

Putting Edutainment in Practice: From Courseware Authoring to Logic Games

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Abstract: Modern technology enhanced learning methods often are based on non-traditional instructional paradigms. Mass invasion of educational games feeds edutainment grow, however, it suffers from a lack of cheap and effective implementations of eLearning games of various types making use of domain content of given course. The article describes a software framework for rapid prototyping of problem-oriented educational games based on a simple, light-weight content model offering semantic-oriented content organization. The model uses the constructional paradigm of UML (Unified Modeling Language) class diagram thanks to the fact they directly relate their elements with the parts of a usual ontology (classes, mono- and poly-hierarchies, class attributes, relationships and axioms). Thus, it is easily perceivable by content authors without any knowledge in semantic technologies. Next, authors present a software framework for creation of problem-oriented educational games such as puzzles, quizzes, word and even board games controlled by a game engine assuring automatic content extraction including inter-concept relationships. Thanks to the semantic organization of courseware content, there exist a great variety of educational games which may be easily developed over a course content repository organized according to the model. There are discussed several examples of practical realizations of word and board games built on the top of a semantic model of University course for undergraduate students and representing learning terms, facts, relationships and dependencies within that course curriculum intended for such specific audience. The paper provides results from practical experiments with such problem-oriented games in adaptive eLearning. It concludes with analysis of results about the level of appropriateness of GBL using these educational games for bachelor students in software engineering.

Keywords: word games, semantic, content, model, framework

1. Introduction

Nowadays, more and more studies indicate that pupils and students prefer technology enhanced learning with game elements to traditional instructional design of courseware for school, university and live-long learners (Eng, 2005; Eagle and Barnes, 2009). Modern eLearning enhances educational process with multimedia content such as audio, video, simulations and games. Educational games represent an attractive well proven mean for attracting attention and interest in given course topic (Garcia-Barcena and Garcia-Crespo, 2006; Ke, 2009; Aliya, 2002). Being at the same time entertaining, educative and cognitive, games do complement traditional instructional learning design (Dempsey 1996). These educational games can be seen as a means for determining several of learning activities, for one or more players, with predictable outcome, where goals, constraints, rules for payoff, and consequences are precisely defined (Siang and Rao 2003). Games have already been used successfully in school and university education as well as in professional training courses, for improving students' knowledge by appealing them to solve various problems of given scientific domain and for improving creative thinking (Salen and Zimmerman 2003).

For stream-line usage of educational games in technology enhanced learning, instructors need software tools and frameworks for an effective game construction using course content of particular domain. Semantic structuring of educational content will facilitate its usage in game design and will help a lot rapid and facile creation of games appropriate for eLearning purposes. The present paper describes in brief a model for semantic organization of educational content offering means for presenting concepts, attributes and relationships needed for automatic extraction of content by the game engines. The model is used as a base for construction of a software framework for rapid creation of logic games extracting terms and semantic relationships from the semantically oriented content model. The simplest case of an educational game using content from the semantic model concerns extraction of a single entity (class or instance) without any tracking of inheritance and/or association relations to other entities. Examples for such games may vary from the classical hangman game to anagram games coding the name of the class/instance, a quiz asking for right value of a property, word games of splitting concept names. More interesting case is the one of using typification information about the entity – names or picture of super- or sub-classes for a class, and of the class whose instance is the selected instance. Thus, classical hangman or anagram word games may be

enhanced with giving some hints about finding the answer. Another games constructed on the top of the semantic models are the concept association games and board games mapping positions to textual or multimedia content and applying rules for handling mouse events over these positions. All these games are used for game based adaptive learning in the scope of ADOPTA (ADaptive technOlogy-enhanced Platform for eduTAInment) project. The paper presents practical results of learning an adaptive course in XML technologies using ADOPTA is a software platform for adaptive edutainment based on adaptivity to learning styles and individual learner performance (Vassileva 2011). There is given the students' vision about usage of logic games for adaptive learning and their appreciation of various game types and constructions.

2. Background

Precise game-based learning needs accurate definitions of predictable outcome, where goals, constraints, rules for payoff, and consequences. This chapter presents short overviews of educational game usage for an enhanced eLearning and, on other side, of technologies and practices for semantic organization of educational content needed for efficient construction of games using given course content.

2.1 Educational games for technology enhanced learning

First Mark Prensky (Prenski 2006) has analyzed and summarized the most important characteristics of computer games applied as a mean for learning:

- Games give to learners pleasure and emotions during the game play
- Games encourage learner creativity by including conflicts, competitions and problem solving
- Games motivate learners by using well-defined rules and setting tangible goals
- Games engage the player ego by appealing states of win
- Games are interactive and may be adaptive which challenges the learner

Some of the most popular types of educational games used nowadays are quizzes, puzzles and problem solving games (Ferreira 2008). They may be viewed as board games, which suppose moving figures across a surface (board or a map) using counters (Bontchev and Vassileva 2010). Some quiz games apply board rules for navigation within a quiz in order to move from one question to another and for controlling choice of question complexity (Retalis 2008).

Board games construction may include game engine controlling single users playing the game alone or against an artificial intelligence agent which plays as a real opponent (Feng 2005). In many of the cases games are played as multi-player games enabling participants to learn interactively one from another while playing for fun. However, both the multi-player game design and construction are rather complex than these of single-player games due to player synchronization and communication issues (Bontchev et al 2002).

With the invasion of mobile phones and handheld devices, there are applied more and more mobile games for technology enhanced learning. Mobile learning is defined in (Shiratuddin and Zaibon 2010) as education, which is independent from time and places and the content is offered by portable video devices using wireless transmission. Thus, a modern framework for educational game construction is supposed to be used for creation of games with mobile interface. On other side, for a facile and automatic integration of course content into an educational game, the content itself should be authored and organized by means of semantic structuring.

2.2 Semantic organization of educational content

Modern approaches for semantic modeling of given domain content include taxonomy, lexicon, thesaurus and ontology. Taxonomies provide only hierarchical structuring of domain content but not relationships between conceptual types (terms). Relating concepts from general to specific ones uses a top-down specialization approach. As far as the collection of concepts uses only hierarchies based on inheritance (IS_A relationship), associative relationships (of type HAS_A) are not a feature of a taxonomy in general.

Thesaurus represents a structured vocabulary mostly used for retrieval of resources with consistent indexes. The notation of a hierarchical relationship is "Broader Term" (hypernym) and "Narrower

Term" (hyponym). Unlike taxonomy, a thesaurus allows definitions of associative relationships by means of "Related Term". Thesaurus standards define types of associative relationships (Aitchison et al 1997) such as between cause and event, event and effect, etc. Thesaurus makes use of hierarchical, associative and equivalent relationship types, while all relationships are reciprocal. A search query can be expanded in a way covering equivalent and related terms.

Unlike taxonomy and thesaurus, ontology provides a good knowledge content structuring by describing the nature of the relationships of the domain terms and, thus, provides a formal, explicit specification of a shared conceptualization (Hendler 2001). RDF Schema is a recommendation by the W3C and defines a simple ontology representation language modeling concepts and properties, and restricting domain and range of concepts. OWL (Web Ontology Language) is a XML language developed by W3C for representing ontology by means of data type properties, restrictions (e.g., cardinality), properties types such as transitive, symmetric, inverse and functional, Boolean combinations, enumerations. As well, ontology is able to define class unions, intersections and complements. However, ontology development appeared to be a major bottleneck due to need of many professionals in the domain and powerful modeling tools. Ontology facilitates automatic reasoning but the lack of appropriate graphical notation hampers its wide usage by humans. Unlike OWL, UML (Unified Modeling Language) is designed to be used by both humans and tools (Pilone and Pitman 2005). UML class diagrams may be transformed into OWL as far as they directly relate their elements with the parts of ontology by provisioning classes, mono- and poly-hierarchies, class attributes, relationships and axioms (Grønmo et al 2005). A great advantage of UML concerning class hierarchy design consists in usage of non-monotonic inheritance applied to classes and to class metadata – the monotonous propagation of some class attributes may be forbidden by declaring them with private scope.

3. Authoring of semantically structured courseware

The model for semantic content organization is based on UML class diagrams as an approach for intuitive and visual content modeling providing class hierarchies, instances, class attributes, and relationships plus axioms. It is described in (Bontchev and Vassileva 2011), with explanation of usage of concepts, instances, metadata and some of the model relationships (figure 1). The class called *SuperConcept* has three attributes with classifier scope (with same values for all the instances). The *conceptName* provides the full title of the concept class, while the name of a class instance may be given as a value of one of its properties called "Instance name". For any class, there are shown all its super-classes (if any) on the other side of an *IS_A* link. As well, for a class instance the model shows the class whose instance is it by *instanceOf* reference. A class may contain a content description text and image (again with public visibility and classifier scope) and a list of class properties and resources. Names and values of both properties and resources may be of private, protected, public or package scope and may be annotated within metadata. Any concept may have one or more *HAS_A* relationships of given UML type such as dependency, association, aggregation, and composition. As a minimum, a relationship may have name, direction, and roles and cardinality of the inter-related entities.

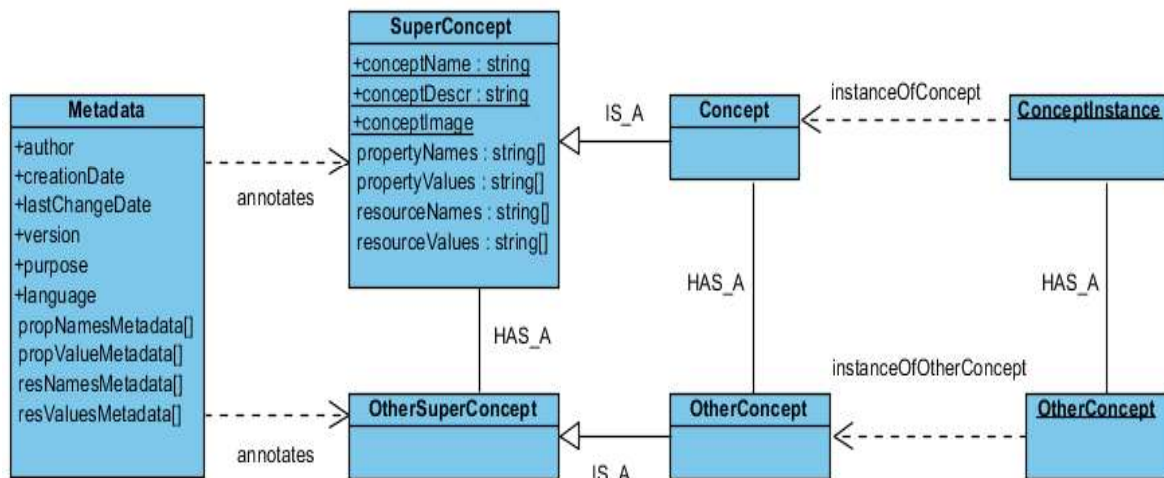


Figure 1: Generalized view of concepts, instances, metadata and some of the model relationships (Bontchev, 2011)

Figure 2 shows a UML class diagram of some terms from a bachelor course in XML technologies. Terms are semantically structured by their inter-relationships and, possibly, with some instances. For example, the terms “xml:”, “NOTATION”, “ID”, “IDREF”, “IDREFs”, “NMTOKEN”, “NMTOKENS”, “Enumerated”, “ENTITY”, “ENTITIES” and “CDATA” are subtypes of “attribute-type” having with it *IS_A* relations. “Attribute DTD declaration” may compose “attribute-type”, “default-value”, “attribute name declaration” and “element name”. There is shown only two instances – one of “Enumerated” and another of “CDATA”.

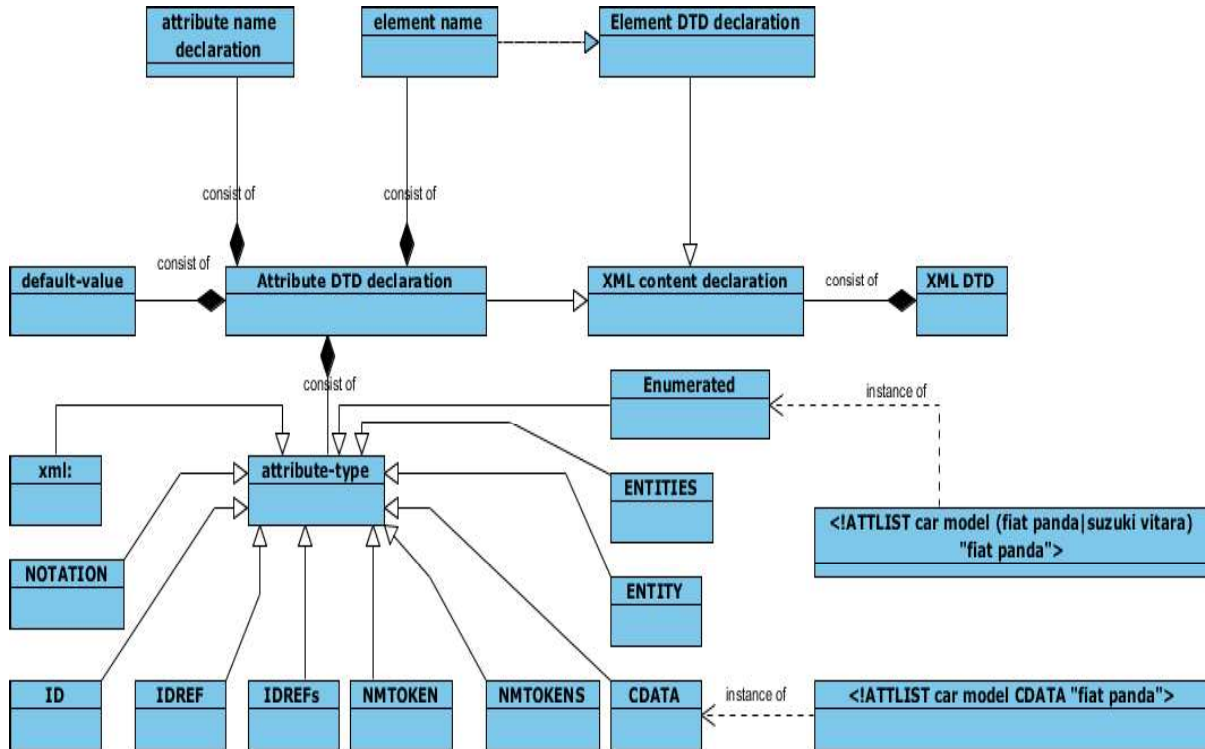


Figure 2: UML diagram of some XML terms and their relationships and instances

Figure 2 illustrates only a small part of the whole UML diagram of XML terms plus their relationships and instances. Such semantically-rich content models are comprised by a plenty of specific terms (such as DTD, XML Schema, DOM, SAX, etc.). These terms and relationships may be automatically extracted and integrated in many logic games concerning these courseware materials. Common functional modules of such games are grouped within a software framework allowing rapid game development on the base of semantically structured course content.

4. Design of logic games using semantically structured course content

This chapter provides a brief description of the framework for construction of logic games such as problem-oriented and word games and, next, presents examples of word games constructed by using the framework and using the semantic content model of the XML technology courseware.

4.1 A software framework for construction of word games

The framework for construction of logic games is implemented in Java and Adobe Flex. It's principal software architecture is shown in figure 3. The framework allows games to be created at low level using built-in custom Flex components. By means of this framework there are realized four games - hangman, anagrams, associations, and memory game as explained further in 4.2. Moreover, it provides possibilities for implementing other types of word and logic games using a Flex editor, where the already existing built-in components are combined and parameterized. Each game object is created by a factory class, which calls a web service with an identifier (id). The web service returns game data for given id and game type.

The framework consists of following four layers:

- E-R data model – keeps the semantically structured course content as a relational model. For the moment, the conversion from the semantically rich model using UML class diagrams to the E-R data model is done manually but authors plan to develop a module for automatic conversion.
- Game business logic – this level contains modules with classes for content's term management (such as *WordItem*, *WordToGuess* and *GuessedWord*), terms inter-relationships management (e.g., *RelationItem* and *RelationsToGuess*), and events management (such as *BoundaryConditionEvent* and *GameOverEvent*). Last events are issued by functions for controlling game run and border conditions line *letterClicked()* and *wordDropped()*.
- Visual components – the level contains Text and Graphic components and listeners to Effects. The text components are formed as a hierarchy having a basic *TextComponent* as a root (with several listeners), while the set of Graphic components includes various components such as *ClockComponent*, *ImageHolderComponent* and *RelationsToGuessComponent* (for 2D games).
- Game components – contains a class for each implemented logic word game and a games factory for launching a game (with possible parameterization).

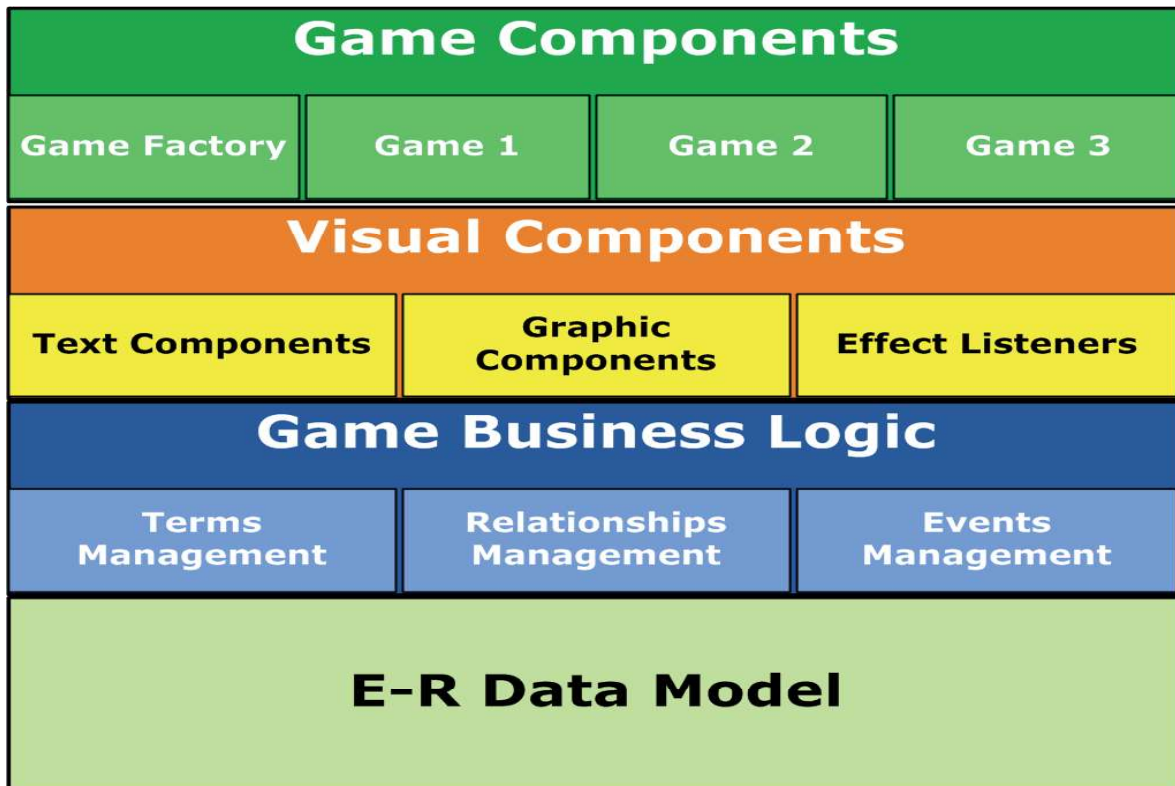


Figure 3: Principal architecture of the software framework for word games' construction

4.2 Sample example of word games constructed by the framework

In order to assess the practical value of the constructed software framework for construction of logic games such as puzzles, quizzes, and other word games, four games of that type have been created, namely hangman, anagrams, associations, and memory game. All these games use the semantically structured content of the bachelor course in XML technology described above. Next, design ideas of the games are presented in brief and illustrated by partial screenshots showing only the main graphic objects but not title, hints, clock, results, etc.

Figure 4 shows a partial view of the hangman game using XML terms from the framework semantic data model. The frame over presents the word or term to be guessed and the frame below contains a keyboard (both graphic components are built in the framework). Learners may get a clue helping them in guessing the term. The both images from the right side are controlled by built-in framework components, too.

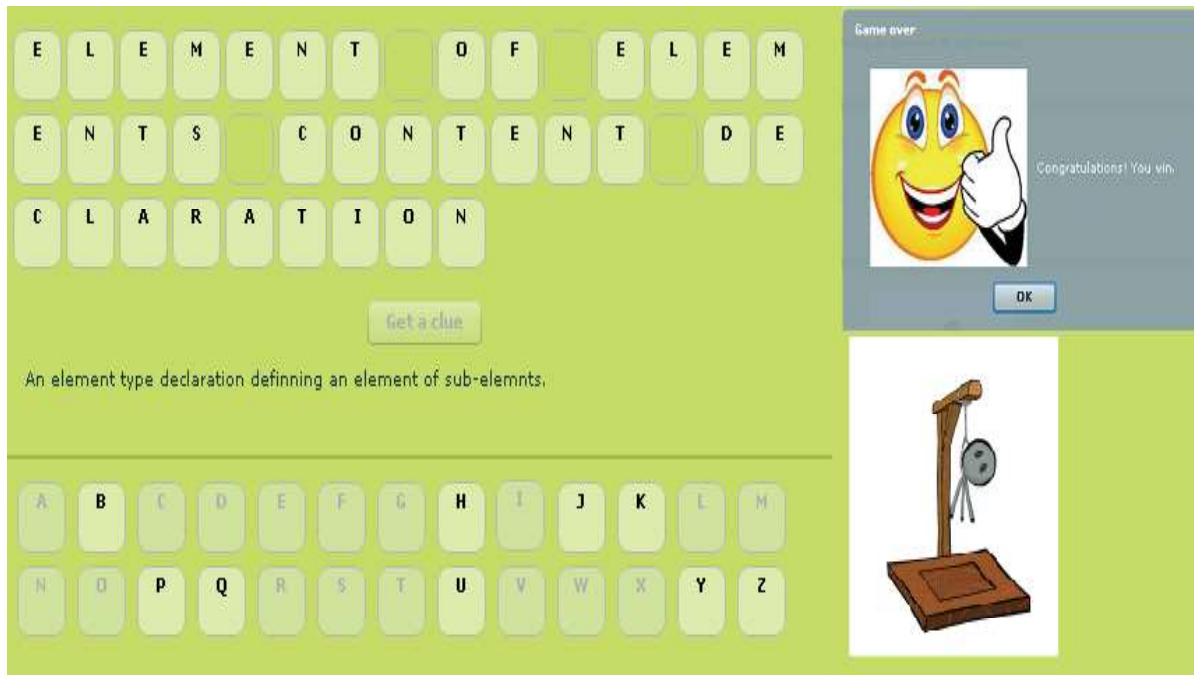


Figure 4: Partial view of the hangman game with XML terms

Next figure presents a part of a screenshot of the anagram game. Learners have to guess the anagram and to drag and drop its letters to the positions at the frame below.

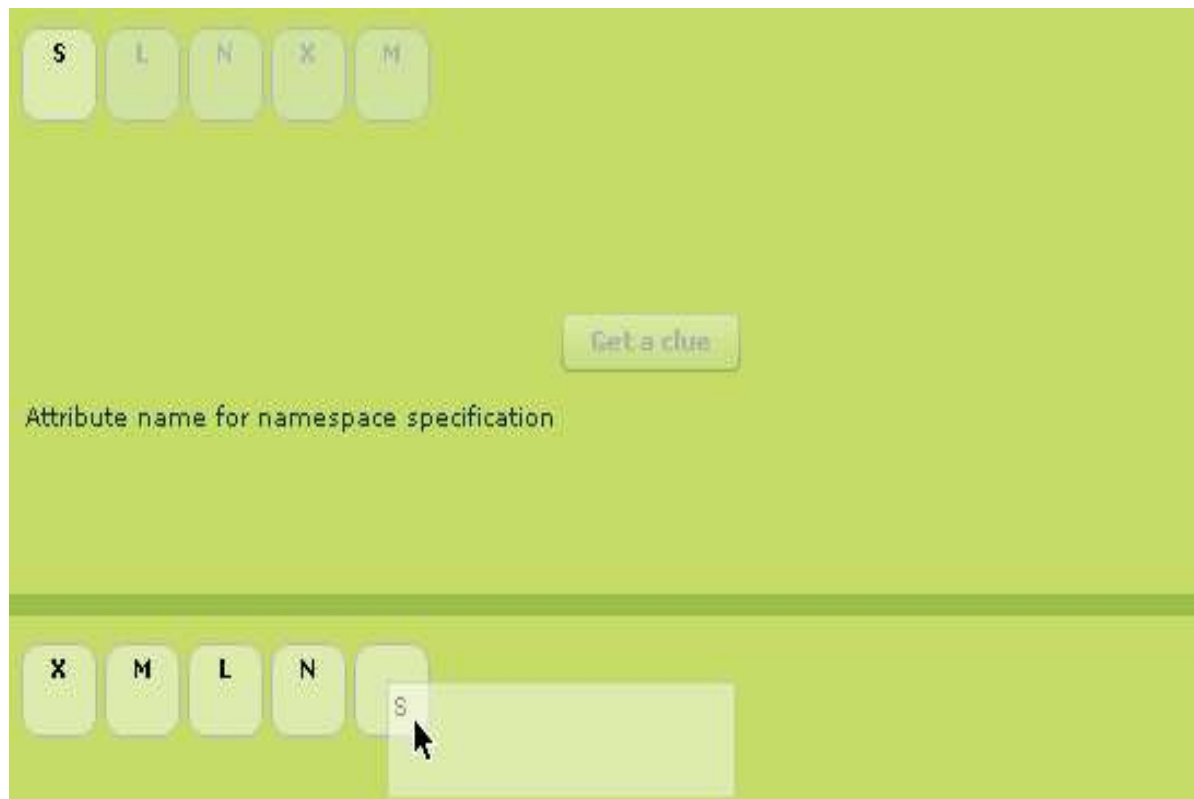


Figure 5: Partial view of the XML terms anagram game

While the games illustrated over deal only with terms of the course content, next two games use both terms and relationships between them. Figure 6 presents a screenshot of unsuccessful finish of the association game, where the learner has to match the concepts shown left to their super-types given on the right side. Thus, the used relationship is *typeOf* though other relations are possible such as *dependsOn*, *consistsOf* and *instanceOf*. Matching is introduced simply by dragging and dropping any of the left terms to one at the right side.

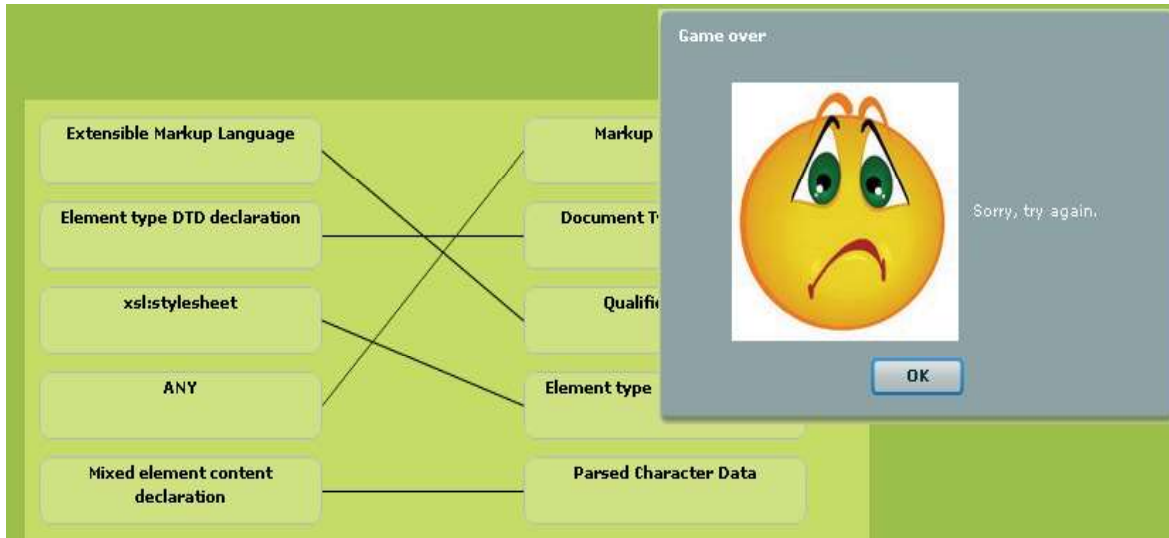


Figure 6: Partial view of the XML term relationships game

Finally, figure 7 gives a partial view of the memory game with matching of XML terms. Here, pairs of term – super-type term are to be found among all the tiles with hidden titles. After mouse click over a tile, its title (i.e., term) turns to be visible. Mouse click on another tiles shows its hidden term, too, and if both the term are in relationship, these tiles disappear and the learner gains a point. Otherwise, on next mouse click on another tile both the tiles disappear and the learner should remember their terms. Thus, the game trains memory of the learner and strengths his/her knowledge in the course domain.



Figure 7: Partial view of the memory game with matching of XML terms

5. Practical experiment end results

The experimental field trial aimed at evaluation of student appreciation of games used for courseware delivery with learning style adaptation (Vassileva 2011). In executed practical experiments participated 49 four-year students of the bachelor program in Software engineering at Sofia University, Bulgaria. The students were taught by several modules of an adaptive edutainment course in XML technologies using the ADOPTA platform and had appropriate instructional design for individual learning styles, i.e. containing paths with LOs most suitable for the combinations of individual learning styles of Honey and Mumford, namely activist, reflector, theorist and pragmatist (Vassileva 2011). The adaptive game-based course occurred to be more efficient in terms of gained knowledge and skills than its non-adaptive version - students taken the adaptive version of the same course demonstrated better performance - with 76,75% average result, while the first group showed 67,14%.

After the course, students filled a questionnaire, which results show adaptive, game-oriented learning is much more appealing and efficient. Some of the questions were focussed on the impact of games over the course at all. The questions with answers in Likert scale are given below:

- Q31: Do you think than presented games in this course correspond to your learning style (theorist/pragmatist/reflector/activist)?
- Q34: Do you think that usage of educational games will improve the adaptive learning process?
- Q37: Do you think that games used within the adaptive course will be more effective through mobile interface?

As well, the questionnaire contained some question with answers in non-Likert scale, such as:

- Q35: What type of game construction can improve mostly learning process? – possible answers here are as follows:
 - *Single user games*
 - *Single user games with artificial intelligence (AI) agents*
 - *Multi-user games*
- Q36: What type of games given below can improve mostly way learning process? – with possible answers:
 - *Strategic games (construction, production, management, ...)*
 - *Logic games (puzzles, mazes, word games)*
 - *Shooting (actions) games*
 - *Role-playing games*
 - *Adventure games*

Figure 8 provides a view of answers for questions 31, 34 and 37. It is obvious that the majority of learners think educational games' usage will improve certainly the adaptive learning process. At the same time, many of them share the opinion the games included into the course do correspond to their learning style, while the dominant styles of these students are found to be theorist and reflector – as expected for mathematicians and software engineers. On the other hand, students do not find game mobile interface to be a must for an effective adaptive eLearning.

Figure 9 represents results about students' vision about game construction types regarding efficiency of eLearning process. As the pie chart shows, the majority of students believe single user games with AI agents to be the most efficient educational types.

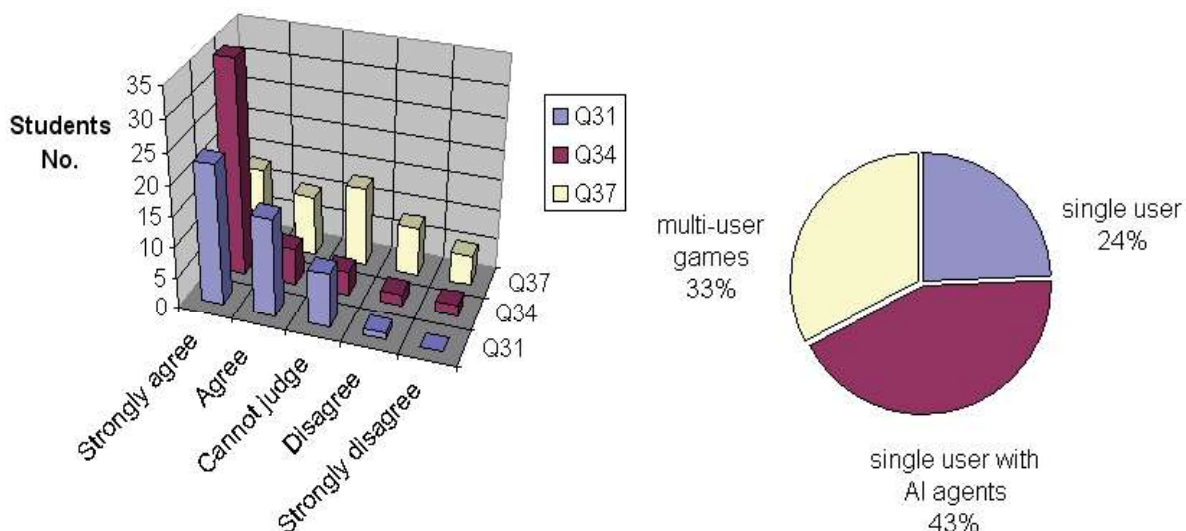


Figure 8: Results for questions 31, 34 and 37

Figure 9: Answers for question 35

Finally, figure 10 provides a bar chart view of results about games types helping mostly the eLearning process. As authors have expected, students prefer at most logic (problem-oriented, word) games

and strategic games for realization of an efficient adaptive eLearning. They recognize shooting, role-playing and adventure games are not appropriate for game-based learning.

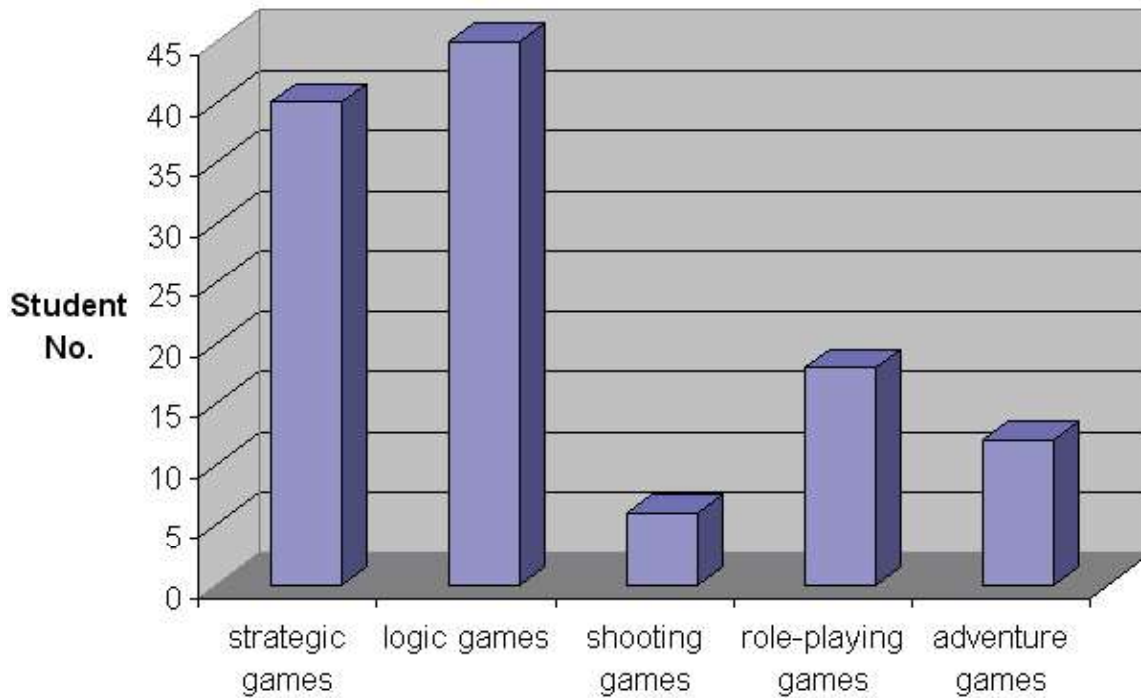


Figure 10: Answers for question 36

6. Conclusions

Game-based learning at schools, colleges and universities may turn to a streamline practice only after having a solid support by simple and efficient frameworks and platforms for fast development of educational games. Game construction tools should provide easy integration of educational content of teacher courseware, which is possible when the content is semantically structured and organized. Therefore, content authors need simple and intuitive enough authoring tools for creating semantically interrelated and annotated content. Next, the semantically organized content should be integrated and extracted at run time in logical problem-oriented and word games.

Though UML is not intended initially for semantic modeling, the approach presented above uses it for semantic content organization and annotation. UML class and object diagrams possess expressiveness lower than OWL but still sufficient for modeling educational content. Moreover, content authors may use OCL (Object Constraint Language) for defining constraints in a formal way if needed. The paper presented an example of semantic organization of educational content from a bachelor course in XML technologies. The UML model was transformed by hand to a relational form and used by a software framework designed for rapid logic game development. The framework was tested by development of a couple of different word games usable for adaptive game-based learning. After game play within sessions of eLearning adaptive to individual learning style, authors analyzed student expectations and preferences of such games. The obtained results are very promising regarding future use of educational games in courses of various scientific and application domains.

As directions of future work, authors envision at least two issues:

- Construction of tools for automatic transformation of UML semantic content models to their internal representation within the framework – probably, by using XML (XML Metadata Interchange) representation of UML models, which is supported by modern UML design tools allowing straightforward interoperability
- Future enhancements of the software framework for logic games construction – with development of graphical interface for a more facile game creation (by drag-and-drop functionalities) allowing even non-programmers to create and test their own word games.

In conclusion, edutainment cannot be treated as panacea. It has been criticized by many researchers because, when a courseware object is much more amusing than educational, students may run the

risk to get lost rather than to receive durable knowledge. That is the reason to develop and use in teaching practices more logic and strategic games rather than shooting and adventure game in order to provide some valuable knowledge to learners by keeping them engaged with intriguing learning material. For sure, such games are supposed to be used not in isolation but together with other instructional methods, with a modern technology enhanced learning environment.

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References

- Aitchison, J., Gilchrist, A., Bawden, D. (1997): Thesaurus construction and use: a practical manual. Aslib, London.
- Aliya, S. K. (2002): The role of computer games in the development of theoretical analysis, flexibility and reflective thinking in children: A longitudinal study. *International Journal of Psychophysiology*, pp. 45-149.
- Bontchev, B., Gabarev, N., Pavlov, H. (2002): "A Mobile Chess Game", *Proc. of 16th SAER Conference*, Varna, Sept. 2002, pp. 138-143.
- Bontchev B., Vassileva D. (2010): "Educational Quiz Board Games for Adaptive ELearning", *Proc. of Int. Conf. ICTE'2010*, ISSN 2070-3724, Issue 66, 28-30 June, 2010, Paris, France, pp. 63-70.
- Bontchev, B., Vassileva, D. (2011): "A light-weight semantic content model for mobile game based learning", *Prof. of IADIS Mobile Learning Conf.*, Avila, Spain.
- Dempsey, J. et al. (1996): "Instructional applications of computer games", *American Educational Research Association*, New York, pp. 8-12.
- Eagle, M., Barnes, T. (2009): Evaluation of a game-based lab assignment, *Proceedings of the FDG'2009 ACM* New York, ISBN: 978-1-60558-437-9, pp. 64-70.
- Eng, T. S. (2005): The impact of ICT on learning: A review of research, *Int. Education Journal*, ISSN 1443-1475, 6(5), 635-650.
- Feng, K. (2005): "Joyce: A Multi-Player Game on One-on-one Digital Classroom Environment for Practicing Fractions", *Proc. of the Fifth IEEE Int. Conf. on Advanced Learning Technologies (ICALT'05)*, pp. 543-544.
- Ferreira, A. et al. (2008): The common sense-based educational quiz game framework "What is it?", *ACM International Conference Proceeding Series*. Vol. 378, pp. 338-339.
- Garcia-Barcena, J., Garcia-Crespo, A. (2006): "Game based learning: a research on learning content management educational games seriously: using the RETAIN model to design endogenous fantasy into standalone educational games," *Education Tech. Research Dev.*, vol.56, pp. 511-537.
- Grønmo, R., Jaeger, M. C. and Hoff, H. (2005): Transformations Between UML and OWL-S., in A. Hartman & D. Kreische, eds, 'ECMDA-FA', LNCS, Springer, Vol. 3748, pp. 269-283.
- Hendler, J. (2001): Agents and the Semantic Web, *IEEE Intelligent Systems*, 2 (16), pp. 30-37.
- Ke, F. (2009): Chapter 1: A qualitative meta-analysis of computer games as learning tools, in Ferdig, R. E. *Handbook of research on effective electronic gaming in education* vol. 1, Information Science Reference, Hershey.
- Pilone, D., Pitman, N. (2005): *UML 2.0 in a Nutshell*, O'Reilly.
- Prensky, M. (2006): *Don't bother me, mom, I'm learning!*, St. Paul, Minn., MN: Paragon House.
- Retalis, S. (2008): Creating Adaptive eLearning Board Games for School Settings Using the ELG Environment, *J. of Universal Computer Science*, vol. 14, no. 17, pp. 2897-2908.
- Salen, K., Zimmerman, E. (2003): *Rules of play: Game design fundamentals*, MIT Press, Cambridge, MA, USA, October 2003.
- Shiratudin, N., Zaibon, S. (2010): Mobile Games Based Learning (mGBL) with Local Content and Appealing Characters, *Int. J. of Mobile Learning and Organisation*, Vol. 4, No. 1, pp. 55-79.
- Siang, A., Rao, R. (2003): Theories of learning: A computer game perspective, *Proc. of the IEEE Fifth International Symposium on Multimedia Software Engineering (ISMSE'03)*, pp. 239-245.
- Vassileva, D (2011): *Adaptive hypermedia systems for technology enhanced learning*, PhD Thesis, Faculty of Mathematics and Informatics, Sofia University.