Educom.ml: A Modeling Approach for Mobile Educational Content

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***Abstract*—This full research paper is concerned with structuring educational content for mobile learning. Mobile devices are present in various areas of society and, in the educational context, the available resources of mobility and connectivity have contributed to their growing adoption. However, the generation of educational content for mobile devices requires special attention to issues such as: (i) restrictions on mobile devices; and (ii) complexity of developing mobile applications, related to the variety of existing platforms. This paper presents Educom.ml, which is a modeling approach for mobile educational content supported by MDE (Model-Driven Engineering) and IMA-CID (Integrated Modeling Approach - Conceptual, Instructional, Didactic). Educom.ml proposes a modeling approach that involves creating models that structure educational content and models that model mobile platforms. In this context, MDE minimizes the complexity of developing cross-platform applications and the automatic generation of educational content. Meanwhile, IMA-CID is responsible for structuring and organizing educational content. To illustrate our ideas, a mobile app was generated based on modeling educational content in the field of elementary mathematics.**

***Index Terms*—Educational Content Modeling, Mobile Devices, Model-Driven Engineering.**

I. Introduction

The use of Information and Communication Technologies (ICT) in the teaching and learning process requires new skills from education professionals [1]. However, educational content prepared for a given ICT cannot always be used for another [2]. In the context of mobile technology, the production of educational content needs to adapt to the physical and cognitive restrictions of mobile devices [3] [4].

When implementing educational mobile apps, it is common for teachers to work together with the development team. However, the mastery of mobile technology is not trivial for teachers, requiring additional skills to produce educational content [5] [6]. In addition, the variety of platforms and mobile devices on the market imposes even more complexity on development [7] [8]. In this perspective, teachers need to better structure the educational content to facilitate its implementation on mobile devices, while developers need to implement cross-platform applications.

This article presents a Educom.ml, which is a modeling approach to generate educational content to minimize the complexity of producing this type of content for mobile devices. The goal is to abstract from the teacher the need to master technical knowledge for the development of educational material for mobile applications. Besides, the proposal is to minimize the complexity of implementing applications between mobile platforms. These objectives are achieved by applying the IMA-CID approach (Integrated Modeling Approach - Conceptual, Instructional and Didactic) [9] and the MDE (Model-Driven Engineering) [10] in modeling educational content.

The challenge of structuring educational content is confronted by the construction of three models, established as part of IMA-CID. The Conceptual Model specifies the main concepts of the domain. The Instructional Model assigns complementar information to the concepts. The Didactic Model is responsible for establishing the sequence of presentation among the concepts. The challenge of generating mobile educational content, in turn, is addressed with the MDE approach, enabling models that structure educational content to be transformed into models that represent the target mobile platform.

This paper is organized as follows. Section II summarizes the background of our research. Section III presents our approach for modeling and generating mobile educational content. Section IV discusses related works. Section V presents the main conclusions and perspectives for future research.

II. Background

Software engineers use models to abstract complexity in the systems development process [11]. However, the models defined during the system development cycle are used only to understand and propose a solution to real world problems [12]. MDE proposes that models be first-class artifacts in the software development cycle [13] [14]. Soon, the models become programmable resources for building software artifacts. Because it is programmable, a model can be transformed into another model (model-to-model transformation), or it can be transformed into source-code (model-to-text transformation). For model transformation to occur, transformation rules must be clearly specified. The rules define the correspondences between elements of the models and the logic applied in the process of transforming one model into another [15].

In our proposal, MDE aims to minimize complexity in the process of implementing the viewing environment for

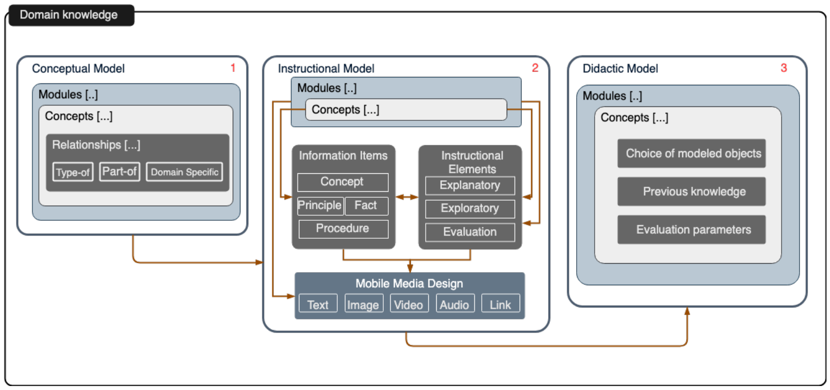

Fig. 1. IMA-CID models.

educational content. However, there is still the challenge of structuring educational content in an appropriate way to the restrictions and resources of mobile devices. In this sense, we adopted the IMA-CID [9] approach. As illustrated in Figure 1, the IMA-CID structures the educational content considering the following views of the knowledge domain:

- The Conceptual Model defines the most relevant concepts in the knowledge domain intended to be taught. The goal is to define a hierarchy of domain concepts. The hierarchy is built by observing the existing relationships among the concepts. Thus, the hierarchy can be characterized by the existence of a composition relationship, that is, a concept is formed by other concepts (part-of relationship). Or, the hierarchy can be characterized by a classification relationship (type-of relationship), in which one concept is of the same type of another. There is also a hierarchy formed by relationships that are specific for the domain (domain-specific).
- The Instructional Model assigns complementary information to the modeled concepts. Its composition involves *Information Items* and *Instructional Elements*. *Information Items* are supported by elements of the Component Display Theory (CDT) [16]. Therefore, in the Instructional Model the following information items are specified: concepts, facts, procedures and principles. *Instructional Elements*, in turn, complement the information items with elements that reinforce the understanding of a concept. Instructional elements can be explanatory (examples, tools), exploratory (examples) or assessment (learning tests).
- Mobile Media Design, is a set of guidelines that conduct the production of text, video and image, considering the physical and cognitive restrictions on mobile devices.
- The Didactic Model establishes the sequence of presentation, that is, in what order the concepts will be presented to the learner. The sequencing of concepts is established by the defining of pre-requirements for the learner to advance in the concept hierarchy. Also, it is necessary to establish an evaluation parameter to determine whether the learner has mastered a concept or not.

Next, the complete process of our proposal for modeling educational content for mobile learning is presented and illustrated in the Elementary Math domain.

III. Generating mobile educational content

In this section, the metamodels that compose our modeling approach for mobile educational content are summarized and discussed. Also, instances of templates for the Elementary Math domain are presented and discussed. The first three stages aim to structure educational content. The next three stages focus on the mobile platform modeling for content presentation. As illustrated in Figure 2, metamodels have been proposed considering two views:

1) The first view focuses on modeling the educational content, which involves the definition of the Conceptual, Instructional and Didactic models of the knowledge domain. These three models are part of the IMA-CID educational content modeling approach. The content production team is responsible for structuring the educational content to instantiate their models. In our work, IMA-CID has been updated to meet the characteristics of mobile learning.
2) The second view focuses on modeling the mobile platform that will create the content modeled by the content production team. Applying transformation rules in the Conceptual, Instructional and Didactic models, the educational content is generated for use in a mobile application.

Next, we present the metamodels for each stage of the educational content generation approach for mobile devices. Instances of metamodels and transformation rules were built using the Eclipse Modeling Framework [17]. Notice that the content production team instantiates only the templates from the first view (stages 1 to 3). The models in the second view (steps 4 to 6) are generated without the instructor interference.

A. Stage 1 – Creating an instance of the Conceptual Model

In this phase of modeling, a conceptual model is instantiated according to the Conceptual Metamodel of Figure 3. The Conceptual Metamodel organizes the content in a relevant

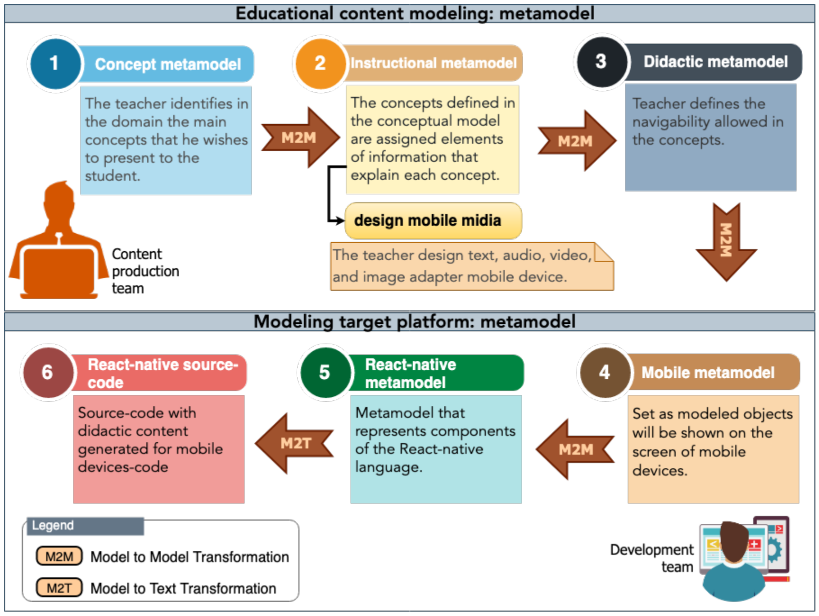

Fig. 2. Overview Metamodel EDUCOM.ML.

hierarchy of concepts that that are intended to be taught. Thus, the content production team identifies concepts and how they are interrelated. As Figure 3 illustrates, initially the attributes of the knowledge domain (CKNOWLEDGEDOMAIN) are defined. The educational content is then segmented into concise and objective modules (CMODULE). This strategy facilitates the organization of the time that the student allocates for the study [18].

The next step is to define the concepts (CCONCEPT) that make up each module. As seen in Section II, the hierarchy of concepts takes into account the characteristics of the relationships (CREFERENCE) existing among them. Relationships can characterize (TYPEREFERENCE) the composition relationship (PART OF), a classification relationship (TYPE-OF) or a domain-specific relationship (DOMAINSPECIFIC). Figure 4 illustrates an instance of the Conceptual Model for the Elementary Mathematics domain. Note that the domain has been divided into five modules. The module "Set and their concepts" consists of seven concepts. Notice that the concept "Finite Set" has a SPECIFIC DOMAIN relationship with the "Sets" concept. The other concepts are not detailed in Figure 4 due to space restrictions.

It is important to highlight that the choice of domain concepts depends on the learning goals and on the audience defined by the teacher. Therefore, the approach does not impose a pedagogical strategy, leaving this issue to be decided by the teacher.

B. Stage 2 – Creating an instance of the Instructional Model

In this phase, complementary information is associated with each concept defined in the Conceptual Model. It is in the Instructional Model that resources such as text, image, video and audio are specified to complement the concepts and improve the understanding of the domain.

According to the instructional metamodel illustrated in Figure 5, concepts (ICONCEPT) are complemented by the

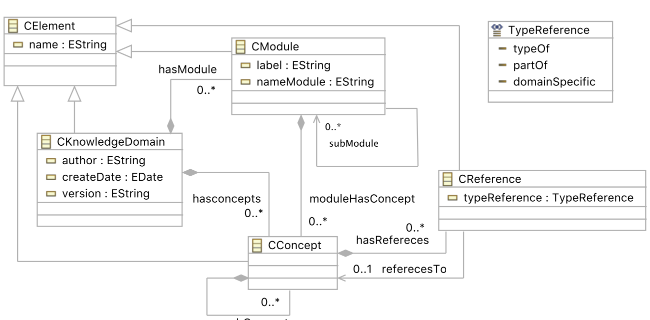

Fig. 3. Conceptual Metamodel (fragment).

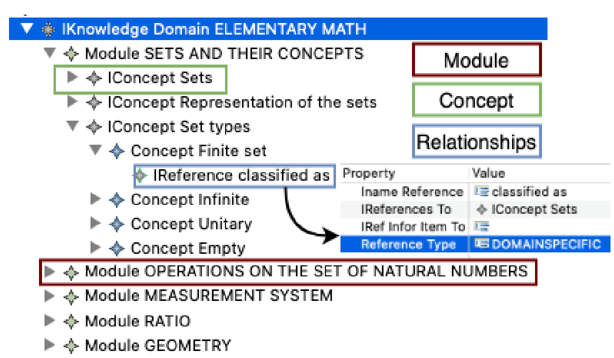

Fig. 4. An instance of the Conceptual Model for Elementary Math domain (fragment).

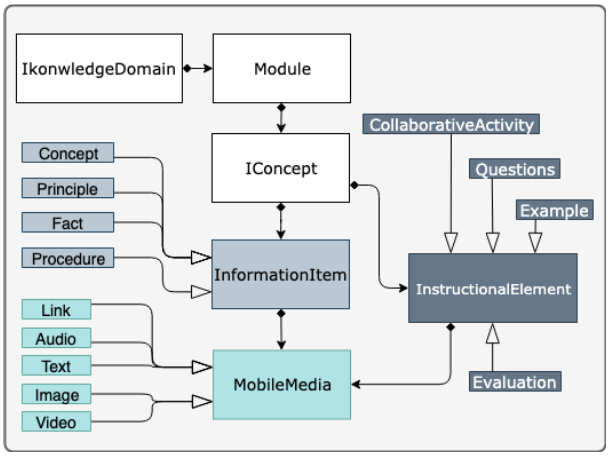

Fig. 5. Instructional Metamodel (fragment).

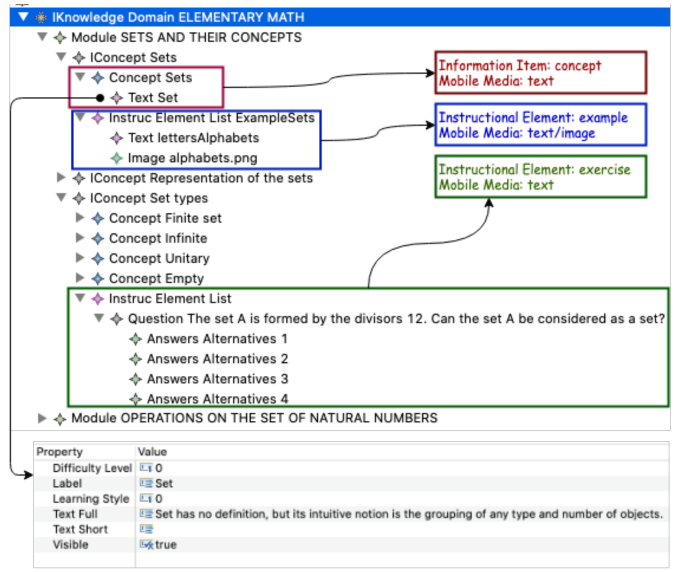

Fig. 6. An instance of the Instructional Model for Elematary Math domain (fragmenet).

definition of *Information Items* and *Instructional Elements*. In Section II we showed that *Information Itens* are supported by concept (CONCEPT), fact (FACT), procedure (PROCEDURE) and principle (PRINCIPLE). *Instructional Elements* are used by the teacher to reinforce the understanding of a given concept. Thus, *Instructional Elements* correspond to complementary information, such as a collaborative activity (COLLABORATIVEACTIVITY), evaluation questionnaire (QUESTIONS) or example (EXAMPLE), which can be associated with a concept.

To specify *Information Items* and *Instruction Elements*, media (*MobileMedia*) is used as a link (LINK), audio (AUDIO), text (TEXT), image (IMAGE) and video (VIDEO). To assist the teacher in the process of defining mobile media, [19] has proposed a set of guidelines that guide media production, considering the physical and cognitive restrictions of mobile devices.

Figure 6 illustrates an instance of the Instructional Metamodel for the Elementary Math domain. According to the model, the concept "*Sets*" was defined by an INFORMATIONITEM:CONCEPT" with the assignment of an element MOBILEMEDIA:TEXT that characterizes the concept of "*Sets*". In addition, to reinforce the understanding of the concept "*Sets*", an INSTRUCTIONAL ELEMENT:EXAMPLE was defined, being described by a MOBILEMEDIA:TEXT and a MOBILEMEDIA:IMAGE element. It can also be seen that a INSTRUCTIONAL ELEMENT:QUESTION was assigned to the concept *Set types*.

Similarly to the Conceptual Model, the teacher can define Instructional Models according to the learning goals, audience and other specificities of the course.

C. Stage 3 – Creating an instance of the Didactic Model

The Didactic Metamodel aims to select the concepts to be presented, as well as to establish a precedence relationship and the sequencing of presentation among the concepts defined in the Instructional Model.

According to the Didactic Metamodel presented in Figure 7, the teacher can establish what previous knowledge (PRIORKNOWLEDGE) the learner needs to master before studying a specific concept. Also, it is possible to define evaluation parameters (ASSESSMENTPARAMETERS) that provide metrics of progress for the next concept.

Following the modeling of the Elementary Math domain, a Didactic Model was instantiated. In the instance illustrated in Figure 8, it was defined that the concept PRIORKNOWLEDGE: MULTIPLYING WITH NATURAL NUMBERS is a prerequisite for studying the concept *Potentiation with natural numbers*. In addition, the VISIBLE property of the *Potentiation with natural numbers* concept was defined as TRUE, indicating its selection to compose the educational content. An ASSESSMENT PARAMETERS: SINGLE: PERCENTAGE: SCOPE: EVALUATION was specified with a metric for assessing the learner's progress to the next concept. In this case, the apprentice goes on to

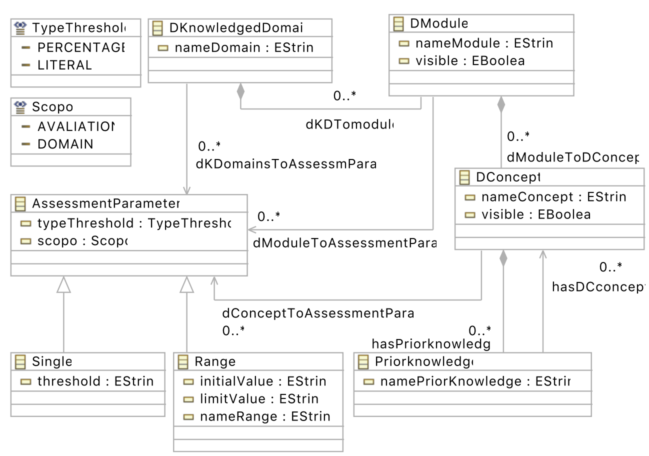

Fig. 7. Didactic metamodel

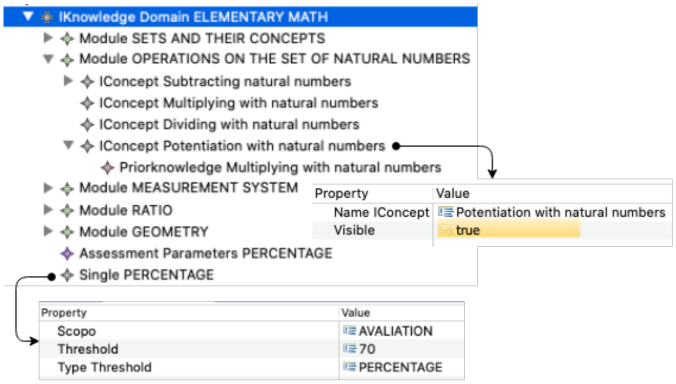

Fig. 8. An instance of the Didactic Model for Elematary Math domain (fragment)

the next concept when reaching 70 % of correct answers in the evaluations, as shown by the property of the element SIGLE:THRESHOLD.

In short, the Didactic Model defines which modeled objects will be presented to the learner, as well as their navigability. Notice that the precedence of concepts and the evaluation parameters are established by the teacher himself, according to his/her preferred teaching strategies and pedagogical models.

D. Stage 4 – Creating an instance of Mobile Model

Figure 9 presents the mobile metamodel, whose objective is to abstract technical details of the mobile technology, proposing which elements of the educational content will be presented on each screen of the application.

The Mobile Model is automatically obtained, without the need of teacher intervention in its creation. Its generation is carried out by applying transformation rules based on the Instructional Model. In summary, the transformation rules use the following correspondences: (i) each concept defined in the Instructional Model corresponds to an element SCREEN of the

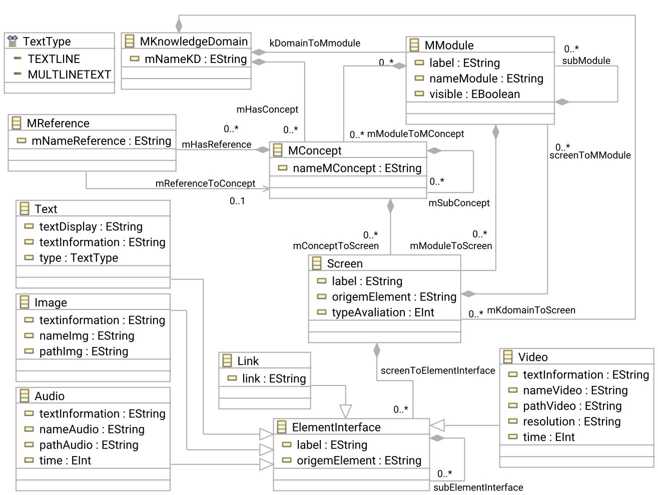

Fig. 9. Mobile Metamodel.

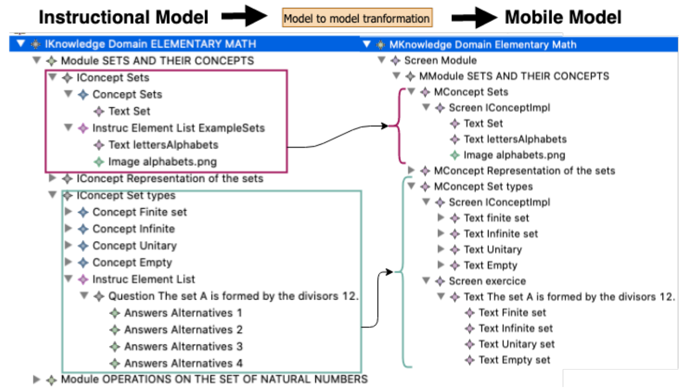

Fig. 10. Transformation of the instructional model to the mobile model. Correspondence between elements.

Mobile Model; and (ii) in the Mobile Model, the Interface Elements (ELEMENTINTERFACE) generalize the media TEXT, VIDEO, IMAGE and LINK. Therefore, *MobileMedia* of the Instructional Model are transformed into Interface Elements.

Figure 10 illustrates the mobile model instantiated for the Elementary Math domain. In the instance, the *"Sets"* concept of the Instructional Model was represented with an instance of the SCREEN element of the Mobile Model, composed of two interface elements (ELEMENTINTERFACE:TEXT and ELEMENTINTERFACE:IMAGE). The process of creating instances of SCREEN elements of the Mobile Model is repeated for all concepts present in the Instructional Model.

Mobile Model is a generic representation of the educational content organization for mobile apps. The goal is to have an interface specification that can be transformed into educational content for different mobile platforms (Android or IOS).

E. Stage 5 – Creating an instance React-Native Model

A difficulty with mobile applications development is the need to develop a cross-platform specific source-code [20]. This hurdle can be overcome with approaches that allow

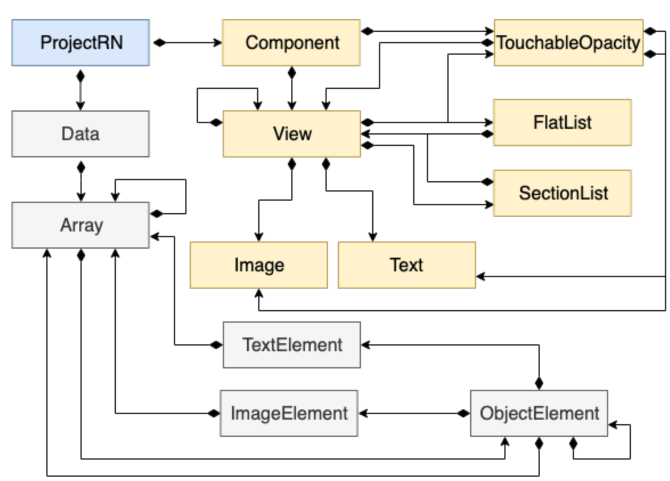

Fig. 11. Reduced reanct-native metamodel.

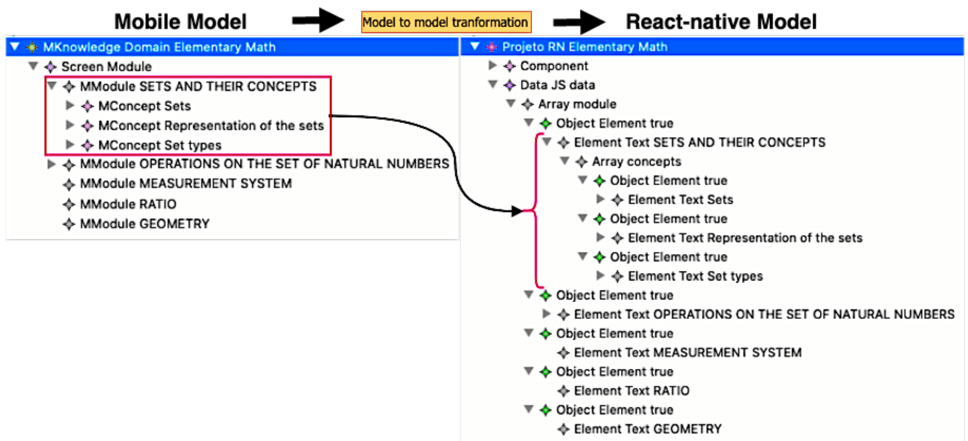

Fig. 12. Transformation of the Mobile Model to the RN Model. Match between elements.

creating a single source-code that generates cross-platform applications [21]. One such approach is the *framework* React-native (RN). Applications developed in React-Native generate native source-code for Android and IOS.

Unlike the Mobile Model, the RN Model aims to model educational content for a target mobile platform. A React-native Metamodel was proposed to represent elements of the React-native language. RN implements mobile applications with the strategy of building reusable components. This logic of creating encapsulated components was used in the implementation of the rules to transform the Mobile Model into an RN Model. In this way, the modeled educational content is transformed into a component that can be reused in different mobile applications.

The React-native metamodel, illustrated in Figure 11, classifies a React-native project into elements of language (COMPONENTS) and educational content (DATA). The purpose of this classification is to differentiate the user interface from the modeled educational content. This strategy facilitates the reuse of educational content modeled in applications that are not generated by EDUCOM.ML. The educational content is structured in an array of elements (OBJECTELEMENT) that is composed of text (TEXTELEMENT) and image (IMAGEELEMENT) elements. Figure 12 illustrates the elements of educational content generated by the transformation of the Mobile Model into an RN Model.

The RN Model generated in this step exactly represents the content that will be used in the interface of the mobile application. The next step of the proposed modeling approach is to transform the RN Model into a React-native source-code. It must be highlighted that the RN Model is generated without any intervention from the content production team.

F. Stage 6 – Generating mobile educational content

Stage 6 aims to generate the source-code of the mobile application with the content modeled by the content production team. In this step, transformation rules are applied to the React-native Model resulting in the React-native source-code. Listing 1 shows a snippet of source-code obtained by applying transformation rules to the models instantiated in the EDUCOM.ML approach. The React-native file (DATA.JS) generated implements an array with educational content for the domain of Elementary Math. User interface implementation components use the DATA.JS component to introduce learning reinforcement concepts and activities to the learner. Figure 13 shows the interfaces implemented to present the modeled educational content. Texts and images displayed in the mobile application are loaded from the React-native component generated by EDUCOM.ML. Screen 1 lists the modules available for study. Screen 2 lists the concepts for a given module. Screen 3 shows the educational content of a given concept. Finally, Screen 4 presents an exercise on a particular concept.

Listing 1. Snippet of generated data.js source-code.

```
const data = [
  { id: Math.random(),
    moduleContent: 'SETS AND THEIR CONCEPTS',
    concepts: [
      { id: Math.random(),
        concept: 'Sets',
        IConceptImpl: [
          {
            text:
              'Set has no definition, but its intuitive
                  notion is the grouping of any type and
                  number of objects.',
          },
          {text: 'Example: the set of letters of the
                alphabets.'},
          {image: require('../assets/alphabets.png')},
        ],
      },
      { id: Math.random(),
        concept: 'Representation of the sets',
        IConceptImpl: [
          {text:
              'The sets are represented by capital
                  letters of the alphabet. The elements
                  of the set are represented in braces
                  and broken down and separated by commas
                  .',
          },
          {text: 'Example: days of the week'},
          {image: require('../assets/exampleSet.png')},
        ],
      },
      {
```

The use of the EDUCOM.ML modeling approach in the El-

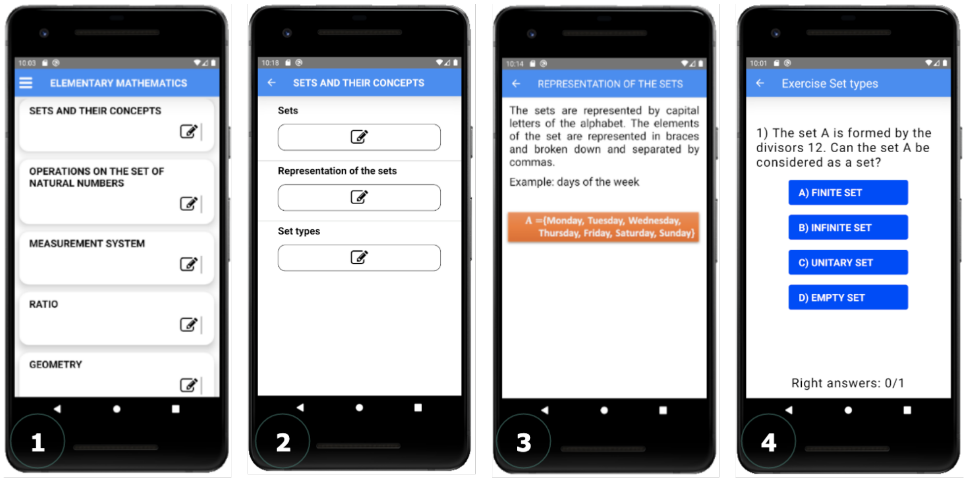

Fig. 13. Mobile educational content generated for Elementary Math.

ementary Math domain has shown promise in minimizing efforts to implement educational content for mobile devices. At this moment, more tests on the use of EDUCOM.ML are being performed. An experiment is being carried out with teachers and aims to confirm the positive points of EDUCOM.ML, as well as to identify points that require further adjustments. The experiment involves teachers, an application development team and apprentices. The idea is that teachers create content from their courses and these are presented to students through mobile applications generated with EDUCOM.ML.

IV. RELATED WORK

Below, we summarize some related works that involve the structuring of content with IMA-CID and the application of the Model-Driven Engineering approach in the teaching and learning process.

Considering the structuring of educational content, the works [9] and [22] were supported by the IMA-CID modeling approach. The work of [9] applies the IMA-CID approach to the Software Testing domain, modeling the educational content for the construction of a slide set. In this work, no tools to help the teacher were proposed. Therefore, all models are built manually. The work [22] presents a web tool to assist the teacher in the construction of the IMA-CID models and to generate educational content. However, the tool only generates educational content in slides and pdf formats.

Souza et al. [23] proposed a guided customization process for the creation of Learning Objects (LO). The process, called CLAssRoOM (guided by the model of customizable learning objects), was developed using the model-oriented software engineering strategy. In short, a DSL (Domain Specific Language) language was proposed to generate source code for Activity Routes. The development team uses the generated code to make the necessary adjustments to create the LO.

Minovic et al. [24] worked on the modeling of LOs for educational games based on the model-driven approach. Metamodels define basic knowledge domain concepts and LOs for educational games. Also, player-game interaction generation capabilities are created, as well as learner learning progress control capabilities. The approach uses UML language and XML technology in its implementation.

Malek et al. [25] proposed a model-oriented modeling approach that consists of emulating and simulating interactions and co-adaptability between the Space, Apprentice, and Activity dimensions. A domain-specific language, called CAAML, provides a metamodel that describes learning scenarios. The DSL describes co-adaptability actions in space and activities. The authors also introduce the CONTACT-Me tool, which transforms CAAML models into IMS-LD models, thus producing learning scenarios and mobile applications that interact with them.

It is important to note that the related works did not address issues related to the generation of content for mobile applications. In contrast, the EDUCOM.ML modeling approach provides the teacher with a guide for structuring educational content, as well as mechanisms that automatically generate modeled content for mobile applications.

V. CONCLUSIONS AND FUTURE WORK

Mobile apps have changed the way people do various tasks. In the educational context, in particular, mobile technology has contributed to facilitating access to information. However, the development of mobile applications for learning imposes the challenge of adequately structuring educational content to the restrictions of mobile devices. Another aspect to consider is that the diversity of platforms and mobile devices significantly increases the complexity of application development.

To deal with the complexity of producing mobile educational content, in this article, we proposed an educational content modeling approach that proposes structuring the content and implementing it on a mobile platform. The structuring of educational content was addressed using the IMA-CID approach, which organizes the knowledge domain through the Conceptual, Instructional and Didactic models. For generating content for mobile platforms, in turn, the MDE approach of software development was considered. Our modeling approach was applied to produce mobile educational content on the domain of Elementary Math.

The results suggest that the use of MDE and IMA-CID approaches can minimize the complexity of producing mobile educational content. Another contribution is that the EDUCOM.ML the approach proposes to abstract from the content production team the knowledge domain for implementing mobile applications

As future work to be carried out in the short and medium-term, we highlight: (i) implementation of an authoring tool to assist the teacher in the task of producing educational content; (ii) validation of the mobile educational content modeling approach with teachers; and (iii) validation of the educational content generated with the students.

ACKNOWLEDGMENTS

The authors would like to thank the Brazilian funding agencies – São Paulo Research Foundation (FAPESP) under grants 2018/26636-2, and CNPq.

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