DOMAIN SPECIFIC MODELS, KNOWLEDGE AND TOOLS TO SUPPORT MULTIPLE LEARNING STYLES FOR ENGINEERING STUDENTS

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As the use of multiple learning styles can improve the students' performance, computer aided instruction is expected to explicitly support them. Searching for their correspondences within software engineering, we identified three concerns that may be applied within learning systems: modeling – for adding symbolic representations; knowledge engineering – for a semantic characterization of the domain of study; and tools – for giving a figural form to learning objects. The article regards the students' practical work that uses instrumentation and measurement, generally present in engineering education. The proposed Web-based solutions targeted the learning improvement based on a combination of learning styles; they lean on: creating visual models of instruments; domain ontology for structuring practical work guidelines specific to engineering; model driven tools for integrating data and generating learning content. An experiment was conducted on a group of engineering students, validating that, under time pressure conditions, the proposed models, knowledge and tools, allow a better comprehension in respect with the traditional text guidelines. This brings into discussion whether the design of learning systems could better support multiple learning styles by introducing more models and knowledge representations specific to the domain of study.

1. INTRODUCTION

The patterns of human intellect have a direct influence on the ways of assimilating new concepts, theories and skills, and their study can leverage the environments for Computer Aided Instruction. The education is influenced by the learning styles promoted in traditional classroom environments or by those mixed with distance learning capabilities. There are multiple classifications of learning styles [1]; in this paper, we consider those defined according to the structure of intellect (SoI) model, introduced by Meeker in [2]:

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– *Symbolic* – one uses representations composed of signs that were given significance by convention or mutual agreement, like letters, numbers, musical notes, mathematical operators, notations.

– *Semantic* – one explains the meaning by introducing written or spoken verbal descriptions.

– *Figural* – the learning content consists of elements perceived or understood directly, like images, sounds, gestures.

To support learning, software has to take into account these styles, and lean on concerns that correspond to their needs. The symbolic style may be represented by modeling elements introduced into the learning content, obtaining abstract and easily comprehensible learning objects. The semantic style corresponds to knowledge, often transmitted with verbal constructions, but also supported by formal representations. The figural style may be materialized by a direct contact of students with real-life learning objects during their practical work, but also by developing more tools to assist them in the learning process. Therefore, an environment for Computer Aided Instruction should approach the following three concerns:

– *Models,* offering simplified representations of the real world.

– *Knowledge,* characterizing the domain of study.

– *Tools,* supporting activities related to the practical work.

Our study investigated how models, knowledge and tools specific to the application domain may be used for an environment that assists the students' practical work with measuring instruments, which is largely spread in engineering faculties. The theoretical background is presented in Chapter 2. The research had an empirical nature and was performed using a Web-based educational tool called EquiLAB, previously described in [3, 4]. This environment contains a library of models for multiple measuring instruments and a collection of lessons based on them, including structured text and multiple visual representations. EquiLAB development included all the three concerns mentioned above:

– Models for describing instrument data and measurement contexts were written in a Domain Specific Language (DSL); they were used with a double role: *descriptive* – for fostering students' understanding, and *imperative* – for integrating, storing and retrieving data.

– Knowledge was introduced as top-level domain ontology, used for defining the main DSL concepts and for structuring the learning content based on a semantic perspective.

– For assisting the practical work, several tools were developed, for computerizing activities like storing and retrieving the students' results, as well as creating structured guidelines based on generated characterizations of instruments.

One compared the students' capability to understand a measuring instrument based on traditional textual specifications, to the situation when they were offered alternative Web-based support created with EquiLAB, including models, knowledge and tools. An experiment was organized with engineering students who were given the two types of descriptions for two instruments that were not familiar to them. One analyzed the scores resulted from 94 test papers, written under a very strict time constraint, and one evaluated the impact of the supported learning styles on their performance. Chapter 3 presents the experiment details and its results.

2. **SOFTWARE ENGINEERING CONCERNS APPLIED FOR ENGINEERING EDUCATION SUPPORT**

For each of the three concerns discussed above there may be two main types of paradigms: *general* and *domain specific* ones (Fig. 1). The approaches intended to be *general* have several advantages: (*i*) they can be reused for numerous clients; (*ii*) they usually lean on standards; (*iii*) they highly support interoperability; (*iv*) they offer a good return of investment for development and training. However, paradigms stressing on generality may be very complex, because they try to incorporate everything that would be necessary, in any situation.

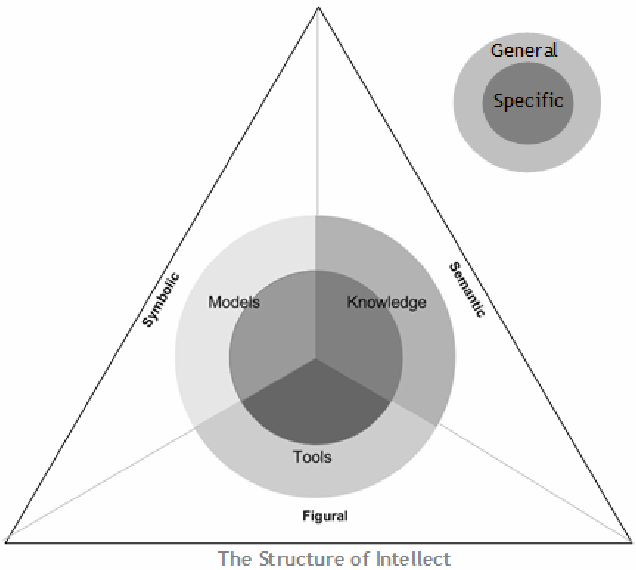

Fig. 1 – Mapping software engineering concerns to the structure of intellect.

The approaches intended to be *domain specific* have their clear advantages: (*i*) they are easier to learn for the domain experts, not only for software engineers, because the level of abstraction directly corresponds to the application domain; (*ii*) they can be used simply, due to suggestive notations; (*iii*) they can serve for developing applications faster, due to specialized tools and increased automation. The drawback of these paradigms is that they may need a large scale of reuse for motivating the investment of developing specific tools.

Models. Traditionally, models have a descriptive purpose, helping people to create simplified representations of physical or conceptual systems, in order to reduce their complexity and to facilitate understanding [5]. Models have been intensely used in all fields of engineering, in various representations, based on more or less symbolic elements: structured or unstructured text, mathematical formulae, graphics, or diagrams conforming to graphical languages. Visualization, in its various forms, is very important for the conceptual understanding of engineering students [4]. Visual representations were identified as one of the three basic elements used for description and communication in education, along with speech and mathematics [6]. Models can also be classified in respect with the modeling language scope, as conforming to: *general modeling languages* (e.g. unified modeling language [7]) or *domain specific languages* (DSLs) [8].

Knowledge. Besides modeling, which gives a simplified representation of a system, there is a need to gather enlarged knowledge about it, using vocabularies, nomenclatures, catalogs, classifications, lexicons, taxonomies etc. Semantic knowledge is often managed in ontologies used for formal conceptualization [9], including terms, relations and rules for combining them [10]. *Generic ontologies*, also called meta-ontologies or core-ontologies in [11], define concepts that are general enough to be used across various domains. *Domain ontologies* are defined to be reusable in a given domain, which can be medicine [12], automobiles [13], laws [14], etc.

Tools. The tools used for application software can be compared based on criteria like: integration, conformity to standards, life cycle support, or formality level; here we are interested of their scope. A typical classification outlines two main classes [15]:

– *Tools for general-purpose applications* – used for information processing common to a large variety of application domains, like word processing, database management, spreadsheets;

– *Tools for specific-purpose applications* – pertaining to applications that are function specific for end-users of a given business or field.

Application for Engineering Education. The above presented concerns were implemented in the EquiLAB environment [4], offering two main functionalities:

– Create practical work guidelines by generating Web pages from pre-defined instrument characterizations, shared among teachers.

– Support integration of non-homogeneous data acquired by students, originated from a large variety of instruments; the stored information is expected to concern the entire measurement context, including the characterization of measured objects and of settings regarding the instrument or the experimental setup.

In order to apply the three above presented concerns, the development of EquiLAB was based on three important objectives:

– *Use models conforming to domain specific concepts to facilitate symbolic learning.*

A Domain Specific Language was defined, in order to abstract the measurement context and facilitate data integration, by interpreting instrument models conforming to it. A library of instrument models conforming to this DSL was created.

– *Take into account the specific domain knowledge to support the semantics understanding.*

The objective was reached by defining an ontology for characterizing any kind of instrument, and by using it for structuring the generated practical work guidelines and also for identifying the main elements of the DSL.

– *Define specific tools to assist activities of the practical work and the figural learning*

Several tools were developed in order to manage the learning content and the students' results.

Related Work. Models, along with standardization, are necessary for the reusability and interoperability of distance learning solutions, identified as important challenges for engineering education in a study involving more than 1500 students, presented in [16]. Data types specific to power systems equipment were also introduced in [17]. A review on the use of ontologies to support learning processes is given in [18], where one analyzes approaches like concept mapping, collaborative creation of knowledge, annotating shared artifacts, collaborative inquiry, and meta-cognitive tools. The work is based on the cultural-historical activity theory, to be able to establish links between individual learning and its effect within the social environment. The learning tools related to this approach are those pertaining to applications or environments specific to a certain domain of education, like: foreign languages [19]; architecture [20]; medicine and healthcare [21]. The application of EquiLAB for a thermocouple system with the acquisition based on LabView was also presented in [22].

3. **EXPERIMENT AND RESULTS**

We organized an experiment with 47 students from the fourth year of Automation and Computer Science Faculty, after they had completed a course of Measuring Systems. We asked them to take two tests, concerning measuring instruments, based on two kinds of documentation: a traditional one, similar to that supplied by the producer and based on text, and one based on the new Web-based guidelines, generated with EquiLAB. A detailed description of the latter may be found in [4]. The students had 15 minutes to read the documentation and then answer to several questions, for verifying how well they were able to understand the instrument under a time constraint. They had no previous knowledge about the instruments, and no instruction was performed related to the notation used in the visual models. The two tests were supervised and verified by the same instructor, and they were based on different instruments. The questions were graded as described in Table1.

Table 1

Test Details

QUESTION	**Maximum Score**
What are the physical quantities measured with this instrument?	20
Is it necessary to set up the instrument before performing the measurement? How?	20
How can you characterize the sample used for the measurement?	20
Which of the two instruments do you consider more complex?	10
Can you estimate the ratio of their complexities?	10
Present the similarities that you can identify between the two instruments.	20

We considered three instruments used for the characterization of magnetic materials in a technical magnetism laboratory [23]. For performing a measurement, one sets the magnetic field desired for a material sample, then one measures two physical quantities: the magnetic field value actually obtained, plus a supplementary quantity, which depends on the instrument: the magnetic moment for the Vibrating Sample Magnetometer (VSM 7304, from LakeShore); the magnetic induction for Hysteresisgraph (from Brockhaus); the magnetic polarization for the Single Sheet Tester (SST C-100 from Brockhaus).

The measurement is influenced by the material and by the sample shape - both of them characterized within the *MeasuredObject* concept. Based on the domain expertise, each instrument is recommended for a different family of magnetic materials, therefore, besides these quantities, each instrument has its own set of supplementary output *Data* (e.g. the shape coefficient for VSM, the maximum energetic index for Hysteresisgraph, and the power losses for SST). Besides, the *Experiment* settings are different in respect with the hysteresis cycle shape correspondent to the magnetic material type (soft, hard, or semi-hard magnetic materials) [23]; the hysteresis cycle represents the graphical representation for the function between the two measured quantities, obtained by increasing and decreasing the magnetic field between two values.

We prepared 8 versions of tests, with various combinations of these instruments, and we analysed the results globally, as they had a similar complexity. For estimating the degree of understanding, we determined the distribution of scores on five categories: poor (20 points or less), fair (20 to 40 points), good (40 to 60 points), very good (60 to 80 points) and excellent (more than 80 points).

Figure 2 shows the normal distribution of the entire collection of students' scores for the text and the new Web-based generated guidelines comparatively, so the understanding generally becomes good instead of fair.

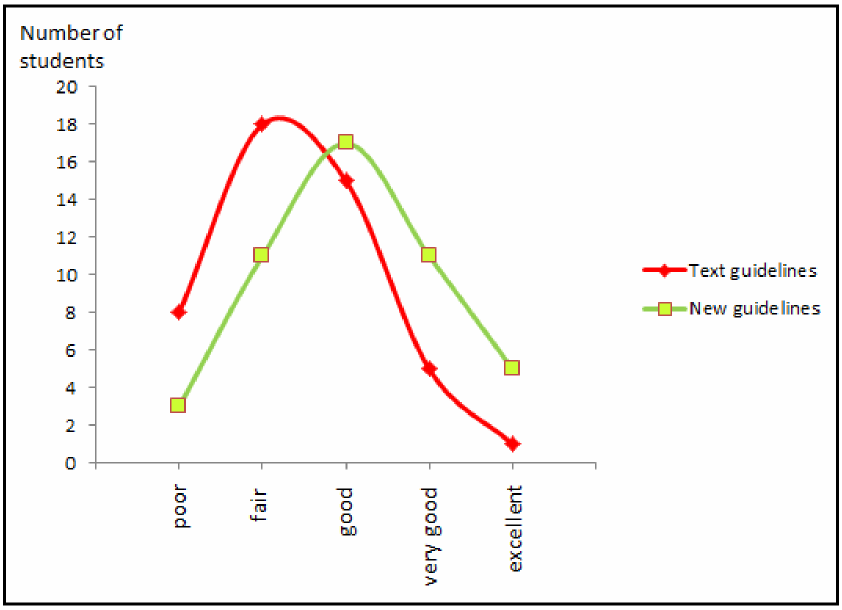

Fig. 2 – Score distribution for the tests based on text *vs*. Web-based guidelines.

Two pie charts are represented in Fig. 3, for the tests based on the text and on the new, generated guidelines respectively. The number of students with the poor score decreased with 11% and the number of students with excellent scores increased with 9%. One third of the students managed to obtain excellent and very good scores, comparatively to only 13% for the traditional guidelines.

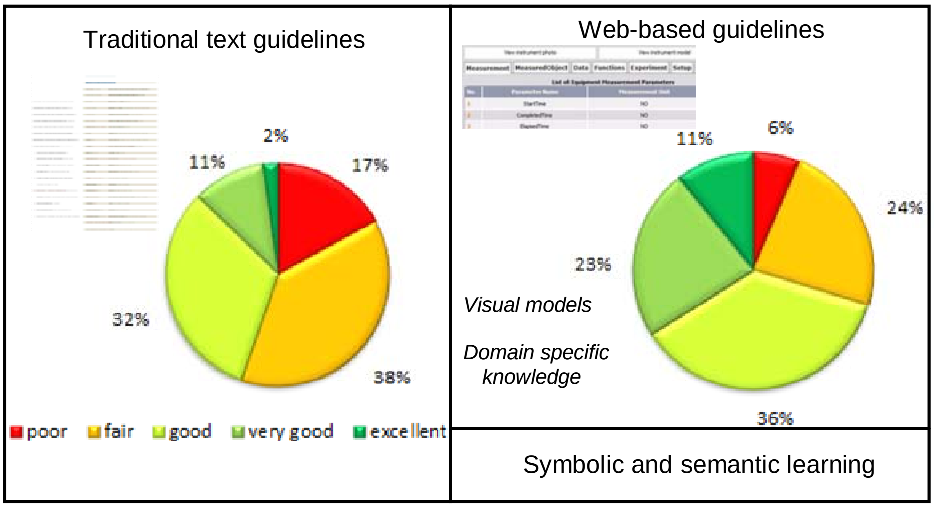

Fig. 3 – Score distribution for the tests with the traditional text guidelines and the new Web-based ones, supporting symbolic and semantic learning.

Summarizing, after evaluating each student's scores for the two tests, we noticed that, generally, the new guidelines helped them improve their number of points. The average score increased with 16.43 points and an improvement of minimum 10 points was found for 60% of the students. Several statistics are also included in Table 2.

Table 2

Score statistics

Criterion		**TEXT GUIDELINES**	**New guidelines**
Score distribution	Excellent	2 %	11 %
	Very good	11 %	23 %
	Good	32 %	36 %
	Fair	38 %	24 %
	Poor	17 %	6 %
Average score		40,28 points	54,43 points

4. CONCLUSION

The article analyzed software concerns that map to the symbolic, semantic and figural learning styles. Models offer simplified, symbolic diagrams, indicating the conformity to generic domain concepts; they are useful both for their descriptive power, especially in their visual form, and for driving execution, introducing more automation and generic functionality. Knowledge gives a representation of the semantic meaning, and adds details in a structured and hierarchical way; it is essential for creating well-organized frameworks for learning. Tools respond to the need to directly manipulate learning content and results during the practical work, offering support for the figural learning.

This work was focused on the realization of the previously discussed concerns (models, knowledge and tools) for Computer Aided Instruction in engineering laboratories with measuring instruments. The solution is domain-specific in order to be easily used, but it is also highly reusable, because the practical work based on measuring instruments is present in numerous subjects from the engineering curriculum. The study conducted on a group of undergraduate students who volunteered for this experiment proved an improvement in their comprehension when using the Web-based guidelines that include visual models and are organized according to the instrument domain ontology. Thus, under similar time constraints and complexity challenges, the average score increased with 35 % when using support for the symbolic and semantic learning styles.

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REFERENCES

1. E. Y. Huang, S.W. Lin, T. K. Huang, *What type of learning style leads to online participation in the mixed-mode e-learning environment? A study of software usage instruction*, Computers and Education, **58**, pp. 338–349, 2012.
2. M. N. Meeker, *The Structure of Intellect: Its uses and interpretation*, Columbus, OH, Charles Merrill, 1969.
3. A.D. Ionita, A. Olteanu, T. Ionescu, L. Dobrica, *Automatic Transformations for Integrating Instrument Models across Technological Spaces*, Romanian Journal of Information Science and Technology, **14**, *1*, 2011.
4. A.D. Ionita, A. Olteanu, *Support Students' Experimental Work in Electrical Engineering with Visual Modeling*, Rev. Roum. Sci. Techn. – Electrotechn. et Energ. **59**, *1*, pp. 107–116, 2014.
5. S. Mellor, K. S. Scott, A. Uhl, D. Weise, *MDA Distilled: Principles of Model- driven Architecture*, Addison-Wesley, 2004.
6. C. Savander-Ranne, S. Kolari, *Promoting the Conceptual Understanding of Engineering Students through Visualisation*, Global Journal of Engineering Education, **7**, *2*, pp. 189–199, 2003.
7. J. A. Matteo, *Preservation Engineering: Framing a New Curriculum*, Preservation Education & Research, **4**, pp. 93–106, 2011.

8. ***, *OMG unified modeling language (OMG UML), superstructure*, Version 2.3, 2010.
9. M. Harsu, *A Survey on Domain Engineering,* (Tech. Rep. No. 31), Finland, Tampere University of Technology, Institute of Software Systems, 2002.
10. T. R. Gruber, *Toward principles for the design of ontologies used for knowledge sharing*, International Journal of Human-Computer Studies, **43**, pp. 907–928, 1993.
11. R. Neches, R. Fikes, T. Finin, T. Gruber, R. Patil, T. Senator, W. R. Swartout, *Enabling Technology for Knowledge Sharing*, AI Magazine, pp. 36–56, 1991.
12. G. van Heijst, A. Schereiber , B. Wielinga, *Using explicit ontologies in kbs development*, International Journal of Human and Computer Studies, **46**, 2–3, pp. 183–292, 1997.
13. P. Wennerberg, *Aligning Medical Domain Ontologies for Clinical Query Extraction*, Proceedings of the Student Research Workshop at EACL 2009, pp. 79–87, 2009.
14. M. Feld, C. Müller, *The Automotive Ontology: Managing Knowledge Inside the Vehicle and Sharing it Between Cars*, Proceedings of the 3rd International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI 2011), Austria, 2011.
15. N. Casellas, M. Blazquez, A. Kiryakov, P. Casanovas, M. Poblet, V. R. Benjamins, *Opjk into proton: Legal domain ontology integration into an upper-level ontology*, Meersman, R. et al. (Eds.), Lecture Notes in Computer Science, **3762**, pp 846–855. Springer, 2005.
16. M. Stefanovic, *The objectives, architectures and effects of distance learning laboratories for industrial engineering education*, Computers and Education, **69**, pp. 250–262, 2013.
17. S. Vukmirovic, A. Erdeljan, I. Lendak, D. Capko, *Unifying the Common Information Model (CIM)*, Rev. Roum. Sci. Techn. – Electrotechn. et Energ., **57**, *3*, pp. 301–310, 2012.
18. H. Allert, H. Markkanen, C. Richter, *Rethinking the Use of Ontologies in Learning*, E. Tomadaki & P. Scott (Eds.), *Innovative Approaches for Learning and Knowledge Sharing*, EC-TEL 2006 Workshops Proceedings, pp. 115–125.
19. G. Blattner, *Web 2.0 Technologies and Foreign Language Teaching*, Encyclopedia of E-Leadership, Counseling and Training., USA, IGI Global, pp. 89–107, 2012.
20. M. Juvancic, M. Mullins, T. Zupancic, *E-Learning in Architecture: Professional and Lifelong Learning Prospects E-Learning-Organizational Infrastructure and Tools for Specific Areas*. In E. Pontes, A. Silva, A. Guelfi & S. Kofuji (Eds.), *INTECH*, Croatia, 2012, pp 159–182.
21. R. A. Bergin, U.G.H. Fors, *Interactive simulated patient—an advanced tool for student-activated learning in medicine and healthcare*, Computers & Education, **40**, *4*, pp. 361–376, 2003.
22. A. Olteanu, G. Stamatescu, A.D. Ionita, V. Sgârciu, *Enhanced Data Integration for LabVIEW Laboratory Systems*, The 8th International Symposium on Advanced Topics in Electrical Engineering, Bucharest, Romania, May 23–25, 2013, pp. 1–6.
23. V. Ionita, L. Petrescu, *Magnetic material characterization by open sample measurements* , Rev. Roum. Sci. Techn. – Electrotechn. et Energ., **54**, *1*, pp.87–94, 2009.