Problem-Solution Process by Means of a Hierarchical Metacognitive Model

Michiko Kayashima[1], Alejandro Peña-Ayala[2,3,4], and Riichiro Mizoguchi[4]

[1] College of Humanities, Tamagawa University, Japan
[2] WOLNM, [3] ESIME-Z & [3] CIC [3] National Polytechnic Institute
[4] Institute of Scientific and Industrial Research, Osaka University
kayasima@lit.tamagawa.ac.jp, apenaa@ipn.mx,
miz@ei.sanken.osaka-u.ac.jp

Abstract. We propose a Metacognitive Model devoted to problem-solving. It stimulates abstraction, modification, and instantiation metacognitive activities. Our model holds a hierarchical structure, a learning paradigm, and a workflow to skills acquisition. Such a model is a reference for problem-solving processes.

Keywords: Metacognitive model, abstraction, instantiation, class modification.

1 Introduction

Our metacognitive model enhances learner's cognitive skills. It aims individuals to become better learners and problem solvers. This paper is organized as follows: In section 2 we overview the underlying items of our model; whereas, a description of our Metacognitive Model is set in section 3. We summarize the contributions of our model and the future work to be achieved in the conclusions section.

2 Metacognitive Model's Baseline

Our model accounts: Flavell's Metacognitive Monitoring Model [1], the Meta-level/object-level Model set by Nelson and Narens [2], the workflow for skill acquisition designed by Anderson [3], and the Metacognitive Activity Model [4].

2.1 Metacognitive Phenomena

The Metacognitive Monitoring Model holds four classes of phenomena: *knowledge*, *experience*, *goals-tasks*, and *strategies* [1]. The knowledge holds a set of beliefs about person, task, and strategic factors that bias cognitive activities. The experiences represent subjective internal responses about preconditions for achieving a task and expectations of progress or completion of a task. Goals-tasks depict what the task is and the desired outcome to be fulfilled. Strategies are ordered processes devoted to control one's own cognition and to ensure the achievement of a goal.

G. Biswas et al. (Eds.): AIED 2011, LNAI 6738, pp. 484–486, 2011.

2.2 Two Abstraction Levels Architecture

The Meta-level/object-level Model organizes cognitive processes into a meta-level and an object-level [2]. The former pursues to control internal cognitive processes and the later controls the mental activity achieved by individual in the external world. A monitoring flow is performed when the meta-level is informed by the object-level about the cognitive activity. A control flow is triggered when information goes from the meta-level to the object-level for changing the behavior at the object-level.

2.3 Skills Acquisition Workflow

The workflow for skill acquisition tailored by Anderson embraces three stages: *cognitive*, *associative*, and *autonomous* [3]. The Cognitive stage enables learner to get knowledge by objectivism practice. The outcome is *declarative knowledge* of the skill. The associative stage privileges the constructivism practice by problem-solving exercises. As a result, it adds *procedural knowledge*. The autonomous stage aims the learner to develop more domain problems, whose cases are diverse and represent increasing degree of complexity. This stage produces *refined knowledge* of the skill.

3 A Profile of the Metacognitive Model

Our Metacognitive Model is organized as a multi-tiers architecture [4]. The structure allocates cognitive activities according to their target of control and interaction. At the top, a metacognitive learning paradigm is set to represent the manipulation of classes. At the middle tier, a cognitive model for problem-solving is outlined. It encompasses a sequence of cognitive activities to represent the process of problem-solving. At the bottom level, a double-loop cognitive model is tailored. It accounts the skills acquisition workflow to acquire, evolve, and refine knowledge.

3.1 Metacognitive Learning Paradigm

The paradigm encompasses three cognitive operations to manipulate classes: 1) *abstraction operation*: monitors a problem-solving process at the "object-level" and yields a class to generalize its attributes at the "meta-level"; 2) *modification operation*: revises and updates class attributes at the appropriate grey-level. It holds three class operators: *addition*, *modification*, and *deletion*; 3) *instantiation operation*: occurs when a suitable class, an abstraction at "meta-level" of a problem-solving process, is successfully chosen to "control" cognitive activities at the "object-level".

3.2 Cognitive Model for Problem-Solving

Our model achieves eight activities: 1) *observation*: creates cognitive products in working memory (WM); 2) *abstraction*: sets a class at meta-level; 3) *rehearsal*: maintains contents in WM; 4) *evaluation*: qualifies class attributes; 5) *modification*: tunes the class attributes; 6) *virtual execution*: applies operators to cognitive objects to test the class; 7) *selection*: chooses the class for being instantiated, 8) *instantiation*: deploys a representation of the class at the object-level to guide the problem-solving process [4].

3.3 Double-Loop Cognitive Model

The model follows three stages to acquire knowledge skill. In each stage, cognitive activity is performed as a double-cycle. A cycle contains three items: *input*, *process*, and *output*. At instance-level, input reveals the cognition of external objects, whilst at the meta-level it corresponds to monitoring. Process is the cognitive model for problem-solving at meta-level; whilst at object-level it reveals the cognitive activities to problem-solving. Output depicts the control flow from the meta-level to the object-level and the actions to be fulfilled at the instance-level.

4 Conclusions

Our model extends the Flavell's Metacognitive Monitoring Model by adding a structure of three tiers. The model also enhances the Meta-level/object-level Model by means of class operators and class activities. As a future work, we plan to develop a computer-based prototype to implement our Metacognitive Model.

Acknowledgments

The second author gives testimony of the strength given by his Father, Brother Jesus and Helper as one WOLNM project. The research holds a support from grants: CONACYT 118962, CONACYT 118862, CONACYT-SNI-36453, SIP-20110398, SIP-EDI: DOPI /3189/08, COFAA-SIBE, and a Grant-in-Aid for Scientific Research (C) 22500894 in Japan.

References

1. Flavell, J.H.: Metacognition and Cognitive Monitoring: A New Area of Cognitive-Developmental Inquiry. American Psychologist 34, 906–911 (1979)
2. Nelson, T.O., Narens, L.: Why Investigate Metacognition. In: Metcalfe, J., Shimamura, A.P. (eds.) Metacognition: Knowing about Knowing. MIT Press, Cambridge (1994)
3. Anderson, J.: Acquisition of Cognitive Skill. Psychological Review 89(4), 369–406 (1982)
4. Kayashima, M., Inaba, A.: The Model of Metacognitive Skill and How to Facilitate Development of the Skill. In: Proc. Int. C. Computers in Education, Hong Kong, pp. 277–285 (2003)