MOF-based metamodel for pedagogical strategy modeling in Intelligent Tutoring Systems

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***Abstract*—This paper introduces a MOF-based metamodel for pedagogic strategy modeling in Intelligent Tutoring Systems. The metamodel is named METAGOGIC and allows the generation of pedagogical strategies models using endogenous mapping between the abstraction layers of the MOF framework. In METAGOGIC the pedagogical strategies are represent in three main sections named *Context*, *PedagogicalApproach* and *InstructionalActivity*. Consistency of pedagogical strategies model generated from METAGOGIC was validated using the technique of tracing. The validation result showed that the model was consistent with METAGOGIC specifications.**

***Keywords*—intelligent systems; pedagogical strategy; intelligent tutoring system; metamodel; MOF**

I. INTRODUCTION

An Intelligent Tutoring System (ITS) is an intelligent system that provides individualized instructions to students [1], [2]. One of the main components in an ITS is the tutor module [3]. The pedagogical model contained in the tutor module is responsible for determining the learning objectives and selecting pedagogical strategies that are most appropriate to guide the learning process of a particular student [4]–[6]. The pedagogical strategies are the set of actions performed to facilitate the instruction and learning of students.

The design of mechanisms for the formulation of pedagogical strategies in ITS is a complex task due to the number of variables involved. In particular, the selection of the methods or pedagogic tactics to be used for the development of a certain lesson requires ITS holds an extensive repertoire of pedagogical knowledge.

In the context described the aim of this paper is to introduce a MOF-based metamodel for pedagogic strategy modeling in Intelligent Tutoring Systems. The metamodel is named METAGOGIC and is configured according to the standard MOF (Meta Object Facility) of Model Driven Architecture (MDA) [7] methodology. MOF standard provides a sequence of transformations and refinement of models. The transformations allow designers to have general schemes easily adapted to integrate metacognitive components in the personalized process of adaptation of pedagogical strategies in ITS. This work is novel because none of the proposals described use MDA to address the problems of complexity of pedagogic strategy modeling in ITS.

The validation was performed by generating a model of pedagogical strategies from the specifications in METAGOGIC. The consistency of the model generated from METAGOGIC was verified using the technique of tracing.

The validation shown that the metamodel METAGIGIC can be used by designers of ITS because it generates consistent pedagogical strategies models.

The paper is organized as follows: Section II describes the theoretical foundation associated with MDA. Section III describes the theoretical support associated with teaching strategies. Section IV describes the components of the METAGOGIC metamodel. Section V presents the approach used for mapping. Section VI shows the validation results and finally the conclusions are presented.

II. FRAMEWORK OF MODEL DRIVEN ARCHITECTURE (MDA)

MDA is an approach from the Object Management Group's (OMG) [7] for the development of model-driven software. In MDA, the development of a system is viewed as a sequence of transformations and model refinement [8].

The architecture is based on standard Meta Object Facility (MOF) [7]. The MOF standard provides a framework for the management of metadata and a set of metadata services to enable the development and interoperability of model and metadata driven. Figure 1 shows an example from Bragança and Machado [9], which describes the MOF metadata architecture for modeling the schema of a database. The figure shows the relationships between models in different layers of the MOF architecture.

MDA is based on the following three elements: (i) Model. The models are used to develop the system abstractions [9] at various levels and from different perspectives; (ii) Transformation Model. The system development is a series of sequential transformations between models in different designs predefined [9], [10]; (iii) Meta-model. The models themselves are expressed by meta-models that allow meaningful integration and transformation among models, specifically through tools [11]. Therefore, a metamodel is a model of a model. Figure 1 shows an example of the meta-modeling layers.

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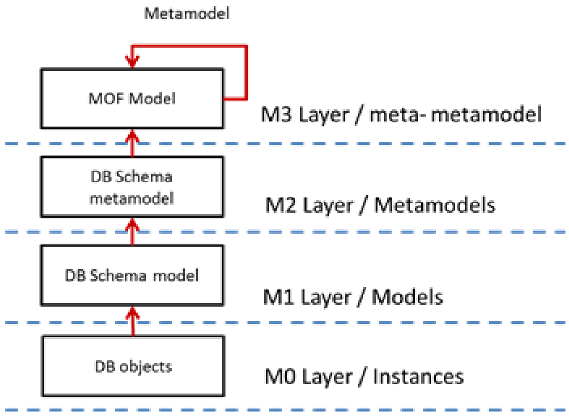

Fig. 1. MOF Architecture [9]

MDA architecture is based on a meta-modeling of four layers: (i) meta-Meta-modeling layer, which corresponds to MOF and defines an abstract language for metamodel specification; (ii) metamodel layer, which consists in metamodels that are defined in the standard MOF; (iii) layer model, which includes real-world models; (iv) the layer of "real world" which includes real-world things.

III. PEDAGOGICAL STRATEGY

The instructional plan configures the pedagogic strategy used for each student. The purpose of the pedagogic strategies is to facilitate the instruction and learning of students [12]. Pedagogic strategies are of a general nature [13] referring to abstract teaching methods [14]. Pedagogic strategies are oriented towards configurations of activities and interfaces between the student and the medium imparting learning.

In educational environments, the pedagogic strategies are action plans designed to manage issues related to sequencing and organizing the instructional content [12], [15] specifying learning activities, deciding how to deliver the content [14] and employing pedagogic tactics [5].

IV. PEDAGOGIC STRATEGY METAMODEL

METAGOGIC is a MOF-based metamodel for pedagogic strategy modeling in ITS. Three relationships between the concepts are used in METAGOGIC: (——) denoting *Association*; (—▷) denoting *Generalization* and (◇—) denoting *Aggregation*. The *Association* denotes functional relationships between concepts belonging to metamodel (e. g., the relationship between *TeachingMethod* and *LearningTheory* concept in Fig. 4). The "*isBasedOn*" relationship is understood as the *TeachingMethod* is linked to one or more *LearningTheory concept*.

Generalization represents hierarchies between metamodel elements (e.g., the relationship between *PedagogicalApproach* and *PedagogicalRecommendation* in Fig. 2). *PedagogicalApproach* is a particular case of the *PedagogicalRecommendation* concept and inherits all its features.

Aggregation represents relationships between concepts which are composed of other concepts (e. g., the relationship between *Context* and *Course* in Fig. 3). The *Context* contains one or more concepts of *Course*.

A. Metamodel core specification

In METAGOGIC the pedagogical strategies have a structure based on three main sections that facilitate the creation of adaptive user models. This structure is according to the specifications described in [13] and [16]. The sections works like adaptation levels and are represented as MOF classes: *Context*, *PedagogicalApproach* and *InstructionalActivity*. Figure 2 shows the METAGOGIC core specification.

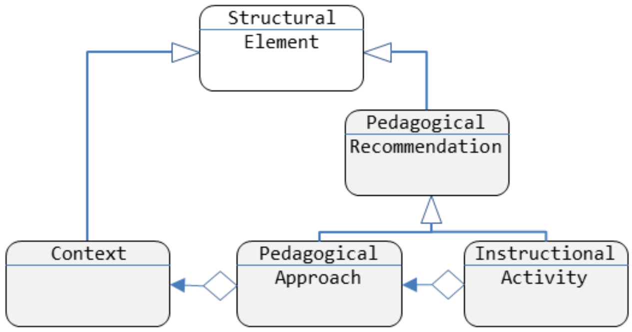

Fig. 2. METAGOGIC core specification

The first section of adaptation is the context where the student, course and lesson are specified. The second level of adaptation corresponds to the pedagogical approach of the strategy. In this section the pedagogical theory, navigation style and method of teaching of the pedagogical strategy are specified. The third section of adaptation corresponds to the organization and presentation of the content of a lesson. At this level the components of the lesson; the contents, resources and pedagogical tactics are specified.

B. Context

The context specification contains the general input data used to configure the pedagogical strategy. The context of the pedagogical strategy identifies three main aspects: (i) the student who will configure the strategy; (ii) the course; and (iii) the lesson in which the strategy will be contextualized.

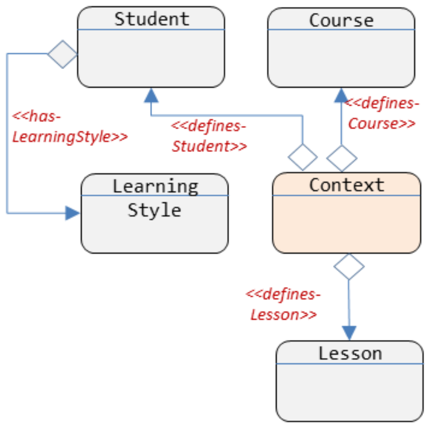

Fig. 3. Pedagogical strategy: Context specification

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The Context has a *performance property* that stores the result of the recommendation of the strategy for a particular student. The performance of the strategy depends on the performance of the student in the lesson and has a scale of *low*, *medium* and *high*.

1) Student: Student profile is based on the next aspects: learning styles and performance on the course.

The term learning styles refers to the concept that individuals differ in regard to what mode of instruction or study is most effective for them [17], [18]. The learning style of the student is one of the most important characteristic to be considered for adaptation of learning in ITS [19]. The approach used in this work for modeling the student learning style was based on the model developed by Felder [20].

2) Course: A course consists of one or more lessons.

3) Lesson: Each lesson has a structure that varies according to the student profile.

C. *Pedagogical approach*

The pedagogical approach addresses the strategy from learning theories and teaching methods. The pedagogical approach is set from the context of the pedagogical strategy, so it is possible having for each student an individualized pedagogical approach. Pedagogical approach is composed by navigation style, pedagogical theory, the teaching method.

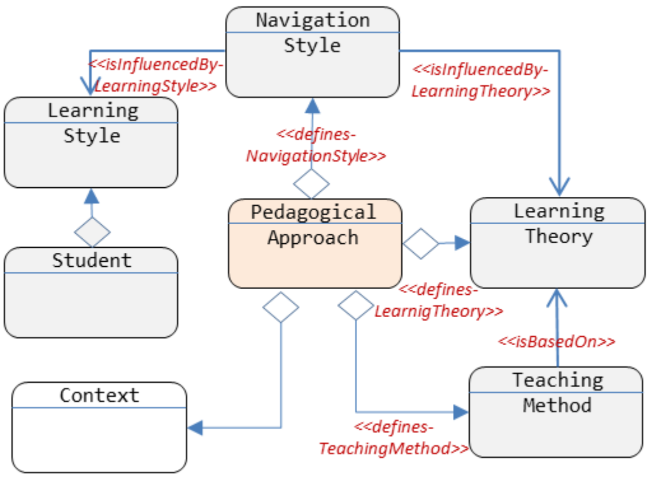

Fig. 4. Pedagogical strategy: Pedagogical approach specification

The PedagogicalApproach has a *performance property* that represents the effectiveness of the teaching method and learning theory recommended to the student. *Performance* property has a scale of *low*, *medium* and *high*. For example if a student achieves a high performance with the current setting of learning theory and teaching method, then the *performance property* of the *PedagogicalApproach* will be *high*.

1) Learning theory is composed of a diverse set of theoretical frameworks, which try to explain how individuals access knowledge. Many features of pedagogical theories can be partially modeled computationally. In our case we have only included those characteristics that can be modeled computationally, as the type of content sequencing, the type of assistance provided to students and the type of evaluation.

2) *The pedagogical strategies* are implemented under the criteria of learning theories [21]; otherwise it would be limited to sequence of activities and tasks without clear educational purpose [22].

3) *Teaching method:* A teaching method comprises the principles that imply an orderly logical arrangement of tactics and activities used in lessons of a course. The teaching methods are based on pedagogical theories; each method may contain all or part of the pedagogical principles of theory which is derived.

The teaching methods are modeled as classes that are composed of a set of pedagogical tactics and which have an organization of activities, based on a theory of learning

D. *Instructional activity*

For each student the instructional activity defines: (i) the most appropriate pedagogic tactics to address the contents of the lesson; and (ii) the format and the order in which the learning resources will be presented in a specific lesson. Instructional activity is composed by *LessonComponent*, *PedagogicTactic* and *LearningResource*.

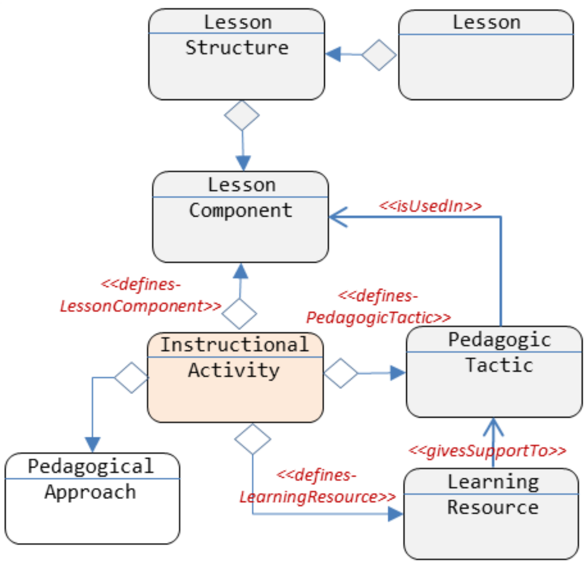

Fig. 5. Pedagogical strategy: Instructional activity specification

1) Lesson components are the sections in the lesson activities are organized. Some components of the lesson cannot be used by some students because of their style of learning, e. g. students with reflective style of learning they could not use the component activities of the lesson.

2) Pedagogic Tactics are composed of actions and resources which are used in the interaction with the student [5] for providing a personalized teaching.

3) Learning resources are digital objects such as images, animations, simulations, web pages, and more.

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Learning resources are the carriers of the content of the lesson and have different formats.

V. Mapping Approach

Mapping is the specification of a mechanism for transforming the elements of a model conforming to a particular metamodel into elements of another model that conforms to another (possibly the same) metamodel [7].

The mapping approach used is *endogenous mapping* because the main objective that addresses this work is to facilitate the modeling of pedagogical strategies in ITS.

Endogenous mapping in this work consists of a series of rules that allow the generation of models of pedagogical strategies (M_1 layer) based on the METAGOGIC specifications (M_2 layer). In this case e*ndogenous mapping* is used to the creation of a model in M_1 layer in which each model element of M_1 corresponds to one metamodel element of M_2 layer. The list of the translation operations is given in a generic language with operations including the MOF *Reflective* interface.

```
[1] ForAll view vi  in {ViewSet = View.ref_all_objects
    (false)} do
[2] domain = ref_create_instance (“Domain”,vi.name, …)
[3] M2.ref_add_value(“containedConcepts”, domain)
[4] ForAll classi in { ClassSet = vi.ref_value
    (“containedClasses”)} do
[5] concept = ref_create_instance (“Concept” ,
    class.name, ... )
[6] domain.ref_add_value(“containedConcepts”, concept)
[7] ForAll propi in {CollProperties =
    classi.ref_value(“attribute”)} do
[8] feature = ref_create_instance (“Property ”,
    prop.name,…)
[9] concept.ref_add_value(“feature ”, feature)
```

The *Reflective* interfaces of MOF allow: create, update, access, navigate and invoke operations on M_1-level *Instance objects*. For example in *line [5]* a *concept* artifact in M_1 layer is created as an instance of (*instanceOf*) a class from M_2 layer with similar name using the MOF *Reflective* interface `ref_create_instance`.

VI. Validation

A. Trace validation

In this type of validation, the behavior of different types of specific entities in the model is traced (*followed*) through the model to determine if the logic of the model is correct and if the necessary accuracy is obtained [23]. The description of METAGOGIC artifacts shows a situation of how a possible model of *Pedagogical strategy* is generated in M_1 from the metamodel at M_2. The model generation process is followed by the instantiation of a model for application in real life (M_0) from the model layer M_1. Figure 1 shows the section of the metamodel (Layer M_2 in *MOF*) which metacognitive models used in the validation are generated.

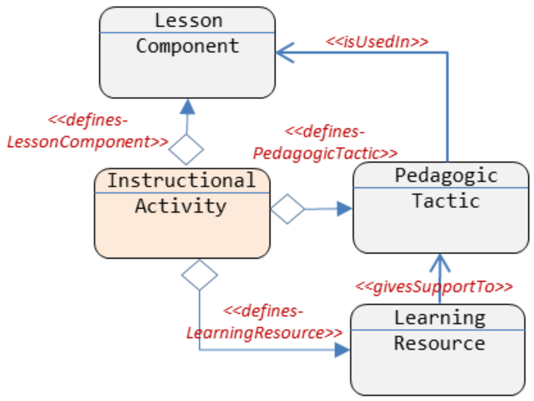

Fig. 6. METAGOGIC (Layer M_2 in MOF) with a partial view of instructional activity specification.

A *Pedagogical strategy* model for an Intelligent Tutoring System (ITS) was generated from the METAGOGIC in the first tracing validation process [24], see Figure 6.

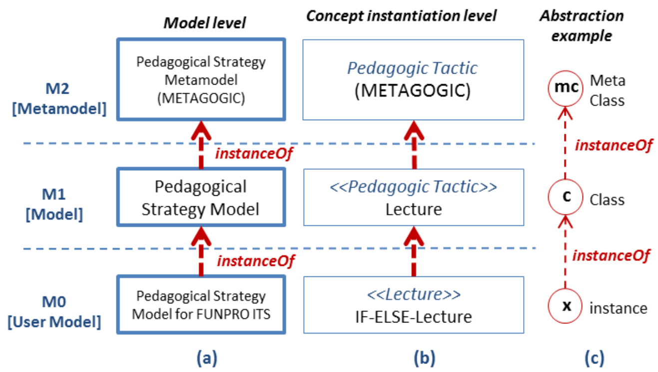

Fig. 7. Section (a) shows an example of element at each MOF layer; Section (b) shows an example of artifacts generated from each level in METAGOGIC for an ITS Pedagogic strategy model; Section (c) represents abstract notation of elements at each MOF layer.

In [24] *Tutor Module* provides the learning objectives based on student characteristics. In addition, *Tutor Module* offers a range of *pedagogic tactics* for the student to achieve personal learning objectives. *Pedagogic Tactics* are composed of actions and resources which are used in the interaction with the student for providing a personalized instruction. Each lesson has a structure that varies according to the student profile. The components of the basic structure of a lesson are the following sections: Introduction, definition, explanation, example, activity and evaluation.

Not all learning resources can be deployed in all parts of the lesson. Figure7 shows a model for the explanation of a lesson topic (some content) in [24].

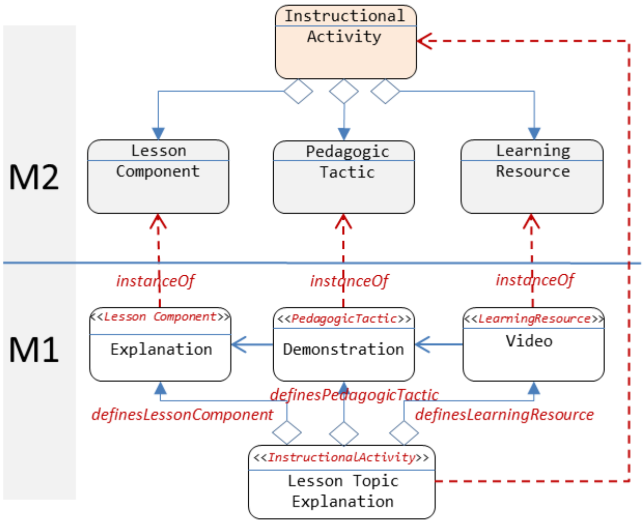

Fig. 8. Example of a partial pedagogical strategy model generated for an ITS corresponding with Figure 6

Below one of the basic rules used to verify traceability of the models is presented. The traceability *rule (1)* checks instantiations of artifacts between different layers of the MOF.

M_0 (x): *x* is an instance in M_0 layer
M_1 (c): *c* is a class in M_1 layer
M_2 (mc): *mc* is a meta-class in M_2 layer
In (x, y): *x* is a model artifact instantiated from *y*
In2 (x, y): *x* is a model artifact with instantiation trace from *y*

$$\forall\ x,\ c,\ mc\ In(x,\ c) \land In(c,\ mc) \Rightarrow In2(x,\ mc) \quad (1)$$

The partial mapping from MOF metamodel (METAGOGIC) to ITS *Pedagogical strategy* model is listed in Table I.

TABLE I. ITS – MAPPING TABLE

METAGOGIC concept	Artifact in Pedagogical strategy model
LessonComponent	*Explanation*
PedagogicTactic	*Demonstration*
LearningResource	*Video*
InstructionalActivity	*Lesson Topic Explanation*

Model in Figure 7 and the mapping table (Table I) show that the user model is consistent with the metamodel section in Figure 6. The results described in the validation show that the models generated from METAGOGIC are reliable because they have consistency and are based on an international standard.

VII. CONCLUSIONS

In this paper a MOF-based pedagogical strategy metamodel named METAGOCIC was described. METAGOCIC has a central core based on classes: *Context*, *PedagogicalApproach* and *InstructionalActitvity*. The *Context* contains the general configuration of the pedagogical strategy. The *PedagogicalApproach* addresses the strategy from learning theories and teaching methods. *InstructionalActivity* defines the most appropriate pedagogic tactics to address the contents of the lesson. The structure of the pedagogical strategy allows generating models with three levels of adaptation.

METAGOGIC uses *endogenous mapping* based on a series of rules that allow the generation of models of pedagogical strategies in M_1 layer from the specifications contained in M_2 layer.

A pedagogical strategy model based on an ITS from real live was generated from METAGOGIC. The validation results indicate that METAGOGIC is a metamodel that can be used by designers to model pedagogical strategies in ITS.

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REFERENCES

[1] Z. Rongmei and L. Lingling, "Research on Internet Intelligent Tutoring System Based on MAS and CBR," *Res. Internet Intell. Tutoring Syst. Based MAS CBR. Archit.*, no. doi:10.1109/IFITA.2009.511, 2009.

[2] R. M. Viccari and J. A. Jiménez, "ALLEGRO : Teaching / Learning Multi-Agent Environment using Instructional Planning and Cases-Based Reasoning (CBR)," *CLEI Electron. JOURNAL, Vol. 10, NUMBER 1, Pap. 4, JUNE 2007*, vol. 10, no. 1, pp. 1–20, 2007.

[3] Z. Wang, "Design and implementation of an intelligent tutoring system for English instruction Xuejing Gu 1,2 Jie Hel Siyi Zhengl Wei Wangl 2.," *Intell. Comput. Intell. Syst. (ICIS), 2010 IEEE Int. Conf.*, no. 29–31 Oct, pp. 166–169, 2010.

[4] H. Barros, A. Silva, E. Costa, B. Ig, O. Holanda, and L. Sales, "Engineering Applications of Artificial Intelligence Steps , techniques , and technologies for the development of intelligent applications based on Semantic Web Services : A case study in e-learning systems," *Eng. Appl. Artif. Intell.*, vol. 24, no. 8, pp. 1355–1367, 2011.

[5] C. Bezerra da Silva, "Pedagogical Model Based on Semantic Web Rule Language," *2012 12th Int. Conf. Comput. Sci. Its Appl.*, pp. 125–129, Jun. 2012.

[6] K. S. Cheung, J. Lam, N. Lau, and C. Shim, "Instructional Design Practices for Blended Learning," *2010 Int. Conf. Comput. Intell. Softw. Eng.*, pp. 1–4, Dec. 2010.

[7] OMG, "OMG Meta Object Facility (MOF) Core Specification," 2013.

[8] F. Chitforoush, M. Yazdandoost, and R. Ramsin, “Methodology Support for the Model Driven Architecture,” in *14th Asia-Pacific Software Engineering Conference (APSEC’07)*, 2007, pp. 454–461.

[9] A. Bragança and R. J. Machado, “Transformation Patterns for Multi-staged Model Driven Software Development,” *2008 12th Int. Softw. Prod. Line Conf.*, pp. 329–338, Sep. 2008.

[10] W. Raghupathi and A. Umar, “Exploring a model-driven architecture (MDA) approach to health care information systems development.,” *Int. J. Med. Inform.*, vol. 77, no. 5, pp. 305–14, May 2008.

[11] L. Iovino, A. Pierantonio, and I. Malavolta, “On the Impact Significance of Metamodel Evolution in MDE,” vol. 11, no. 3, pp. 1–33, 2012.

[12] C. W. Woo, M. W. Evens, R. Freedman, M. Glass, L. S. Shim, Y. Zhang, Y. Zhou, and J. Michael, “An intelligent tutoring system that generates a natural language dialogue using dynamic multi-level planning.,” *Artif. Intell. Med.*, vol. 38, no. 1, pp. 25–46, Sep. 2006.

[13] W. Dick, L. Carey, and J. Carey, *The systematic design of instruction*, 6th ed. 2005.

[14] R. Mizoguchi, Y. Hayashi, and J. Bourdeau, “Ontology-Based Formal Modeling of the Pedagogical World : Tutor Modeling,” *Stud. Comput. Intell. 2010, Vol. 308, Adv. Intell. Tutoring Syst. Pages 229-247*, pp. 229–247, 2010.

[15] C. W. Woo, M. Evens, J. Michael, and A. Rovick, “Dynamic instructional planning for an intelligent physiology tutoring system,” *Comput. Med. Syst. - Proc. Fourth Annu. IEEE Symp.*, pp. 226–233, 1991.

[16] B. Boulay and R. Luckin, “Modelling Human Teaching Tactics and Strategies for Tutoring Systems,” *Int. J. Artif. Intell. Educ. (2001),*, vol. 12, pp. 235–256, 2001.

[17] O. O. Demirbas and H. Demirkan, “Learning styles of design students and the relationship of academic performance and gender in design education,” *Learn. Instr.*, vol. 17, no. 3, pp. 345–359, Jun. 2007.

[18] C. Tulbure, “Learning styles, teaching strategies and academic achievement in higher education: A cross-sectional investigation,” *Procedia - Soc. Behav. Sci.*, vol. 33, pp. 398–402, Jan. 2012.

[19] F. Arias, J. Jiménez, and D. Ovalle, “Instructional planning model in intelligent tutorials systems,” *Rev. Av. en Sist. e Informática*, vol. 6, no. 1, 2009.

[20] R. M. Felder and E. R. Henriques, “Learning and Teaching Styles In Foreign and Second Language Education,” *Foreign Lang. Ann.*, vol. 28, no. 1, pp. 21–31, Mar. 1995.

[21] R. Irfan and M. U. Shaikh, “Framework for Embedding Tacit Knowledge in Pedagogical Model to Enhance E-Learning,” *2008 New Technol. Mobil. Secur.*, pp. 1–5, Nov. 2008.

[22] F. Ozdamli, “Pedagogical framework of m-learning,” *Procedia - Soc. Behav. Sci.*, vol. 31, no. 2011, pp. 927–931, Jan. 2012.

[23] R. Sargent, “Verification and validation of simulation models,” in *Proceedings of the 37th conference on winter simulation*, 2005.

[24] M. Caro, D. Josyula, and J. Jimenez, “Metamemory for Information Retrieval from Long-term Memory in Artificial Cognitive Systems,” in *Annual Conference on Advances in Cognitive Systems: Workshop on Metacognition in Situated Agents*, 2013, pp. 1–17.

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