaning from his or her experiences and actions.

CP is markedly distinct of other disciplines because proficiency in other areas does not predict success. Evidence suggests however, that deliberate practice is a key element in the acquisition of programming competencies (Scott et al, 2013). Learning activities encourages deliberate practice. Deliberate practice generates experience as Dabbogh (2005)'s SC view highlights. A body of examplars thus would help to direct independent learning activities.

2.4 Body of Examplars

In my experience teaching CP, I have found that worked examples or problem statements serving as reference points relating to a particular topic, are invaluable to learning outcome, and designing of instructions.

For example:

#1 Problem statement (topic Iterations or looping): *Write an algorithm that displays the total of all numbers from 10 to 20 inclusive.*

Model solution:
```
t = 0
for c = 10 to 20 step 1
   t = t + c
display t
```

#2 Problem statement: *Write an algorithm that asks the user to enter 5 numbers, then displays the largest number after the input. For example, if the numbers entered are 89, 45, 9, 91 and 90, then the output should be 91.*

Model solution:
```
input num
largest = num
for c = 1 to 4
   input num
```

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```
   if num > largest
      largest = num
display largest
```

Made available in sufficient numbers before, during and after topic, learners that make use of the provided examplars, tend to fall in line with course expectations at the minimum, much faster, and independently.

Should another problem statement (for example: *Write an algorithm that displays the total of all even numbers from 30 to 39*), be challenged to the learners, then some reference point for guidance may be available.

A body of examplars, forming the first component of the theory-based design framework, is a database of worked examples made available by course designers for both the learners and instructors. For the learners, this database would serve to influence independent learning activities and experience gathering. For instructors, the database would guide the designing and aligning of instructions to topic.

2.5 Pedagogical Models: Knowledge Building Communities (KBCs)

A pedagogical model, the second component of the theory-based design framework, is a cognitive model or theoretical construct derived from knowledge acquisition models or views about cognition and knowledge, which form the basis for learning theory (Dabbagh, 2005). In this paper for example (as Figure 2 and 3 show), from the situated cognition view knowledge acquisition model, the focused *KBC* model was derived. In other words, theory to practice was linked using a pedagogical model.

Some of the other noted pedagogical models available include *open learnin*g, *distributed learning, learning communities* and *communities of practice*.

A common goal of KBCs, is to advance and share knowledge of the collective (Dabbagh, 2005). In knowledge building, discourse, ideas, theories, hypothesis, and other similar intellectual artifacts, are objects of enquiry. These objects are scrutinized, improved, and put to new use as participants progressive discourse analogous to the enquiry processes of research communities (Gan et al, 2007). Driven or helped by the body of examplars, ideas and discourse about algorithm design for given problem statements would normally then be at the minimum level required for the course.

In initiating a CP KBC session for example, the instructor could present a problem statement such as:

Write an algorithm that asks the user for 6 pairs of first names and ages, then displays the name of the youngest person at the end of the input. For example, if the pairs entered are "Paul", 16; "Dianna", 14; "Tuvak", 16; "Dwayne", 23; "Kayeem", 21 and "Allison", 23, then the output should be "Dianna".

to generate (a) an initial idea or solution from one of the groups possibly in reference to or guided by the body of examplars, and (b) recursive discourse evidenced by debugging results from the same and other groups, until a final solution agreed by the collective, is arrived at or until KBC session times out.

In my own experience in learning and teaching CP at the university level, the art is best learnt in peers, with regular feedback from instructors, referencing the body of examplars for possible similar challenges, examining what others have done for similar projects (and most times copying a prior approach), and deliberate practice.

Phillips (2007) describe learning in a KBC classroom as a by-product of creation of a new knowledge, but the focus of classroom work is the continual improvement of ideas. In the case of CP problem statements, members of the group would be encouraged to use the body of exemplars as a starting point on which to build new design ideas.

2.6 Instructional Strategies: Promoting Collaboration + Providing Scaffolding

Lead by the pedagogical model and guided by the body of exemplars, the specifications of the instructional strategies form the third component of the theory-based design framework. Instructional strategies are what instructors do to facilitate student learning (Dabbagh, 2005). Dabbagh presented other noted instructional strategies in *articulation, reflection, role-playing, exploration* and *problem solving*.

2.6.1 Promoting Collaboration

In collaborative learning, information sharing is not enough – students are expected to learn to work together so that the deliverables are from group effort (Lazarva, 2015).

From a constructivist or situated cognition perspective however, Dabbagh (2005) defined collaborative learning with the emphasis of encouraging students, in their respective work groups, to engage in joint negotiation of alternatives through argumentation and debate. Therefore Dabbagh viewed social negotiation as an integral component of collaborative learning.

In a small group of CP students for example, we can often find varying levels of cognitive and experience strengths among the members. One or few maybe stronger in analyzing problem statements, another maybe stronger in visualizing user experience, and another maybe stronger in flowcharting. For a CP project, these strengths will need to be maximized and shared among the members for the end product to be at the minimum required level for the course. Social negotiation allows for members of a group to share workload with minimum conflict and promotes peer tutorial (Dabbagh, 2005; Duffy & Cunningham, 1996).

In E-learning contexts, collaborative learning and social negotiation over a student CP project can be enacted using:

- Online group discussion (for problem statements)
- Share ideas online
- Using an online database for recoding designing, flowcharting and coding ideas
- Virtual chat and video conferencing (brainstorming, debating, group sharing of ideas)

2.6.2 Providing Scaffolding

Scaffolding, a short-term strategy as intended, is used to help students through a learning task that is just outside their level competency (Ontario, 1992).

The concept of instructional scaffolding has its origins in the work psychologist Vygotsky (Foley, 1994). For a positive learning outcome, an appropriate social interactional framework must be provided (Foley, 1994; Bruner, 1978). Foley explains that scaffolding is viewed as a gradual process of internalization by the learner of routines and procedures. As the learner’s competence grows, the scaffolding is gradually reduced until the learner is able to function autonomously in the given task and generalize to similar circumstances.

Scaffolding is no longer restricted to interactions between individuals as Foley describes. Puntambeker et al (2005) argues that with an increase in project-based and design-based environments for teaching engineering, science and mathematics in the context of a classroom, the notion of scaffolding is now increasingly being used to describe the prompts and hints in tools to support learning. Artifacts, resources and environments themselves are being used as scaffolds.

Dabbagh (2005) recommends a different approach from that of Foley. As novice students and students who already have a significant knowledge base require different levels of task support to push them to perform at their potential development zone, Dabbagh suggests a layered structure to scaffolding. In a group setting, the required support level of each member could vary. This layered approach would help to prevent weaker members from slowing down the stronger members.

For example – at the design stage of a CP group project, the instructor, aided by the body of examplars, could (1) develop a set of flowchart exercises at increasing levels of difficulties leading to minimum level required for the project, and (2) provide a one-to-one out of class and/or emailing mentoring sessions with students in need.

3. CONCLUSION

The main objective of this paper has been to contribute to the advancement of introductory computer programming education at the university level through the additional delivery mode option of E-Learning. The paper presented a proposed four-component theory-based design framework built on Dabbagh (2005)’s three-component framework. Dabbagh’s framework emphasizes the systematic and transformative interaction between the knowledge building community pedagogical model driven by situated cognition and constructivist views of learning, instructional strategies that support group work on computer programming learning projects while managing guaranteed conflicts, and online learning technologies that could sufficiently allow students to record, debate, discuss and share their coding and design specifications on a CP course. A forth, but initial component in that of a body of examplars would serve to "level the playing field" going into a CP session or topic, depict the course topic expectations early, reduce the stress levels of and conflicts among learners in a KBC environment, and provide that crucial guidance needed by both the learners and instructors in an e-learning CP environment especially in the general absence of a sufficient body of knowledge usually associated with CP courses.

Armed with this new understanding of learning from a distance and the theory-into-practice framework that characterizes the instructional implications of situated cognition, computer programming instructors have the knowledge and tools to carefully craft e-learning programs with strategic interactions to promote proper computer programming practice and meaningful learning.

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