Chapter 7
A Knowledge-Based Approach of Modeling an Internet-Based Intelligent Learning Environment for Comprehending Common Fraction Operations

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ABSTRACT
The goal of the study in this chapter is to support learners to engage in the active learning of common fraction operations from the constructivists’ perspective. An Internet-based Fraction-learning Intelligent Learning Environment (IFILE) is designed under the knowledge-based approach to model the learning process of the target topic. It is intended to optimize the interaction opportunity of learners by providing pedagogical tools and intelligent features. The two pedagogical tools provided are graphical support and electronic blank sheet. The intelligent feature discussed in this chapter is the Next Step Support for helping learners to break the impasse in fraction operations. The key activity of the construction of the Next Step Support of this knowledge-based application is designing rules as embedded units to sense and react to all facets of the fraction evaluation process. This chapter discusses further how the IFILE is designed for developing learning properties from the constructivists’ standpoint.

DOI: 10.4018/978-1-60960-842-2.ch007
INTRODUCTION

This chapter reports a study that aims to engage learners in the active learning of common fraction operations from the constructivists’ perspective. A review of literature indicates that learners seldom easily master the procedural knowledge about addition/subtraction of fractions in conventional mathematics classrooms (Charalambous & Pitta-Pantazi, 2007; Kong & Kwok, 2002; Lamon, 2001; Ross & Bruce, 2009). It is because the traditional instructional emphasis on the algorithmic approach makes learners suffer from the shortcoming of separating knowledge from meaning, in turn the inefficient operations for problem-solving with fractions.

The procedural knowledge about common fraction operations is important for learners to understand rational number as a new dimension of the number system (Clarke & Roche, 2009; Lamon, 2001; Moseley, 2005). Based on our cognitive task analysis (Kong & Kwok, 2003) with results concuring with that of recent research by Charalambous and Pitta-Pantazi (2007), Charalambous, Delaney, Hsu and Mesa (2010) and Rittle-Johnson and Koedinger (2005) in the related fields, there are three core cognitive tasks related to addition/subtraction of fractions with unlike denominators. These three cognitive tasks involve 1) the concept of a common fractional part, 2) the knowledge of fraction equivalence, and 3) the application of prior knowledge of addition/subtraction of whole numbers to addition/subtraction of fractional parts. Empirical evidences show that the provision of a graphical mental model, which offers the meaning of fraction, in the learning process has the potential to foster learners’ cognitive capabilities to produce and judge visual analogs of fractions, and thereby their performance on problem-solving with fractions (Arcavi, 2003; Ni & Zhou, 2005; Panaoura, Gagatsis, Deliyanis & Elia, 2009).

Constructivists perceive learning as an active process that is constructive and self-regulated. It is established that the provision of an Intelligent Learning Environment (ILE) with suitable pedagogical designs in learning process enables learners to receive learner-centered support for an active knowledge construction, and to accomplish cognitive growth in turn (Gerjets & Hesse, 2004). Mavrikis and Gutierrez-Santos (2010) have advocated a learner-oriented approach for the design of an ILE of which is a learning system containing a large database of facts for learners to explore concepts, ask questions and form hypotheses for testing. The intelligence of such system lies not only in the knowledge representation for the subject domain, but also a model of learner’s interaction with the system. This learner’s model is built by machine learning on learner’s interactions.

With the goal of supporting learners to engage in the active learning of common fraction operations, a design-based research study is conducted to develop an ILE under the knowledge-based approach to model the learning process of the target topic. Design-based research is an increasingly accepted approach for theoretical and empirical study in the field of education (Bell, 2004). It attempts to combine theory-driven design with empirical analyses of learning environments (Bell, 2004; Design-Based Research Collective, 2003; Hoadley, 2004). Design-based research aims to design and explore a whole range of innovations. The most common type of design-based research combines software design and studies in education (Hawkins & Collins, 1992; Hoadley, 2002).

In our design-based research study, the Internet-based Fraction-learning Intelligent Learning Environment (IFILE), which is an ILE with graphical support, is developed based on the framework proposed by Akhras and Self (2000), who have perceived the design of a learning environment as an activity for modeling the process of learning. The IFILE is designed to use its knowledge of subject domain and its knowledge of learners interacting with the ILE for exposing learners to a learning process characterized of the properties such as constructiveness and self-regulatedness, from the cognitive scientists’ perspective.
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