Variability Handling in Educational Context

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Abstract

Today there are many different forms of educational activities present, e.g., traditional lecturing, e-learning, blended learning and living labs. Also, the audience becomes more and more international and heterogeneous in terms of background knowledge of students, their educational purposes, capabilities and expectations. This introduces a high level of variability in educational settings and requires new methods and tools for managing this variability. Customized application of feature models, known in software product line management, is one possible solution applicable for variability handling in educational context. This paper proposes the development of a feature model as the method for variability handling.
Keywords: Variability, feature models, personalized education, xAPI.

1. Introduction

Globalization and advances of information technology impact all areas of human activity, including the education. New forms of education, e.g., e-learning [2], mobile learning [14], [22], blended learning [12], outcome based learning [29], and personalized learning [13] are applied in order to meet today's challenges in an education domain. One of the key problems in such a setting is the necessity to handle a high variability of educational parameters, starting with educational goals [11] and ending up with supporting educational technologies [6].

Researchers are well aware of variability problems [11], [26], and many attempts to handle them have been made. Structural modeling [23], learning analytics [9], intelligent learning management systems [6], [25], [27], [28] and many other methods have been designed, tested, and applied. Most of these methods concentrate on specific variability points, leaving many other variability issues not attended to.

The goal of this paper is to introduce a method for variability handling, which is capable of incorporating all variability points in a given educational situation. The method presented here suggests using feature models. A feature model was already successfully applied in the domain of monitoring [21] the correspondence between educational demand and offer [24]. In this paper we will demonstrate how it can be applied in variability managing in an extremely complex educational project that includes large number of teaching methods and high diversity of students [18]. Feature models are common in software product line management and service

systems [1], [3]. Here their modification for different functioning modes of activities [24] will be applied to educational variability points.
The paper is structured as follows. In Section 2 the related work on variability sources in an educational context and variability handling methods is discussed. In Section 3 the proposed variability handling method is presented and illustrated. In Section 4 the xAPI based solution for module selection is introduced. In Section 5, brief conclusions and directions of future work are stated.

2. Variability Sources and Variability Handling Methods

The following are the main concepts used in this section:
- ***Variability*** – an availability of several options of a physical or virtual phenomenon (context, object, feature, etc.)
- ***Variation point*** that denotes a particular place in a system where choices are made as to which variant to use
- ***Variant*** is a particular option of a variation point

In Subsection 2.1 the main emphasis is put on different sources of variability in the educational domain and approaches of variability handling from the educational perspective. In Subsection 2.2 the background of feature modeling that is used for variability handling from a systems perspective will be discussed.

Variability in the Educational Domain

In the educational domain the notion "variability" is rarely used. Instead, such terms as diversity and personalization are applied [27]. Different methods for handling diversity and achieving personalization are known. These methods can include manual, semi-automated (interactive use of dedicated software) and automatic activities (activity is performed by software alone and the results can be used either by a teacher or student, or administration, or other software application). Below we list some of the approaches for variability handling in education:
- *Manual methods* [19], [21]. By manual methods we mean data analysis that does not use dedicated software. Use of office software can be regarded as part of manual data handling. The data can be obtained by questionnaires, interviews, and document analysis. For larger amounts of data Microsoft Excel Power Pivot possibilities can be used. For using these approaches [21], it is necessary to identify: main indicators to be analyzed; the minimal set of learning outcomes to be analyzed; knowledge evaluation methods and metrics; and criteria for knowledge evaluation. It is also necessary to perform analysis of student characteristics, applying the results obtained to developing study plans, and assigning students to groups and for other purposes.
- *Semi automated methods*. The use of a semi-automated choice of learning path [8], [29] belongs to this category. Usually applications that handle the path include Learning Recognition Course, Carrier Journey and Learning Advisor software. Personalized study plans also belong to this category. Sophisticated systems analysis software may be used as a back-end in such solutions [7], [23]. Utilization of concept maps and graph analysis can be mentioned as some of these. An interesting method for developing personalized learning paths has been developed in Australia [5]. It includes identification of current knowledge of learners, identification of learning paths, identification of performance results, the possibility of adjusting teaching to personal goals and monitoring of goal fulfillment. This method can be used by teachers for applying personalized teaching to individual students or selected groups of students. E-portfolio methods also belong to semi-automated methods. E-portfolios help to see personal achievement in the learning space. Several types of portfolios can be used [16]: evaluation e-portfolios for evaluation of the level of achievement; presentation e-portfolios, that show the learning achievement of an individual in the longer run (related to continuing education and life-long learning); and study and development e-portfolios that include personal development planning.

- *Automated methods*. We put in this category learning analytics [4], [8] and automated learning paths discovery [17], [6]. In learning analytics such methods as data mining can be applied [4]; these give an opportunity to discover previously unknown relationships between learning characteristics and to make predictive decisions with respect to future development for the improvement of the learning environment. Automated learning path discovery requires usage of advanced learning management systems that have a high level of flexibility and built-in procedures for supporting the path generation [6].

The methods discussed above show that, for handling variability, it is necessary to distinguish between different groups of students and/or individual students; to distinguish between different methods used for achieving personalized learning; and it is also necessary to distinguish between different modes (manual, semi-automated, automatic) of method application.

Feature Models for Variability Handling

One of the tools for variability handling is a feature model [3], [10], [15]. A comprehensive survey of feature modeling is provided in [3]. Historically, it started with feature viewpoints in 1998. Initially feature models were mainly related to design-time variability. However the methods designed in this century already can handle run-time variability and variability at any time. In industry the main aspects of systems and software variability are requirements, architecture and components in technical areas; variability scoping and variability-driven evolution as a business concern; variability management and configuration management as an organizational issue; and run-time concerns in evolution and post-deployment activities [3].

The feature models most often are applied in software product line management and in service systems. Usually they concern just software activities. Feature models have different modifications, but all of them represent variation points, variants, and relationships between variants of different variation points. Galster et.al. [10] provide the classification of variability in different dimensions that capture key facets of variability. The classification can be used as the baseline from which the key aspects of variability of different types of software systems can be identified and compared. Galster et.al. [10] identify also the dimensions of variability that are organized in two clusters: the type and the mechanism. The type cluster includes dimensions for introduction and specification of variability, namely, requirement type, representation, artifact, and orthogonality dimensions. The mechanisms cluster of variability refers to the way variability is realized. Our work considers variability modeling and the representation dimension for introduction and specification of variability [10]. Other researchers [3] look at the variation in processes and provide a variation realization approach to automatically implementing and managing concrete process variants.

In [24] it was the first time the variability of functional modes of activities was handled. We inherit the approach used in [24] for variability modeling in the educational domain because the type of functioning mode is relevant in this domain. Here, different activities can be done manually, semi-automatically and automatically, depending on the variability management goals and available tools.

In the next section an excerpt of how the variability model can be used in the sophisticated educational project will be shown and discussed. The variability model itself is the background for variability handling. It helps one to understand where the variation points are, what the variants are, and what the reasonable combinations of the variants are.

3. Feature Model for the Colibri Project

In this section we illustrate how a feature model can be applied to the variability handling in the Colibri [18]. The Colibri is an ERASMUS+ project where students and teachers of 7 universities and representatives of 3 industrial companies form a Living Lab for testing several new teaching methods and combinations thereof. The yearly educational process starts in the spring semester and involves 4 stages. In the first stage, students have e-learning courses. There are 10 different modules, which have three submodules, namely, introductory, basic and advanced. All students take all introductory submodules and at least 2 advanced submodules (with the rule that, if an advanced submodule is taken, the corresponding basic model also has to be taken). Each type of submodules has a particular workload. The overall number of modules is controlled by the total number of hours, which each student is supposed to spend on learning. The module assignment is impacted by student allocation into groups which is done before the studies are started. The aim is to achieve that each group, taking together previous knowledge of each student and knowledge to be obtained in e-learning by each student, overall has knowledge covered by all 10 modules. If this cannot be achieved, the students should cover the modules which are most important for their project as described in the following. For supporting the module selection process the xAPI application, based on the feature model, was developed (it has to be noted here that the application was tested on the Colibri data but has not yet been applied for the actual module selection in the project, see Section 4). After the modules are acquired, each student group, having advisers from academy and industry, performs a unique project that solves a particular industrial problem. Project development starts with the Midway seminar where all students, teachers and industrial representatives meet in person. Afterwards, students and advisers cooperate remotely and after three month meet at the final seminar, where projects are finished and presented. A variability model for the initial stage of the project is presented in Figure 1.

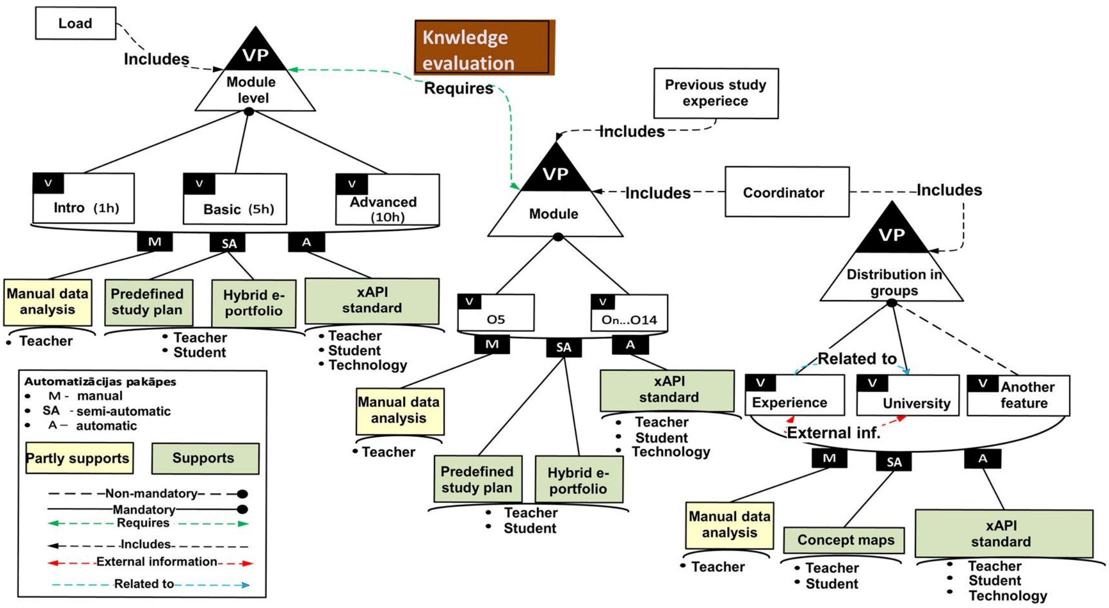

Fig. 1. Feature model for the Colibri project (the first stage, simplified).

Variation points in Figure 1 are denoted with triangles VP, variants are denoted with rectangles V. The factors that additionally should be taken into consideration in the variation points are denoted with white rectangles. These factors also may be represented as variation points, if needed.

The variation point "Module level" shows the number of submodules available. Each submodule may utilize particular teaching and evaluation methods that can be used by students, students and teachers (e.g., using MOODLE forum), or teachers, students, and software (e.g., when analytical software of the learning system analyzes the data).

At the instance level, several teaching methods are used in different submodules of Colibri:

- Introduction level (1 h.):
  - Overview lecture (recommended max. 2 videos)
  - Individual task or assignment
  - Individual task or assignment and peer review
  - Peer learning in project groups

  - Optional literature/material
- Basic level (5 h.):
  - 10 min. self-assessment (and preliminary material)
  - 60-120 min. literature study
  - Video lectures with shorter tasks (around 10 min. lecture/5-10 min. self-correcting questions/working with tools) (120-180 min.) max 50% of video lectures.
  - Self-correcting quizzes and assignments. Quizzes follow a common template.
  - Practical exercises to work with the relevant tools
  - Questions and answers forum
- Advanced level (10 h.):
  - Literature reading
  - Video lectures
  - Group assignments (in 2-4 people groups)
  - Peer assessment workshops: Assignment and peer assessment (students assessing students)
  - Article assignment: reading, discussion, and presentation of work in relation to an article
  - Additional material in the form of videos, books, scientific papers, PPTs, etc.
  - Quizzes

There are methods that use dedicated software (semi-automated methods or automated methods). These are denoted with green color and "Supports" in Figure 1. The methods that use no software or use just general purpose applications are denoted with yellow color and "Partly supports". The methods can utilize manual data analysis if the teacher does all the work without dedicated applications; otherwise it can have a pre-defined study path; can constitute a hybrid e-portfolio, or can be realized automatically.

The next variation point “Module” represents possible choices of the modules according to the rules described above where manual, predefined, hybrid e-portfolio style or automatic methods can be used at the instance level. In this variation point the xAPI was used for experiments.

The third variation point concerns distribution of students in groups, where again manual, semi-automated, and automatic methods can be used.

The feature model shows relationships between the variation points that have to be taken into consideration. The model in Figure 1 does not show relationships at the instance level. However, these relationships are important in cases of dependencies at that level [24]. In Figure 1 they are not shown for the sake of simplicity. Another simplification is that subdivision in manual (M), semi-automated (SA) and fully automated (A) modes of functioning of methods is not repeated for each variant in the variation point, but is just abstractly shown once for all variants of a variation point. This again is done to keep the model as simple as possible. However, if the feature model were used as a basis for software development for variability management, simplifications would not be possible, and the size of the variability model would be larger and all dependencies would be represented.

The above presented feature model covers only the first stage of the Colibri learning process [18]. More variability points would be needed if all stages were represented. In the development of the full variation model the following challenges have to be addressed:

- Multiple variation points - it has to be decided which aspects to consider as variation points and which to leave just as influencing parameters; nested variation points can be considered, too
- Different variation dimensions - in one and the same variation point there might be several variation dimensions (e.g., gender, age, and university of the student)
- For several variation points, the ranges of variation are unknown or only partly known (e.g., background knowledge of students)
- For several variation points the ranges become known gradually

Nevertheless, the method of handling variability by developing a feature model gives an overview of variation points, variants, their implementation modes and methods, and

dependencies among the elements. It also gives the basis for developing software that facilitates variability handling in complex educational settings.
In the next section we will look more closely at the variation point "Module", which was introduced to show the variants of module selections. Here the xAPI learning technology standard was used for the automation purpose.

4. The xAPI for Module Selection

In this section we illustrate how a module selection variation point can be realized using the xAPI in combination with other technologies such as Moodle learning management system. The xAPI is a learning technology standard that provides an opportunity to collect data on a wide variety of student learning experiences, both online and offline [25].
To illustrate the range of variability the calculations were made on the basis of Colibri student handbook, 2016. Here the module variability was defined so as for each student all introductory submodules are to be taken, four basic submodules are to be taken, and two of these basic modules have to be taken up to the advanced level. Basic modules would meet 210 different combinations ($c_{10}^4 = 210$)[13], additionally advanced modules would meet 6 combinations ($c_4^2 = 6$)[14] per student.
In Section 3, with respect to the variation points shown in Figure 1, it was noted that in selection of modules the evaluation of knowledge is needed. The variability management options show that a solution must be obtained according to the respective situation and that methods should involve teacher, student, and technology. The solution should support the following issues of Colibri course variability management:

- evaluation of knowledge
- to be acquired modules offer
- the ability to retrieve reports on knowledge-splitting through the modules
- an opportunity to involve teachers, students, and technology.

The illustrative model for module selection using xAPI is presented in Figure 2.

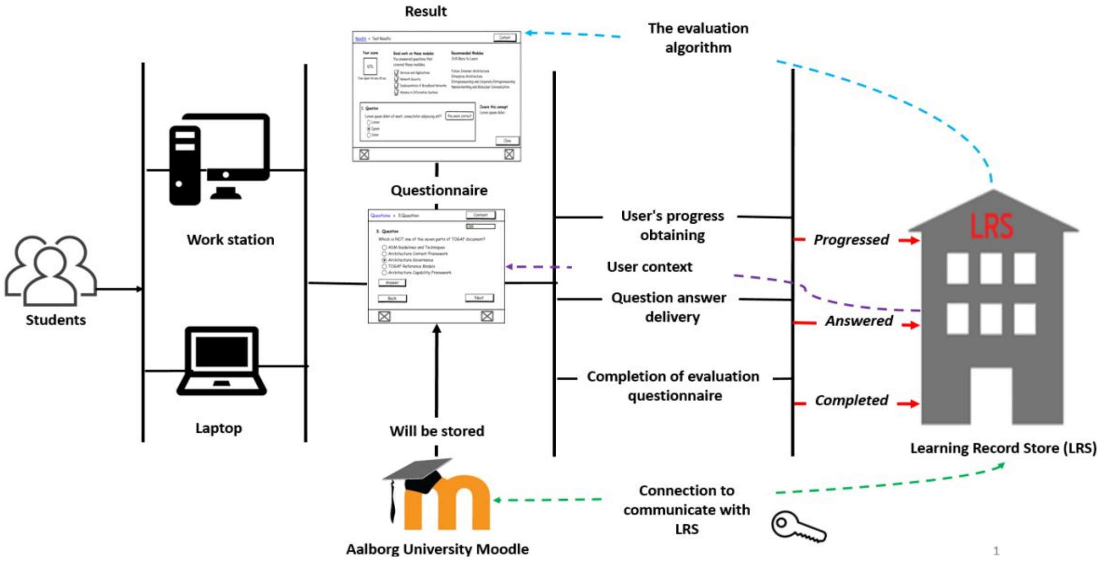

Fig. 2. General model for module selection using the xAPI.

The xAPI standard can be applied for module selection as follows: first the electronic evaluation questionnaire is created in order to facilitate the evaluation of student knowledge and module selection. The questionnaire consists of questions that allow the evaluation of students'

[13] Combinations for basic module selection.

[14] Combinations for advanced module selection

knowledge and see whether particular modules have been successfully acquired in their previous education or in actual learning process.

In Figure 2 the IT solution is viewed from the student's point of view, - i.e., in this case the users are students. Students can access the evaluation questionnaire using a work station or a laptop. Then the questionnaire has to be stored using some technology, in a the Colibri it can be the Aalborg University learning management system (Moodle). The xAPI records activities such as user progress, question answering and completion of evaluation questionnaires. Depending on recorded activities, Learning Record Store (LRS) receives statements that contain such verbs as "progressed", "answered" and "completed". In order to ensure the record accumulation within LRS, the LRS authentication data should be specified in the Moodle. The questionnaire can reflect contextual changes from LRS to students. When the questionnaire is completed, a background process is launched that contains the return of results and the assessment algorithms for showing the results. The interface prototype for the result view is presented in Figure 3.

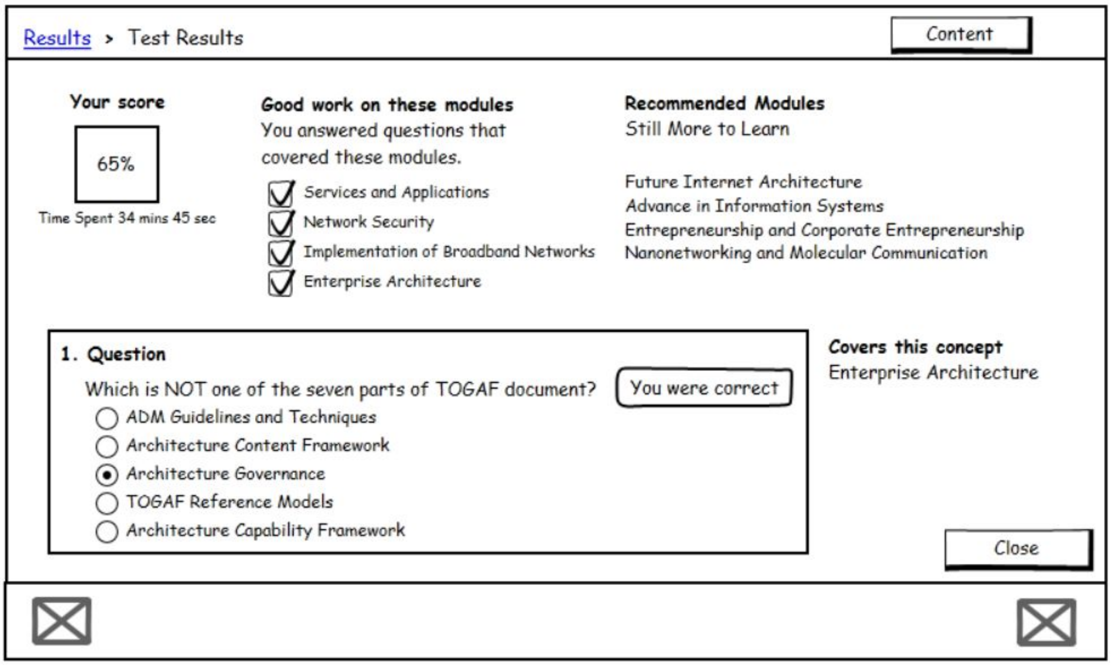

Fig. 3. Interface prototype for results view.

In Figure 3 the results contain an assessment expressed as a percentage of successful answers and time spent filling out the questionnaire. There are also successfully acquired modules and recommended modules presented. Also the student has an opportunity to review answers to questions.

While the xAPI application can automatically show the suggested modules, it does it for the student individually. In a Colibri project students work in groups. Therefore, not only the individual knowledge, but also potentially emergent group knowledge is to be taken into consideration. This knowledge may be influenced by the number of factors discussed in the previous section. While theoretically it would be possible to develop an intelligent application that tries to evaluate the knowledge at the student group level, the development of such application would currently require utilization of knowledge that is very hard to be accumulated. Moreover, when such knowledge is accumulated for a particular group, the decision can be made and suggestions can be provided without the use of the software application. So in this case the manual procedure for group-level knowledge assessment and negotiation of the individual modules would be less time consuming than developing a dedicated application. However, in the longer run, when statistics of several years are accumulated, an intelligent system might be developed, that can learn how to assess group-level knowledge.

5. Conclusions

In this paper we addressed the issue of high variability in today's educational environment and proposed the development of a feature model as the method for variability handling. Currently popular variability handling methods, e.g., personalized learning path and e-portfolio, were overviewed. A simplified example of the variability model of the Colibri project was presented and discussed. The following are the main conclusion made during this research:

- The feature model does not substitute for existing methods of variability handling, it just structures them and puts them into the context of a particular study case; and gives a systematized overview of the variability in a given situation.
- At the level of complexity of the system presented, fully automated variability handling is not always possible due to unknown variability ranges and emerging variability.
- In some variability points manual variability handling can be more effective and efficient than the automated handling (this conclusion is drawn from the practice of distribution of students into groups).
- Therefore a combination of manual and automated variability handling might be the most effective way of variability handling.

Future work concerns investigation of nested, networked, emerging, and emergent variability in the educational domain and the development of instruments for handling these forms of variability.

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