CHAPTER 7 –Affective-Behavioral-Cognitive (ABC) Learner Modeling

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Introduction

This chapter presents a framework for modeling users of e-learning systems that integrates inductive and abductive reasoning over observations including the learner's past and current behavior to develop a joint model for predicting emotions, behaviors, and cognitive states. This ABC Learner Model follows an approach that learners' behavioral responses can be a path to predict, recognize, and interpret their affective state. These behavioral responses are analyzed using a cognitive theory of emotions, which gives us inferences about the possible affective states of the learner. An appraisal component of the model relies on the desirability of events given the learner's objectives, the resulting affective and cognitive states predicted to result from the events, and the consequent behaviors expected.

Most current techniques for modeling learners make relatively strong assumptions about what affective, behavioral, and cognitive states are best for learning, and about what to do in a single interaction turn to maximize immediate learning based on the current states. Most ITSs typically do not learn which user states optimize short- or long-term learning goals, learn what sequence of events will likely elicit particular user states, appraise system attempts toward these goals, or learn appropriate corrective actions based on this appraisal. The ABC Model attempts to fill these gaps by learning to make predictions that take these more complex relations between events, learner states, and time-dependent scenarios into account.

We begin by describing user models in general and the various user states incorporated by the ABC Model. We explain a cognitive theory of affect and behavior and its use in creating user profiles. In the following section, we give an overview of the various categories of knowledge and information about the learner, which are required for creating a learner-specific profile and the methods for obtaining them. After this, we discuss the categorization of events that can occur in an e-learning scenario and the relationship these events have with the learner models. Then, we move on to describe the ABC Model's appraisal mechanism, which relates learner states to their goals. Based on this, the system provides suggestions for the learner in support of the e-learning process. Finally, the system updates the learner model based on observations of the effects resulting from its decisions. In the last section, we provide recommendations for GIFT and how the various aspects of the ABC Model can support the modules present in GIFT to enhance their performance for e-learning environments.

The ABC User Model

The ABC User Model (Figure 7-1) tracks the affective, behavioral, and cognitive states and patterns of the user and applies a cognitive theory of emotions to infer and analyze these states and patterns. This analysis is then used to provide an adaptive and interactive e-learning environment to learners intended to optimize learning based on their individual characteristics, requirements, and preferences. The *affective states* store the information relevant to the learner's emotions. The *behavioral patterns* store the information associated with the way the learner interacts with and reacts to events within the system and their apparent objectives. The *cognitive states* store information associated with the learner's mental processes. This section gives a description of these states and the aspects covered by each.

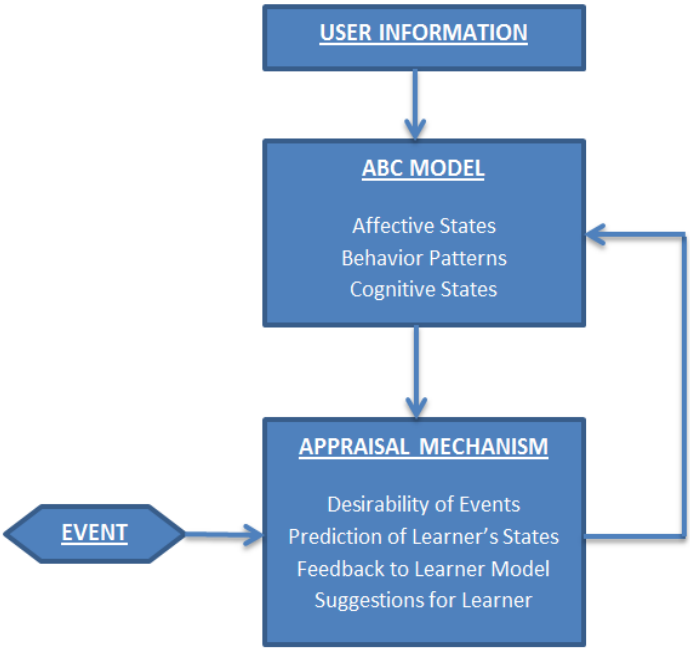

Figure 7-1. The ABC Model

Affective States

The learner model needs to represent and acquire the learner's emotional states. It needs to develop techniques to make predictions and inferences about and based on these emotions. In the ABC Model, emotions are ascribed to the learner based on not only the sensory inputs, but also the learner's behavior and on the events of the world (Martinho et al., 2000). Hence, it needs a cognitive theory of emotions that considers and works with such stimuli. Ortony, Clore, and Collins' Theory of Emotions, OCC Theory (Ortony et al., 1988), is one such cognitive appraisal theory and forms the basis for the affective aspect of the ABC Model.

OCC Theory: Ortony, Clore, and Collins proposed a cognitive appraisal theory that is structured as a three-branch typology, corresponding to three kinds of stimuli: consequences of events, actions of agents, and aspects of objects. Each kind of stimulus is appraised with respect to one central criterion, called the central appraisal variable (Adam et al., 2009). An individual judges the following:

1. The desirability of an event
2. The approbation of an action
3. The attraction of an object

The OCC typology contains 22 emotions, grouped in 6 classes. These are depicted in Figure 7-2. The first branch contains only one class of emotions related to aspects of objects, triggered by the appraisal of the objects with respect to the individual's likings. This class is seldom involved with e-learning environments, usually limited to the cases having virtual characters involved with the learning process. The second branch contains three classes of emotions triggered by the appraisal of the consequences of an event as to its desirability. Different emotions arise depending on the prospect and the focus of the desirability of consequences of events. Individuals can focus desirability either on themselves or on other

individuals. The third branch contains two classes of emotions triggered by the *actions of agents*, which are appraised according to their compliance and conformity to norms and standards.

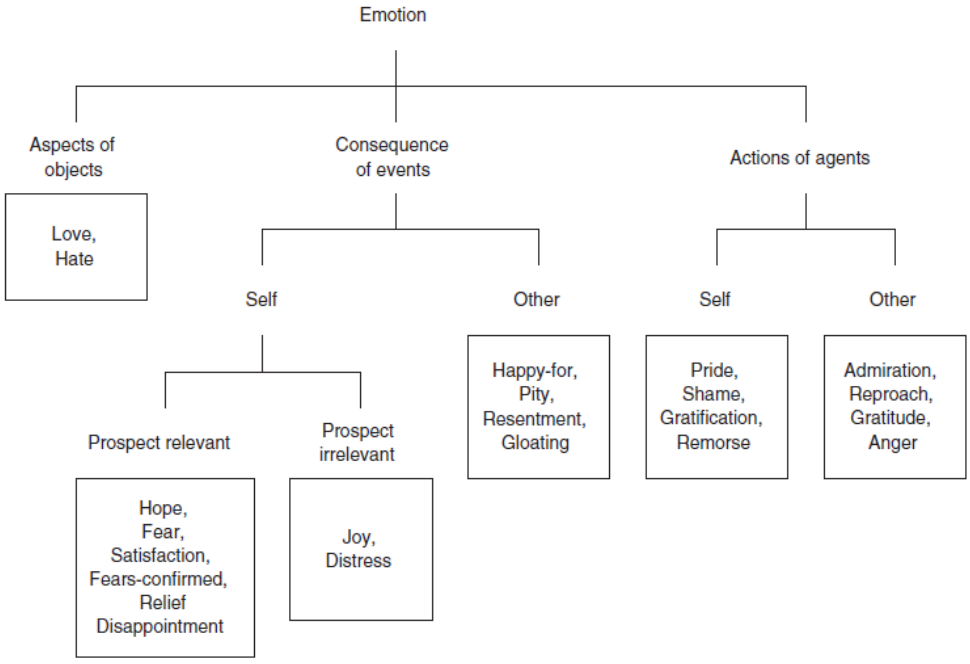

Figure 7-2. The OCC Theory of Emotions typology

Based on the OCC theory, the learner's affective states can be characterized by two types of data: the learner's *emotional profile* and the *emotional states* (Martinho et al., 2000).

Emotional Profile: The emotional profile represents the emotional pattern exhibited by the learner and is constituted by the following:

- *Emotional Class Thresholds*: These represent the assumed emotional "resistance" to the different classes of emotions.
    - For instance, emotional thresholds can model how easily the learner can be disappointed upon not being able to solve a problem. The amount of effort produced by a learner in trying to solve a difficult problem can be used to state the learner's level of resistance to disappointment. If learners have a tendency of not producing enough effort in solving problems related to topics in which they have been performing poorly, it indicates a low level of resistance to disappointment.

- *Emotional Class Decays*: These represent the extent to which emotions represent self-sustaining processes or how long the emotions being experienced by the learner last.
    - It is very difficult to assign emotional decay values, but they can have a significant effect on how the learner behaves in a learning session. They can be inferred from past trends, for instance, some learners get excited upon solving a problem they perceive as difficult and, in such a state, they might make mistakes while working on subsequent relatively easy problems. A decay rate for such an emotion can be assigned by observing patterns and the average time required for saturation.

Emotional States: Two types of emotional states are stored in an ABC Model:

- *Potential Emotional States:* These represent the particular classes of emotions the current situation is likely to provoke according to the learner's inferred attitudes, goals and standard of behavior. Additionally, the model predicts how strong those potential emotions are likely to be.
    - For instance, learners might be expected to feel angry if they get confused by a hint suggested by the system and then fail to solve a particular problem, while they would feel gratitude for the system if the hint helps them solve the problem correctly.

- *Active Emotional States:* The ABC Model classifies the ongoing active emotions of learners based on sensory inputs, system interactions and predictive models.
    - It stores these emotions, along with their *intensity*, that is, the distance between the learner's estimated threshold and the actual current value measured for the respective emotion – the greater this distance, the greater the intensity of the experienced emotion. The active emotional states are one component in the appraisal process discussed later.

Behavioral Patterns

There are two key dimensions of an individual that are most responsible for the way they act: *behaviors* and *personality traits*. Personality traits are persistent characteristics that are demonstrated often under specific circumstances or environments. Because they define habitual patterns of thought and emotion, they provide a foundation for predicting behavior. Personality traits seldom change over time but these can trigger different behaviors under different circumstances and emotional states. The ABC Model incorporates representations of the personality traits and learner objectives, which combined with the affective states, predict the behavior of a learner under given circumstances.

Personality Traits: The ABC Model follows the Five-Factor Model of personality (Conati et al., 2002), which structures personality traits as five domains:

1. *Openness:* the degree of intellectual curiosity, creativity, and a preference for variety.

2. *Conscientiousness:* a tendency to show self-discipline, act dutifully, aim for achievement, and plan behavior.

3. *Extraversion:* sociability and the tendency to seek stimulation in the company of others.

4. *Agreeableness:* a tendency to agree, be cooperative, and go along with others, as well as how important it is for a person to please others.

5. *Neuroticism:* the tendency to experience unpleasant emotions easily, such as anger, anxiety, or depression, indicating the degree of emotional stability and impulse control.

All these dimensions of personality are closely related to the expressional, logical, and emotional personification to varying degrees. Depending on the application being implemented, a different combination of these personality traits might be considered significant for the context of usage. However, it is advisable to use all the dimensions in the model, as some changes in the learner's states might go unnoticed leading to inaccurate predictions under certain conditions. Since the model states that these five factors form the basis of the personality space, one should be able to represent any personality as a combination of these factors.

Goals: Goals are used in problem solving or task execution in learning environments. The learners using an e-learning system have goals and objectives to carry out an associated task or to perform and learn at a certain level. There can be different types of goals depending on the application that is using the ABC Model. A few examples follow:

- Performance related goals with respect to a specific task in an application.
- Goals related to achieving a certain level of understanding of concepts.
- Goals to avoid making errors and mistakes
- Goals to find the most efficient solution to problems
- Goals to perform well with minimum assistance from the system
- Goals to perform better than other students
- Goals to have fun in the learning process

Each of these goals has a different degree of relevance to a particular learner, which leads to events having varying effects on the affective states of the learner (Elliott et al., 1999). The relevance is represented using the following *intensity variables*:

1. Importance to the learner
2. Effort
3. Anxiety
4. Arousal

These variables are assigned a value by using the user information and the personality traits, for instance, the domain knowledge and preference decide the importance and effort associated with a goal and anxiety and arousal depend on specific personality traits and past record.

Cognitive States

Cognitive states represent the state of a person's cognitive processes or their state of mind. They represent the way a learner thinks, perceives, remembers, or solves problems under given circumstances. Hence, they have a large effect on the way a learner assimilates and retains information while using an e-learning system. Similar to the affective aspects of a learner, cognitive aspects are characterized by two types of data: the learner's *cognitive profile* and the learner's *cognitive states*.

Cognitive Profile: The cognitive profile represents the habitual pattern of cognitive behavior exhibited by the learner and is constituted by the following:

- *Cognitive State Thresholds:* These represent the assumed cognitive "resistance" to the different cognitive states.
    - For instance, cognitive thresholds can model how easily the learner can get confused. The rate at which the system provides information to the learners might be beyond their

ability to grasp it. Information about the learner states is monitored and recorded to assign threshold values to the parameters associated with the state and the signals sent by the sensors used for identifying the cognitive state.

- *Cognitive State Decays:* These represent the extent to which cognitive states represent self-sustaining processes or how long the learner persists in the states.
    - As with emotional class decays, it is very difficult to assign values to cognitive state decays. They can be inferred from past trends, for instance, some learners get bored while they are being taught a subject they are poor at and they pay less attention to a system that inhibits the learning process. A system typically responds to such a situation by attempting to refocus the learner's attention. The time span over which the system needs to take such measures can be observed and a decay rate can be assigned accordingly.

Cognitive States: Two types of cognitive states are stored in an ABC Model:

- *Potential cognitive states:* These represent the particular cognitive states the current situation is likely to provoke according to the learner model. For instance, learners might be expected to feel drowsy if they are currently getting bored and confused by a topic being taught by the system.

- *Active cognitive states:* The ABC Model classifies the ongoing active mental states of learners based on sensory inputs, system interactions, and predictive models. It stores these states, along with their *intensity*, that is, the distance between the learner's estimated threshold and the actual current value measured for the respective mental state – the greater this distance, the greater the intensity of the experienced state.

Based on the information representing the learner's affective, behavioral, and cognitive states, the ABC Model predicts how a learner is going to behave on the occurrence of an event. The next section describes the various types of user information required to build the user model and the ways of collecting the information.

User Information

The information about the user forms the basis of a user model and is a primary means of characterizing it. User models are created by processing different types of user information such as beliefs, characteristics, preferences, objectives, etc. The raw information about the user is processed to create the ABC Model. The user information can be classified into five categories: characteristics, capabilities, preferences, domain knowledge, and goals. Each of these categories is briefly described in this section followed by some means of gathering the information about the user.

Types of Information

Characteristics: These are normally captured within a profile of the user, such as gender, age, interests, and personality traits. This information helps in predicting the user's behavior under specific circumstances and aids the agent in making better decisions. This information can also be relevant to infer other more specific information such as preferences.

Capabilities: Some systems need to model the capabilities of their learners (e.g., the ability of the learner to understand a recommendation or explanation provided by the system). Modeling capabilities include

modeling human learning, memory, and cognitive load limitations, which would allow a system to adjust the length and content of explanations as appropriate to ensure the learner is capable of assimilating it.

Preferences: These are used in interactive systems to make suggestions for the learner or in interface agents to select the information that is most relevant to the learner. The preferences often help the system recognize any tendencies of a learner toward particular options or solutions, which, in turn, helps in estimating the mistakes and errors made by the learner.

Domain Knowledge: These represent the learner's beliefs about a specific domain of knowledge. The knowledge of the concepts and terms the learner understands, allows the system to produce responses incorporating those concepts and terms while avoiding the concepts that the learner might not understand. This type of content is relevant for intelligent learning environments, which aim at considering the learner's state of knowledge to facilitate generation of explanations.

Goals: Goals have already been described briefly in the previous section on behavioral states. The effort that a learner puts in depends on the goals, and hence, the need to store information on these is an immediate result of the need to support the learner to adequately achieve their tasks and performance level. We describe later in this chapter how these goals and objectives affect the desirability of the events in an e-learning environment which in turn helps in modeling the learner's state.

Methods of Gathering Information

There is no absolute method for collecting the above-mentioned types of information; instead, a combination of methods should be used. This helps in gathering different segments of information, which can be combined together and then classified accordingly to generate a holistic model of the learner. The following are some of the methods that can be employed for this purpose:

- **Survey Forms:** These are often seen as a quick and easy means of collecting valuable learner information. These allow information collection in an objective and standardized manner, which helps in direct storage, usually without any need of further processing. For example, the learners can be asked about their specific traits on a particular scale and they can be asked to choose their preferences from a list. This is not usually possible with open-ended questions having a subjective nature since they can generate huge amounts of data. This makes their handling and processing a complicated task as the relevant information needs to be extracted from the learner's responses. This, survey forms should be used mostly for specific information about the learner, for instance, the characteristics, likes, dislikes, and basic objectives.

- **Learner's Academic Records:** These often reveal a huge amount of information about the academic background of the student learner. The knowledge of academic background helps in analyzing the familiarity the learner has over specific domains covered by the learning environment and, to some extent, describes the learner's relative ability to grasp different content. Learner records also help in estimating a range in which the learner can perform, which can be used to deduce the learner's objectives and expectations associated with the e-learning system.

- **Pretest and Questionnaires:** These are used to evaluate comprehension and deduce high level goals while using the e-learning system. The pretest can have different sections aimed at assessing the learner's skills related to various domains like mental ability, problem solving, and initial understanding of different subsections of a topic. Some questions can be specially designed in order to get information on the personality traits of the learner. Depending on the learner's performance, a basis can be created for the goals, focus areas, and most frequent errors.

- **Sensors:** The ABC Model gathers information about the learner's affective and cognitive states by the use of various sensors. These can be based on audio, video, infrared signals, thermal imaging, heart rate, respiration rate, etc. Passive sensors can be used to sense learner behavior unobtrusively, avoiding any negative impact on learning process (Sottilare et al., 2012). Sensors send signals to the learner model indicating the current state being experienced by the learner and this information is used to infer profiles related to emotional and cognitive states.

Events

In the context of the ABC Model, an event is an activity or a happening that can affect the realization of learner's goals and has the potential to modify the learner's affective and behavioral states, either directly or indirectly. Events can result from the actions of either the learner or the system, and hence, can be of two types based on the source of origin: *learner-generated events* and *system-generated events*. Based on their effect on the realization of the goals and objectives, events can be classified into the following two categories (Martinho et al., 2000):

- **Desirable Events:** events that lead to or facilitate the realization of goals and objectives.

- **Undesirable Events:** events that prevent or inhibit the achievement of goals and objectives.

In both cases, the degree of desirability is proportional to the importance of the goal and the degree to which the event contributes to or impedes the achievement of the goal.

Relation Between Events and Learner Model

The ABC Model recognizes the emotions based on the OCC cognitive psychological model of emotion, which considers 22 categories of emotions. Relevant categories of emotions are selected depending on the e-learning application for which the model is being used. Some of the emotional and mental states most relevant to e-learning environments are joy, distress, fear, disappointment, surprise, anger, boredom, confusion, attention distraction, and shame.

The events are assigned a desirability value based on their predicted effect on achieving goals, which is directly related to the learner model states. The desirability helps the system decide how a learner is expected to react to a particular event, under a given state. For example, an event inhibiting the achievement of a goal will be much more undesirable for a learner who has been ascribed a high value for the neuroticism trait and is already in a distressed emotional state compared to a happy learner with a positive attitude. According to OCC, joy and distress are elicited when a person focuses on the desirability of an event in relation to the individual's goals. Joy occurs when a person is pleased about a desirable event that takes place and distress when that person is displeased about an undesirable event. For instance, for learners who have the intention of pleasing the teacher and their parents, obtaining a good grade is a desirable event. Similarly, different cognitive states become active depending on the desirability of an event.

It is necessary to determine the learner's goals in order to verify the desirability of events. Students who have a learning goal are oriented toward developing new skills and abilities, and try to understand their work, improve their level of competence, and learn new things. When learners have performance goals, they want to demonstrate that they have the associated abilities. They feel successful when they please the teacher or do better than other learners, rather than when they understand something new.

Moreover, different classes of emotions are elicited depending on the source of an event. For example, an event that facilitates the learner's goals can generate positive emotions such as joy for the event, *gratitude* toward the system for system-generated events, or *pride* in the case of a learner-generated event. Corresponding negative emotions for an event inhibiting one's goals are *anger* and *shame*.

Appraisal Mechanism

A user modeling system needs to have a mechanism to appraise emotion-inducing stimuli, so that the affective and cognitive states are predicted with a high level of accuracy. People have a perception of the world and this leads to activation of emotions. The appraisal structure makes use of inductive and abductive reasoning over these perceptions. Induction allows inferring the conclusion from the premise with a high probability. For example, if learners have a tendency to behave in a particular way while experiencing some specific states, then the system predicts that behavior under similar circumstances in future. On the other hand, abduction allows inferring a premise as a plausible explanation of a consequence. For example, if undesirable events result in particular learner states, then these states arising after the occurrence of an uncategorized event can be used to classify it as undesirable. According to OCC theory, emotions are elicited from three different perspectives: consequences of events happening in the world, action of agents, and aspects of objects existing in the world. Based on the learner information, the ABC Model attempts to predict how the learner perceives different events. The predicted learner perception is used to infer the changes expected in the learner's affective, behavioral, and cognitive states on the occurrence of an event.

Desirability of events is estimated with respect to the learner's goals and this may elicit *consequence of events* emotions like satisfaction and distress. Appraisal of actions, whether of the learner or the system is done with respect to the learner's predicted standard of behavior and this may elicit *action of agents* emotions like admiration and remorse.

The ABC Model keeps a record of the past changes in the learner's affective and cognitive states, which is used to ascribe the potential states. Based on these and the information about the learner, the system makes predictions regarding the learner's expected behavior. This predicted behavior is compared with the actual observed behavior of the learner and depending on the level of conformation between the two, appropriate modifications are made to the learner model and the prediction models. Now based on the observed events or actions and the learner's current state, the system infers the changes activated by the event and the further actions expected to result from these changes. These inferences are then stored in the learner's model to be used for appraisal of future events. The system appraises events by assigning them a relevance related to the learner's goals and then estimates them using the OCC theory of emotions to evaluate each affective and cognitive parameter. This can be done using machine learning and pattern matching techniques. Predictions regarding the learner's behavior are also made using machine learning techniques based on the affective state of the learner and the information in the learner model.

Now based on the observed changes resulting from an event or an action and the knowledge of how the learner behaved under similar situations in the past, the system incorporates pedagogical strategies and provides suggestions to help the learner acquire states that enhance the learning process (D'Mello et al., 2009). For problem solving environments, the ABC Model keeps track of the possible steps at each stage and if the learner solves a problem incorrectly, then the system appraises the point of error in the solution and highlights it to the learner (Balakrishnan, 2011). When the learner makes an error, the ABC Model records the learner's states and associates them with the error. This helps in identifying the potential mistakes the learner might make in specific states, so when such a state arrives in the future, the system helps the learner to avoid making the mistake by producing hints.

Discussion and Recommendations for Learner Modeling

The ABC Learner Model framework described here integrates inductive and abductive reasoning to develop a learner model for predicting the learner's affective, behavioral, and cognitive states in an e-learning environment. We have described a convenient approach for the implementation of learner models based on the affective, behavioral, and cognitive states of the learner. It allows the system to predict learners' future ABC states based on their personal information and cognitive evaluation of events that elicited a specific emotion or behavior. The ABC model appraises events in terms of desirability and learns about the events that elicit specific emotions, and hence, decides the appropriate tactic to apply to enhance learning. Being independent of domain and not involving any predetermined assumptions, the proposed framework can be integrated into any e-learning environment. The affective and cognitive profiles can be used to focus on specific challenging states of a learner demanding special attention. Incorporating predicted future states allows the system to modulate learners' critical behavior in advance by giving appropriate suggestions.

GIFT, a service-oriented framework of tools, methods, and standards to aid computer-based tutoring systems described in previous chapters, can benefit by incorporating aspects of the ABC Model into its framework. The various types of information required to create the learner models can support GIFT's Domain Module in assessing the learner's performance and providing relevant content as feedback. GIFT's Learner Module functions to determine the learner's affective and cognitive states and this module can use the method in the ABC Model for predicting learner states. The ABC Model observes and analyzes learner performance over a period and creates affective and cognitive profiles that have threshold values and decay rates associated with the states in consideration. Incorporating these parameters can assist the learner module in determining learner states more effectively.

The ABC Model's appraisal mechanism predicts the changes resulting from an event and facilitates suitable interactions to enhance the learning process. GIFT's Pedagogical Module decides when feedback needs to be provided to the learner, and hence, can benefit from the ABC Model's appraisal mechanism. The appraisal mechanism can also support the trainee module for predicting the learner's state. Moreover, the Assessment Construct of GIFT, which is used for post-hoc analysis, can utilize the learner's affective, behavioral, and cognitive profiles created by the ABC model.

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