

Ontological Organization of Academic Emotions toward Knowledge Description and Management about Learners Mental States

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Abstract: Recently, the research in intelligent educational systems has much interest in exploring data from academic settings to understand learners behavior and mental states. We have been developing IMS (Intelligent Mentoring System) which performs automatic mentoring by using an ITS (Intelligent Tutoring System) to scaffold learning activities and an ontology to provide a specification of learner's models. To provide learner's models in mentoring, the ontology describes qualities and quality values on awareness which are conceptualization of subjective evaluation. To specify relationships among qualities on awareness in academic settings, this study organized academic emotions in the psychological research and proposed their ontological descriptions.

Keywords: Ontology, academic emotions, control-value theory

1. Introduction

Recently, learners' situations have been tried to recognize through their face images, eye movement, and other physiological indices which pertain to semi-conscious behaviors of learners during operation of e-learning systems. Analysis of data obtained from such the behaviors can provide understanding of learners' mental states such as confidence or confusion (Arroyo et al., 2009; Muldner et al., 2009; Kojima et al., 2012) in addition to learners' knowledge structures focused by researches about Intelligent Tutoring System (ITS). On the basis of the analysis, Intelligent Mentoring System (IMS) which supports learning from both aspects of knowledge and mental states has been developed (Kojima et al., 2012; Muramatsu et al., 2012). In conceptual framework of IMS, interactions between user and system are captured in two levels of cognitive activity; high-level interactions (HLI) and low-level interactions (LLI). The HLI explicitly pertains to user's awareness and is consequently illustrated by data resource which is sampled in large grain sizes. In contrast, the LLI does not always pertain to user's awareness and is consequently illustrated by data resource which is sampled in very smaller grain sizes. In e-learning environment, behaviors of learners who gaze problem and selection statements of a multiple-choice test are regarded as LLI resources. Muramatsu et al. (2012) developed an ontology to provide consistent descriptions of knowledge about relationships among LLI resource and mental states of learners which is task-oriented and independent from knowledge structures of specific study domains. In concrete terms, they described *multiple-choice test event* and positioned a learner's eye movements and mental states in it.

Their ontology well illustrated co-occurrence of semi-conscious behaviors and mental states felt by learners in multiple-choice tests. However, it does not have enough description how mental states are occurred in each academic setting. For implementation of IMS, the learner's model should contain knowledge how mental states of learners are identified by their feelings to learning activities and materials. The feelings are often represented by subjective qualities such as conviction and hesitance (Muramatsu et al, 2012) or emotional dimensions such as easy/difficult, boring/interesting, confused/comprehending and tired/concentrating (Nosu & Kurokawa, 2006). Thus, the current study aims to generalize the

ontological descriptions concerning the mental states, according to concepts of academic emotions proposed in psychological researches. To be more precise, we organize concepts and theory of emotions in academic settings, and propose ontological descriptions of them, to specify relationships between so-called academic emotions and subjective qualities which are used to represent learners' mental states.

2. Emotions in Academic Settings

In the study area of psychology, emotions of learners related to academic learning, class room instruction and achievement are referred to as *academic emotions* (Pekrun et al., 2002). Especially ones related to achievement are specified as *achievement emotions* (Pekrun et al., 2011). This questionnaire consists of scales about nine emotions; enjoyment, boredom, anger, hope, anxiety, hopelessness, pride, relief and shame. These nine emotions can be divided into two types according to their object focus; *activity emotions* which pertain to ongoing achievement-related activities, and *outcome emotions* which pertain to the outcome of these activities. Enjoyment, boredom and anger are included in the activity emotions. Moreover, the outcome emotions include *prospective outcome emotions* such as hope, anxiety and hopelessness, as well as *retrospective outcome emotions* such as pride, relief and shame.

Academic emotions are conceptually explained on the basis of control-value theory which is proposed by Pekrun (2006). In this theory, two kinds of appraisals are of primary importance; appraisal of subjective control and value. The former pertains to perceived controllability of achievement-related actions and outcomes, and the latter pertains to subjective importance of achievement-related activities and outcomes. In activity emotions, control and values refers to action rather than outcomes. For example, when a learner feels competent to master the learning material and perceives the material as interesting, enjoyment for studying is induced. The prospective outcome emotions are identified by whether there is some lack of control to attainment of success (positive value) or avoidance of failure (negative value). For example, when a student expects that s/he could fail an examination and perceives the examination as important, s/he feels anxious before the examination. In contrast, retrospective outcome emotions are induced when success (positive value) and failure (negative value) are perceived to be caused by internal factors. That is, the control concerns whether the outcome was caused by the self, or by other persons and external circumstances.

3. Ontological Descriptions

3.1 Method to Build Ontology

For the purpose that knowledge on academic emotions and subjective qualities is appropriately managed under an ontology, we expanded concepts of quality and quality values. These concepts are already defined in a top-level ontology YAMATO (Yet Another More Advanced Top-level Ontology; http://www.ei.sanken.osaka-u.ac.jp/hozo/onto_library/upperOnto.htm). In despite of wide applicability over domains, they are distinguished from human recognitions including sensations and perceptions. For example, generic quality of sweet foods and drinks is not sweetness as a result of perception, but is contained amount of materials which make human to taste sweetness. That is, the "sweetness" which human perceive is just named as if it was a quality of sweetness (Tarumi, 2010). Therefore, the attributes of emotions which are perceived by humans have to be psychologically or subjectively defined in distinction from the YAMATO's qualities and quality values.

In the following subsections, we introduce ontological descriptions for knowledge pertains to emotions in academic settings. First, qualities and quantities are expanded to cover

psychological or subjective attributes on the basis of human awareness. Second, antecedents of academic emotions are specified in an appraisal action which takes object focus and be associated with subjective value and control.

3.2 States, Actions and Attributes Related to Awareness

According to Barušs, consciousness is defined as all subjective awareness characterized by intentionality, and to the explicit knowledge of one's situation, mental states or actions evidenced behaviorally (Barušs 1987). This definition indicates two types of consciousness; one is subjective consciousness and the other is behavioral consciousness. Thoughts, feelings and sensations which occurs to persons are regarded as a subjective awareness, and the awareness expressed through one's behaviors is regarded as a behavioral awareness (Barušs, 2000). That is, the behavioral consciousness is defined as an operationalization of the subjective consciousness to deal the awareness in objective researches.

In YAMATO, the awareness can be specified with *external state* and *actor state action*. Figure 1 shows state of *being aware* and *awareness-focused action*. The state is defined as a subclass of the external state in YAMATO. Objects of awareness are represented by *of what* role-holder played by a physical or semi-abstract thing, and subjective qualities are represented by *quality on awareness* which plays *subjective quality*. The action is defined as a subclass of the actor state action in YAMATO and composed of slots of doer, object and result. Since the doer's awareness can be observed only when it is explicitly expressed, *content of awareness* is defined as a role-holder of a content role under the result slot. The *object of awareness* which is role-holder in the object slot is linked to the content of awareness by *depend on* link.

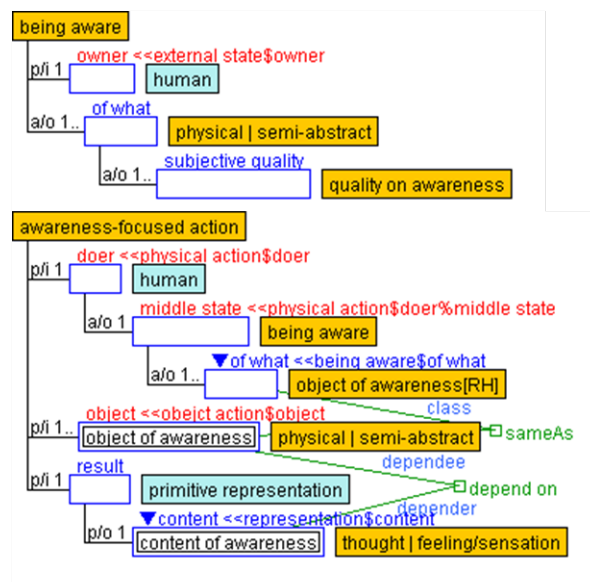


Figure 1. State of being aware (upper) and awareness-focused actions (lower)

The definitions of the object and content of awareness enable to distinguish attributes which human recognize from YAMATO's qualities and quality values. Subjective qualities (such as conviction and hesitance) and emotional dimensions (such as easy/difficult, boring/interesting, confused/comprehending and tired/concentrating) are attributes which only exist in human awareness. Figure 2 shows qualities and quality values on awareness. Each is defined as a subclass of qualities and quality values in YAMATO. The *quantitative perceptual quality value* is divided into *primitive perceptual quantity* and *composite perceptual quantity* which are conceptualization of psychological quantities. The *quantitative perceptual quality* is divided into *unipolar perceptual quality* and *bipolar perceptual quality*

which take quality values; primitive perceptual quantity and composite perceptual quantity respectively. Adding to the quantitative perceptual quality value, they take qualitative perceptual quality value.

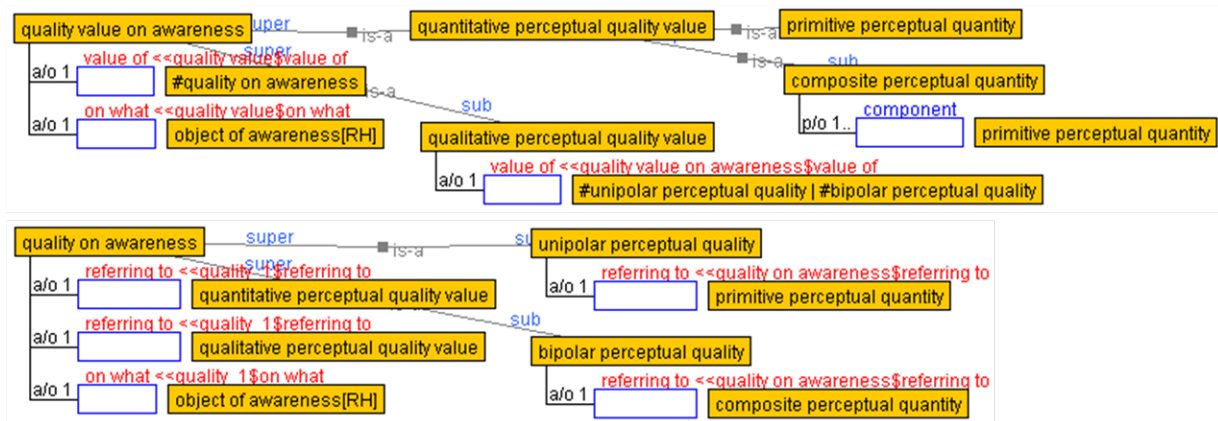


Figure 2. Quality value on awareness (upper) and Quality on awareness (lower)

3.3 Subjective Measurement and Appraisal

In psychometric methods using rating scales, subjective evaluations are often expressed as a point on rating scale. The previous research by Nosu and Kurokawa (2006) used rating scales to obtain subjective evaluation of emotion under e-learning environment. Here, we specified an action to *rate on scale* which is located under the awareness-focused action (Figure 3). The subjective evaluation can be regarded as transforming subjective quality on the doer's awareness into a representation. Because a numeric value subjectively measured is equal to the scale marking of selected point on a scale, the *value* slot of the *subjective measurement* and the *scale marking* slot are linked by the *same as* link.

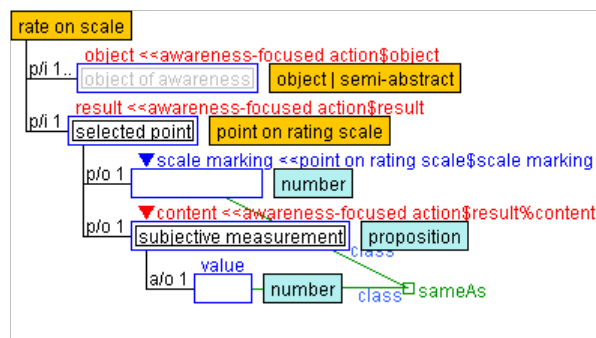


Figure 3. Action to rate on scale

Whereas the emotional dimensions of subjective evaluation such as easy/difficult, boring/interesting, confused/comprehending and tired/concentrating are specified as attributions on awareness through the action to rate on a scale, academic emotions are thought to be identified by objects of awareness as "object focus" and their attributes on awareness as "antecedents" of appraisals. Thus, we conceptualized an action to appraise and its subclasses on the basis of doer's awareness (Figure 4). The action to *appraise* is a subclass of the awareness-focused action as well as the action to rate on scale. The object focus in the control-value theory is defined as an object of awareness played by occurrent in the *of-what* slot of doer's middle state. Activities and outcomes in academic settings are regarded as occurrent things rather than continuant things, because the object focus which concerns the doer of the action exists just in his/her awareness pertains to past, present and future. In our ontology, the subjective value and control which are antecedents of appraisals are defined as

attributes of the object focus, because the doer is thought to feel that the antecedents are attributed to the object of awareness. Emotions induced in the appraisal are described in the content which is played by proposition. This proposition does not exactly indicate an emotion itself which the doer feels but an emotion expected to be occurred in the doer's awareness, because this action is a conceptualization of control-value theory which provides identities of each academic emotion. This action can be divided into three subclasses; activity focused, outcome/prospective focused and outcome/retrospective focused. The starting time of the activity focused is specified in interval, implying the object focus is ongoing thing. In the outcome/prospective focused, the ending time of action is before starting time of object focus. Inversely, in the outcome/retrospective focused the ending time of action is after starting time of object focus. These imply that object focus in each outcome focused action refers to occurred thing in future and past respectively.

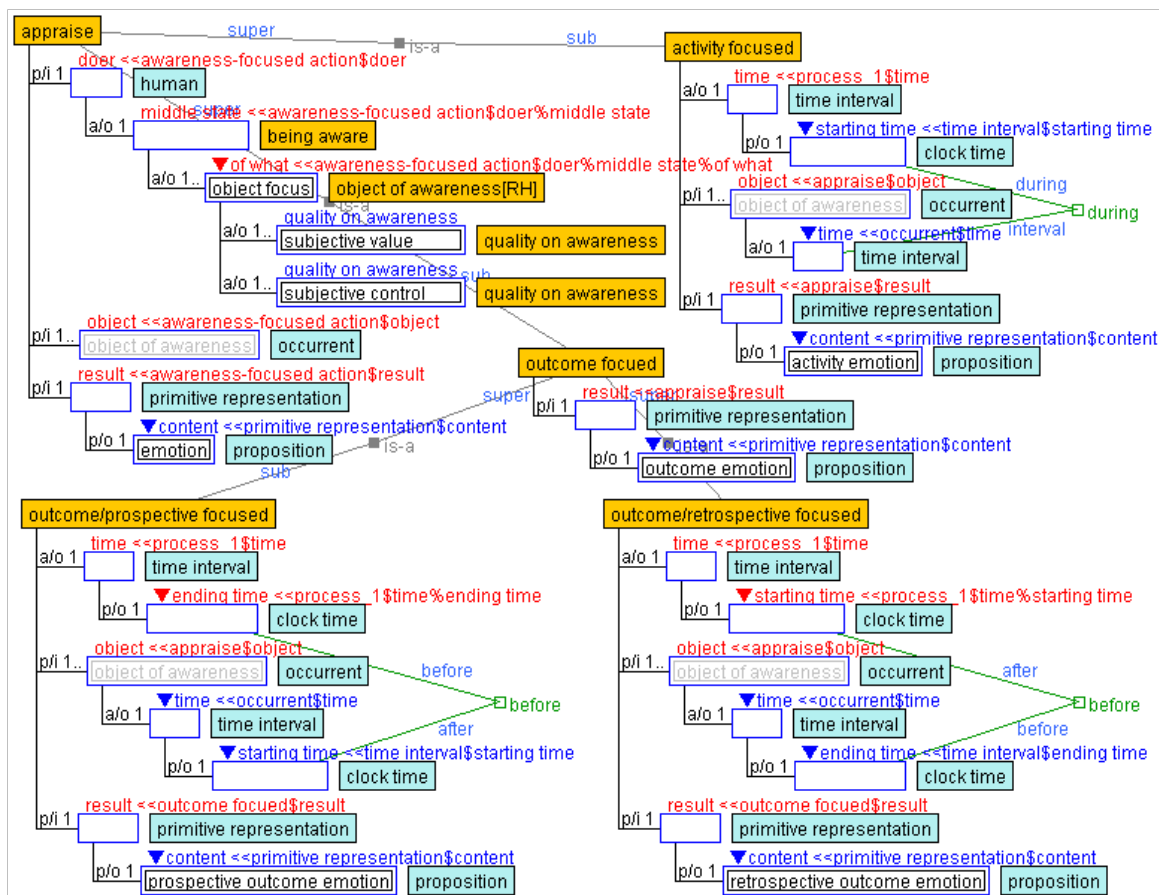


Figure 4. Action to Appraise and Its Subclasses

4. Discussion and Conclusion

In the current study, we generalized ontological descriptions pertain to mental states according to concepts of academic emotions and control-value theory. We introduced concepts of attributes on awareness, and specified actions to rate on scale and action to appraise. In action to rate on scale, subjective qualities are described as a role played by quality on awareness under the state of *being aware*, and transformed into subjective measurements played by propositions. In action to appraise, academic emotions are specified by an object focus and its subjective values and controls which are played by qualities on awareness.

These descriptions can clarify relationships between academic emotions and subjective qualities which are defined as qualities on awareness. In case of e-learning environments, learning materials such as multiple-choice tests can be object focus, and activity emotions

such as enjoyment, boredom and anger can be induced. The subjective qualities mentioned in Muramatsu et al. (2012) and emotional dimensions measured in Nosu & Kurokawa (2006) play roles of subjective controls or values which identify academic emotions. For example, when learner's mental states are estimated as interesting and comprehending, enjoyment is expected to be an academic emotion. In this situation, the quality of interesting plays subjective value which takes quality value of positive or negative, because subjective evaluation on a scale of interesting correlated to dimension of positive/negative affect according to a research on structure of academic boredom by Acee et al. (2010). On the other hand, the quality of comprehending plays subjective control in the situation, because it can be regarded as controllability to master the learning material. On the basis of our ontology, such the situation is described as an instance of "activity focused" action, and the enjoyment is an instance of "activity emotion" which fills its result slot. The subjective qualities (interesting and comprehending) is also described as an instance of "subjective value" and "subjective control" which are attributed to the objective focus. Estimation of learner's mental state in that example can be provided by such the system developed in Nosu & Kurokawa (2006), by using template matching of facial expressions and biometrical signals obtained through learner's activity. To organize components of academic emotions in a certain situation, our ontological descriptions would be applicable to other real systems. Hence, they form prototype of framework to manage subjective qualities which implemented in learner's model of IMS.

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