

Educating Programmers: A Reflection on Barriers to Liberate Practice

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Abstract

Programming is a craft which often demands that learners engage in a significantly high level of individual practice and experimentation in order to acquire basic competencies. However, practice behaviours can be undermined during the early stages of instruction. This is often the result of seemingly trivial misconceptions that, when left unchecked, create cognitive-affective barriers. These interact with learners' self-beliefs, potentially inducing affective states that inhibit practice. This paper questions how to design a learning environment that can address this issue. It is proposed that analytical and adaptable approaches, which could include soft scaffolding, ongoing detailed informative feedback and a focus on self-enhancement alongside skill development, can help overcome such barriers.

Keywords

Computer Science Education, Computer Programming, Laboratory Instruction, Affective Development, Feedback, Self-Beliefs, Barriers.

1. Introduction

Recently, there has been a drive to revitalise computing education (Gove 2012), in part, due to criticisms published by The Nesta Trust (Livingstone & Hope 2011) and The Royal Society (Furber 2012). Unfortunately, few beginners appear to find writing code easy and enjoyable (Jenkins 2001; Jenkins 2002), so crafting an effective learning environment is not a trivial task. Moreover, despite considerable research into programming instruction since the inception of Computer Science as an academic discipline, many learners have not acquired the desired level of competency (Soloway, Bondar & Ehrlich 1983; McCracken *et al.* 2001; Tew & Guzdial 2011). Even some whom appear to perform well in early tutorials choose not to pursue the discipline (Beaubouef & Mason 2005; Carter 2006). Such issues are so pervasive that the British Computer Society (BCS) declared programming a *grand challenge* for education research (McGettrick *et al.* 2005).

An aspect of this challenge that the authors have encountered is getting learners to engage in frequent practice. Evidence suggests that levels of *effort* (Ventura 2005), *comfort* (Wilson & Shrock 2001; *ibid.*) and *depth* (Simon *et al.* 2006) predict success in a first programming course. This is in line with the theory that it can take approximately ten years

of deliberate practice to become an expert (Ericsson, Krampe & Tesch-Romer 1993; Winslow 1996; Ericsson 2006). Unfortunately, learners often claim that they *lack time* or *have no motivation* to do so (as in Kinnunen & Malmi 2006). So if deliberate practice is a key element in the acquisition of programming competencies, how do educators create learning environments that successfully encourage practice?

2. Cognitive-Affective Barriers and Deliberate Practice

In order to appreciate how to facilitate frequent practice, the barriers that prevent it should be explored. Programming is markedly distinct from other disciplines because proficiency in other areas does not predict success (Byrne & Lyons 2001; Erdogan, Aydin & Kabaca 2008) and some believe that there are no effective aptitude tests (McGettrick *et al.* 2005; Caspersen, Benedsen & Larsen 2007), assuming that aptitudes for programming even exist (Ericsson, Krampe & Tesch-Romer 1993; Jenkins 2002). This is because the learning material sometimes demands something very novel to new learners (Huggard 2004), drawing on skills that, at present, are seldom developed prior to programming instruction:

By means of metaphors and analogies we try to link the new to the old, the novel to the familiar. Under sufficiently slow and gradual change, it works reasonably well; in the case of a sharp discontinuity, however, the method breaks down.

(Dijkstra 1989, p. 1398)

The sudden sense of “radical novelty” (*ibid.*) forms an unexpected challenge for many learners, presenting a barrier to learning. This is because those without prior experience need to adapt to thinking about the intangible and abstract concepts which are needed to describe the mechanics behind the code they are writing (Du Boulay 1989). Barriers can even arise as early as the first stage of instruction. Consider how someone new to reading program code might conceive the mechanics behind an assignment operation, such as:

```
a = 1;  
b = 2;  
a = b; // what is the value of a?
```

Bornat, Dehnadi and Simon (2008) found that for “simple” assignment operations that “hardly look as if they should be hurdles at all” (p. 54), students held many different mental models for how the program may execute. Even after a few weeks of instruction, some participants failed to apply the correct model consistently in a diagnostic test. This illustrates that the ways in which learners conceptualise computer programs can be diverse and incorrect models may persist without some intervention. Consequently, it is important not to dismiss the early challenges experienced by individuals as: trivial; a lack of effort; or a lack of talent. Put elegantly, “if students struggle to learn something, it follows that this is for some reason difficult to learn” (Jenkins 2002, p. 53). These issues can be addressed through *soft scaffolding*, such that individual understandings are continuously probed to enable the timely delivery of tailored support (Simons & Klein 2007). Through this, misunderstandings are traced and corrected through the provision of intermediate learning objectives. When not promptly addressed, such issues can impede progress as learners are forced to the edge of, or perhaps beyond, their “zone of proximal development” (Vygotsky 1978, p. 86).

Yet, Kinnunen and Malmi (2006) note there can be “individual variety in how students respond to the same situation” (p. 107). Many learners who encounter such challenges are

able to overcome them without assistance, albeit perhaps after some frustration. So why are some people tenacious while others seem helpless? A potential candidate for mediating this response is an individual's academic beliefs. Notably, implicit beliefs surrounding programming aptitude. Dweck (2002) divides learners into *entity-theorists*, who believe their aptitude is a natural fixed trait, and *incremental-theorists*, who believe their aptitude is a malleable quality which is increased through effort. These two groups demonstrate different behaviours when they encounter difficulty (ibid.), as summarised in Figure 1:

	Entity-Theorists	Incremental-Theorists
Goal of the student?	To demonstrate a high coding ability	To improve coding ability, even if reveals poor progress
Meaning of failure?	Indicator of low programming aptitude	Indicative of lack of effort, strategy, or pre-requisites
Meaning of effort?	Demonstrates low programming aptitude	Method of enhancing programming aptitude
Strategy when meets difficulty?	Less time practicing	More time practicing
Performance after difficulty?	Impaired	Equal or improved

Table 1. The potential influence of different theories of aptitude (Adapted from Dweck 2002)

Too often, it is the case that learners start to believe an inherent aptitude is required to become a programmer. Such beliefs inhibit practice. Thus, it is important that programming pedagogies reinforce the incremental theory. An example might include the liberal use of *detailed informative feedback*. This approach focuses on improvement through illustrating weaknesses to overcome, rather than merely labeling learners with summative grades. The latter might be interpreted as a judgment of aptitude. However, many learners “often focus on topics associated with assessment and nothing else” (Gibbs & Simpson 2004, p. 14) so some form of marking is often necessary as an extrinsic motivator.

While Dweck's (2002) dichotomy is useful in illustrating some differences, it does not explain why some learners seem far more determined than others. Potential factors, as Huggard (2004), Rogerson and Scott (2010) affirm, are the negative affective states that learners can experience as they write code. These “states[,] such as frustration and anxiety[,] can] impede progress toward learning goals” (McQuiggan, Lee & Lester 2007, p. 698). However, while some learners become overtly frustrated with the *all or nothing* nature of preparing a computer program for compilation, others press on without complaint, demonstrating an admirable level of experimentation and debugging proficiency. This can be somewhat surprising given that anything short of a completely syntactically correct set of coded instructions will result in failure and it is unusual for those at an introductory level to write robust code on their first attempt.

A potential candidate for mediating how learners are able to overcome negative affect is academic self-concept. That is, “self-perceptions formed through experience with and interpretations of one's environment” (Marsh & Martin 2011, p. 60). Many domain-specific forms of self-concept demonstrate a reciprocal relationship with academic achievement in their respective areas (ibid.) as well as, more generally, interactions with study-related emotions (Goetz *et al.* 2010). Extending this notion, learners who *believe* that they are programmers, those with a high programming self-concept, may be able to overcome frustrations and anxiety more easily. Thus, maintaining high levels of motivation. However, how can self-concept be enhanced? A meta-analysis of 200 interventions shows that

practices which target a domain-specific facet of self-concept, with an emphasis on motivational praise and feedback alongside skill development, yield the largest effects (O'Mara *et al.*, 2006). Other aspects of effective practice might also emphasize learning activities that are enjoyable and nurture senses of pride (Goetz *et al.*, 2010).

3. Conclusion

Learners often need to practice writing code frequently in order to acquire basic programming competencies. This paper questions how learning environments can be better designed in order to facilitate deliberate practice, describing three potential barriers to deliberate practice: the radical novelty of the learning material; the belief that some inherent aptitude is required; and the emergence of unfavourable affective states. It is proposed that examples of good practice might include: soft scaffolding; on-going informative feedback that encourages a growth mindset; and an emphasis on self-enhancement, through motivational feedback and pride-worthy activities, in addition to skill-development. However, empirical enquiry is needed to establish the potential impact of these problems and proposals.

4. References

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