

# TIO – a Software Toolset for Mobile Learning in MINT Disciplines

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**Abstract.** A web-based tool-set called TIO was created for mobile learning with emphasis on study courses in mathematics, informatics, natural sciences and technology (MINT). Mobile learning is a variant of E-learning which is based on mobile user devices with Internet access. It was tested for numerous software and hardware configurations users may have and proved to be technically working. TIO consists of a modified version of the open-source E-learning system ILIAS and a tool set. The experience with TIO was that mobile learning is useful for MINT subjects provided that numerous end user devices are supported and several text systems as well. We found that mobile learning is especially useful for professionals because they can learn in their free times in a flexible way. Finally, we found that an emotional component should be existent to make mobile learning more lasting.

**Keywords.** Mobile learning tool, MINT, single-source publication, social media

**Key terms.** KnowledgeEvolution, KnowledgeManagementMethodology, Didactics, KnowledgeManagementProcess, ICTInfrastructure

## 1 Introduction

Mobile learning or M-learning is a new form of E-Learning. Mobile learning means that pupils, students, or professionals are learning via mobile devices such as notebooks, E-books, handhelds, PDAs, smartphones, tablet PCs, iPads, iPods or gaming consoles. The term MINT stands for mathematics, informatics, natural sciences and

technology. The combination of both, i.e. the application of M-learning in MINT subjects is not yet found in literature but addressed in this paper. Because there is no software that supports M-learning for MINT subjects, it had to be developed. The scientific questions of this project are: how should a tool-set look like that optimally supports M-learning for MINT subjects, and what are the benefits and disadvantages of teaching MINT subjects by means of M-learning in general. The latter question will be answered in the future because TIO can be used for a subsequent pedagogical evaluation of the effect and the adoption of M-learning in MINT subjects. It is the technical basis and thus a prerequisite for assessing the benefits and disadvantages. The first research question will be answered in the following because tool-set called “Technical Informatics Online” (TIO) is presented which is a software platform for computer-aided distance learning that is web-based and that has an emphasis on MINT disciplines and on mobile learning. TIO is a front-end for authors of teaching material, and at the same time it is a user interface for learners. It provides for both groups spatial and temporal flexibility in creating content and in consuming it.

Basically, TIO is for the editing of teaching material, its distribution to various mobile end-user devices, for managing study courses, and for learning these course materials. TIO supports so-called single source publishing and serves as a social media for its users in order to make learning a deeper and thus longer-lasting experience. Single source publishing allows to create, to maintain, to retrieve and to deliver the very same content for many heterogeneous end user devices while it is stored only one time in one file. In order to achieve this, a TIO-internal XML-based data structure called “xml4tio” was defined that can be converted by TIO tools into various output formats which optimally support the respective end user device. Because these devices are very different in their capabilities, several presentation formats must be generated out of the same source file, depending on the user's preferences and device type.

TIO is based on a modified version of the open-source software ILIAS and of a TIO web application called TIOWA. It provides for numerous E-learning features, including chat rooms, multiple-choice tests, and for the management of the teaching content, the learning courses as a whole and their users.

The rest of the paper is organized as follows: chapter 2 describes the state-of-the-art in M-learning, single source publishing and social. In chapter 3, An overview description of TIO is given that explains its software components and used technologies. In chapter 4, the technical set-up of TIO is explained by means of block diagrams and xml data structures in more detail. Also the made extensions to ILIAS are described briefly here. In chapter 5, a report about field tests of the tool-set is given. The paper ends with a conclusion, an outlook to future work and a reference list.

## 2 State-of-the-Art

### 2.1 M-Learning

M-learning is a modification of E-learning for the purpose of distance education and blended learning based on mobile end-user devices. An overview on M-learning can be found in [4], [5], [6] and [7]. Blended learning means that customers must show-up in a classroom for a fraction of about 20% of their time and are not allowed to study completely from remote.

In theory, M-learning has several advantages: First, mobile devices are already widespread. Thus, no or little investment is needed for the user compared to a desktop PC. This is important for many young clients and for customers from developing countries. Second, mobile devices reflect the life style of the generation of 'digital natives' [8]. Thus the potential acceptance and use of M-learning may be higher than for classical learning styles. Third, mobile devices help professionals to consume content on top of their working hours for the purpose of life-long learning because of the access flexibility they get. They can use free time slots while travelling between work and home for learning, or weekends and holidays in a very flexible way. Fourth, Internet access allows quicker distribution of content and for significant lower media costs compared to all other distribution ways that are based on paper. Fifth, if the sensors of the end-user device such as the GPS position, the tilt- and acceleration-meters are engaged then learning can adapt dynamically to the current location and situation of the learner.

In practice, M-learning faces several problems: First, small screen and key sizes hamper its applicability in all cases except of notebooks. As a consequence, a sophisticated layout and formatting of teaching material becomes less important because such formats may not be displayed. Additionally, limited user input must be tolerated because of keyboard restrictions. Second, a rel. slow Internet access and a limited battery life of the user device must be taken into account. Third, heterogeneous hardware and operating systems with no or small hard disks are common. Mobile devices have more options with respect to CPUs, RAM size, displays and operating systems compared to desktop PCs. This makes it very difficult to present and use teaching content equally on all devices.

Numerous E-learning platforms are already in usage. An overview can be found in [9], for example. However, most of them are intended for use on desktop PCs and not for mobile devices. Furthermore, their features for presenting technical content with formulas for visualization of simulation results and for access to remote laboratories is mostly limited. Finally, Internet access via mobile devices is not explicitly supported. TIO addresses these problems and supports text types that occur frequently in MINT subjects.

### 2.2 Single Source Publishing

Single source publishing means that one internal storage format is used out of which diverse customer outputs can be created, such as html with various cascaded style

sheets and pdf. By single source publishing, a simpler updating process of content is possible that allows to reuse the same teaching material for many devices and in various contexts.

Traditionally, single source publishing is implemented by a 1:1 correlation between chapter and character formats in the source texts and, for example, the generated html code for the user. Additionally, source texts may be augmented with tags and comments that give meta information about the text. From this semantic data, converters can create automatically various output formats, provided that sufficient meta data exists.

TIO uses a combination of both. First, it converts teaching materials that is formatted in a traditional way by chapters, sub chapters and emphasizes such as underline, italic and bold into the common intermediate storage structure xml4tio. Subsequently, it converts xml4tio into the needed user formats. Finally, it uses ILIAS and a self-developed web application called TIOWA to disseminate the requested content in the desired format via mobile Internet.

### 2.3 Social Media/Web 2.0

Social Media is a generalization of the term web 2.0. It denotes that users are not only consumers of content via download but also producers via upload. It denotes furthermore that users are interacting with each other in the web. Examples of popular social network services are Facebook, twitter, YouTube and Wikipedia. TIO strives to be a social media for distant learning in the MINT disciplines in order to make learning a deeper experience because the distinction between learning and leisure are more flexible then, and because learning gets hereby an emotional component that exists also in a classroom but not in a computer system.

## 3 Description of TIO

TIO combines E-learning via the Internet with mobile communication. It allows thus for learning from anywhere and at any time. TIO is focused but not limited to mobile user devices. It can be used also with desktop computers. Content creation can be accomplished by authors via the commercial text system “Adobe Frame Maker” [1] if technical manuscripts have to be written. A TIO tool converts these Frame Maker texts in xml4tio. If the editing of mathematical texts is required then a self-developed tool called LearnDSL (Learn Domain Specific Language) can be used for the convenient writing of formulas in a style similar to LaTeX but more user-friendly. LearnDSL converts mathematical texts into xml4tio. Finally, Open Office Writer [2] is supported by TIO for all other use-cases. A macro-based converter transforms Open Office texts again in xml4tio.

TIO is based on the wide-spread ILIAS E-learning platform [3] for which several adaptations and extensions were developed. ILIAS implies PHP [10] as programming language and SCORM [11] as a content format. TIOWA in turn allows to upload teaching material and to convert it from xml4tio into SCORM and html. TIOWA uses

Ajax [12] which provides for the students to interact with TIO as if it were a local application running on his hand-held device. Ajax employs several technologies such as Javascript [13], XML [14], HTML5 [15] and CSS3 [16]. An important part of TIOWA are several converters which are based on XSLT [17]. In principle, TIOWA and ILIAS could even be used independently from each other for the creation, storing and dissemination of teaching material. For example, TIOWA could also be connected to other learn management systems such as Moodle [24].

**Aims and Features.** Our extensions to ILIAS provide for the following features:

First, authors can create teaching material in that text system that is preferable for them and their content. After content creation, support for an automated conversion into the intermediate xml4tio file format is provided by TIO. Xml4tio is an xml schema definition that is used to store content on a TIO server [25].

Second, formatting instructions stored in xml4tio is reduced to a minimum because small screens can not display sophisticated presentations that were created in Power Point, for example, in a satisfactory manner.

Third, the use of the common storage format has the potential for easier access and for better maintaining a large amount of teaching material, as it is needed for a Bachelor or Master courses, for example.

Fourth, TIO supports multiple end-user devices and operating systems by engaging browsers as the only needed software at the end-user device.

Fifth, TIO supports the learning process not only for full time students, but also for part time customers, together with training on the job for life-long learning of professionals. Therefore, it can be used by universities and enterprises.

Sixth, the teaching material is structured by TIO into ‘learn objects‘ which can be compared to book chapters but may contain audio, video, text, graphics, formulas, visualization of simulation and access to remote laboratories, as well as exercises and multiple choice tests for each topic.

Seventh, TIO can administer a large number of students as customers and a large number of courses as well because it uses ILIAS which has proven to be a reliable system.

Eighth, most of the TIO portals are multilingual, currently in German and English, which gives also a transnational aspect.

## 4 TIO Set-up

TIO’s set-up is based on three (virtual) servers, one for authors, one for students, and one for backup (**Error! Reference source not found.**).

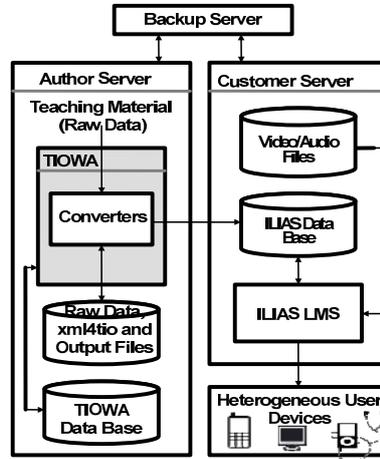


Fig. 1. General hardware setup of TIO

All servers use UBUNTU Linux. On the author’s server, our TIOWA web application is the main software component, together with several converters between storage formats. TIOWA is the frame in which authors create, maintain and convert learn objects. Additionally, a relational data base is provided that cares for authentication and authorization of authors and system administrators, and that maintains different versions of teaching objects. Teaching objects are stored as files in xml4tio. In **Error! Reference source not found.**, the software set-up of the author server is shown. On the customers server, ILIAS is the software which cares for student administration and examination, inter-student communication and content dissemination. In **Error! Reference source not found.**, we see the block diagram of the customer server.

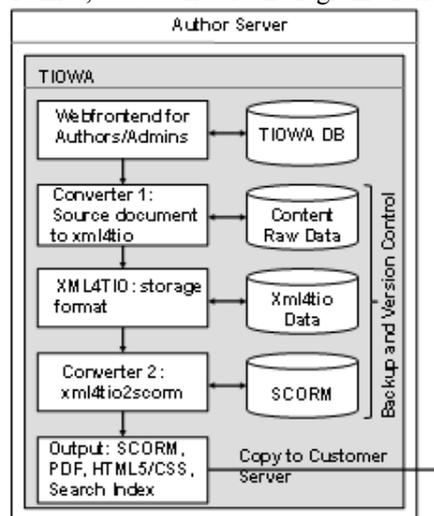


Fig. 2. Set-up of the customer server

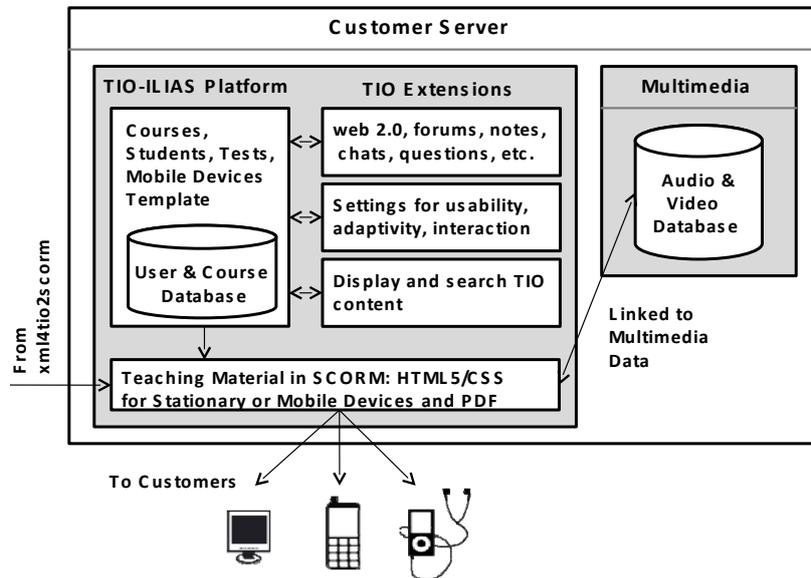


Fig. 3. Set-up of the customer server

The information which student is enrolled in which course is stored in a MySQL data base. Audio and video recordings of teaching objects and whole lectures are stored as standard files with references to xml4tio and SCORM data structures. SCORM and xml4tio are both based on xml. SCORM is a collection of specifications and programming interfaces. It stores user preferences, records learning goals, logs learn progress and describes which resources a learn object has. A resource is a set of texts, pictures, audios, videos and URLs that is organized as a tree. Each tree resembles the chapters and subchapters of a traditional lecture of 45-90 minutes and can be augmented by meta data that describe the learn object. This meta data allows to search for content. Furthermore, possible sequences can be specified in which students can consume learn objects. Finally, the path through a sequence of teaching objects can be declared as a function of the answers the user gives in multiple-choice tests. The backup server provides for a safe operation by copying automatically data from the author and customer servers. In the following, all described components are explained in more detail.

#### 4.1 The TIOWA Web Application

For content creation, management and format conversion, TIOWA was programmed in PHP 5.4 and Javascript as a web application for the authors. It uses MySQL 5.6 [19] as data base for authors and administration, jQuery and Ajax for easier communication with the user via dynamic web pages, and an Apache web server for page generation in HTML5 and CSS. TIOWA allows to upload content from an author's computer to the TIO server, to convert it into xml4tio, to update and backup it, to

move it to the customer server and, in the final step, to reformat the content for display, depending on the respective output device. For this purpose, TIOWA accesses xml4tio data, author/admin data and SCORM data. From the viewpoint of xml4tio, TIOWA is an application for single source publishing.

## 4.2 XML4TIO for Single Source Publishing

Xml4tio is a xml schema definition [24] and the core of TIO. For the conversion of teaching material into xml4tio, two files and one extra folder must be created: First, a 'container.xml' file is established that stores a description of the teaching material as meta data. In case of B/M modules, the meta data are based on the Bologna module description [20]. Otherwise, the author must provide an arbitrary text as abstract. Additionally, container.xml binds together all teaching objects into lectures and all lectures about the same topic into one Bologna module. Second, a 'content.xml' file must be created that stores the content of the Bologna module.

The first layer of the syntax tree of xml4tio comprises the xml tags module, title, author, section and presentation unit. These tags can subsequently be specialized by additional tags and/or attributes in more layers. Especially remarkable is for example the 'media' tag that can have as attribute 'picture', 'animation', 'applet', 'scene3d', 'sound', 'video' and 'experiment'. This offer shows the capability of TIO in media presentations for MINT subjects.

## 4.3 Converters for Storing and Disseminating Teaching Material

There are converters from OO Writer, Adobe Frame Maker and LearnDSL into xml4tio. A reverse conversion for a so-called round trip is normally not possible because nearly all character and chapter formatting instructions are deleted during the conversion process. However, if the author limits himself in his text system on the few formatting data that xml4tio has then he can also perform a roundtrip.

Additionally, there exists a converter for transforming xml4tio into SCORM, html5 and pdf. These formats contain less formatting information than the authors' original documents.

The main difficulty the converters are facing with stems from the fact that humans normally do not treat their lecturing materials as a formal text. This means, that beside the used character and chapter formats, several hand-made changes exist in real-world lectures. Such documents can not be converted. To detect these flaws, a xml4tio validator is provided that checks whether the lecture is structured according to the xml4tio schema definition.

**Conversion of Teaching Material into XML4TIO.** For the LearnDSL converter, own software in Java was written. For the OO Writer, a PHP software was created that transform valid OO texts into xml4tio. Prerequisite for that is that a prescribed LearnDSL and OO character and chapter format catalogue is used without any manual additions or modifications. Furthermore, specific rules have to be obeyed with respect to the structure of the teaching material.

For the Frame Maker (FM) converter, basically the same restrictions hold as for the

Writer converter. However, no software has to be programmed as in the LearnDSL or OO case. FM must only be set from unstructured to structured mode. Then it can directly deliver the desired xml schema. FM uses as input for this schema a so-called Element Definition Document (EDD) file [21]. This means that the EDD let Frame Maker know which Elements are allowed and which composition of elements are legal. The EDD additionally prescribes how to format them elements. By means of a proper EDD, a structured text appears to the user of FM nearly as an unstructured text.

The EDD in turn can be created out of a so-called document type definition (DTD) [22] in a two-step manner: first the DTD file must be manually created on basis of the xml4tio schema definition. Then, the DTD can be imported into FM, and an EDD is created automatically by FM.

However, the resulting EDD file must be post processed manually to define the appearance of chapter and character formats of the elements. Such format definitions are made by templates. The manual post processing of the EDD file is also needed to provide for so-called read/write rules which help to convert FM documents into correct xml4tio by transforming FM elements into TIO tags and attributes.

After that, the EDD file must undergo an automatic transformation by XSLT to create proper URLs, names and paths for pictures and other multimedia content according to the xml4tio schema definition. Therefore, an XSLT style sheet was created, and additional EDD rules were defined that call the style sheet.

Finally, FM bundles the DTD together with the EDD that contains format templates and read/write rules into a so called structured application definition. As soon as such a definition exists, the user can just save any structured FM document into xml4tio by simply clicking the "save as XML" button, and the conversion is done.

**Conversion of XML4TIO to SCORM Output.** This converter is called 'xml4tio2scorm'. It is responsible for content presentation because the created SCORM file contains html for a browser, together with CSS formats and links to multimedia data such as pictures and graphics. However, the full potential SCORM has is not needed here. Only a TIO-specific subset is used that is subsequently stored in ZIP format in order to save (virtual) disk space. xml4tio2scorm creates a table of content for the selected study course, its html/CSS and pdf representation and a index for searching. This index is copied automatically as a file into the user space of ILIAS so that students can access it.

Depending on the fact whether the target browser is located in a mobile or stationary device and with respect to the device's screen size, either the table of content is presented simultaneously together with a video recording of the lecture and the text of the teaching material. Or in case of small screens, only one of these three streams is displayed, according to the user wishes. Additionally, it is taken into account that mobile devices may have only limited bandwidth for Internet access. Because of that, offline browsing of previously downloaded teaching material is supported, together with pdf viewing.

#### 4.4 Extensions to ILIAS

The following extensions to ILIAS were made: 1.) students can highlight and comment every line of the teaching material. These comments can be attributed to be either private, visible to the public or open for discussion in a special forum. This makes students to prosumers. 2.) students can ask the author of the teaching material via the Internet by placing their question directly into the script at the proper line which eases the communication between student and teacher/author significantly. 3.) Searching in the teaching material is possible by means of an index. 4.) Fonts, font sizes and colors can be configured individually to provide for better reception. 5.) A table of content can be displayed that helps to get a better overview of the learning material 6.) The SCORM output is adapted to mobile devices with individual screen sizes.

The extensions make students into “prosumers” that contribute to their learn success by own comments and hints in the teaching material that are visible to all others. The improved questioning and chat room feature allows a „learning adventure“ and makes TIO into an Internet-based social media.

## 5 Software Tests and Practical Experiences

For testing the software we received from Clausthal University of Technology three virtual servers which were also administrated by them, including backup and restart in case of system crash. On these servers, three web portals were created: 1.) A portal under <http://webadmin.ti-online.org> for accessing the TIOWA web applications. This portal is for authors and admins. 2.) A portal for general information about the TIO project and for project protocols under <http://ti-online.org>. 3.) A portal for TIO students and other customers to download learning content under <http://ilias.ti-online.org/>. This portal is also for teachers to manage TIO students and courses. It is based on a modified version of ILIAS as described. All portals are maintained by Typo3 [23] as content management system, the last portal is in German and in English language.

### 5.1 End-User Devices and Configurations

TIO was tested with the following end-user devices and configurations: 1.) desktop PCs and notebooks with MS Windows XP/7/8 as operating systems, and with Firefox (>V2), Internet Explorer (>V6), Opera (>V8), Chrome (>V16) and Safari (>V5) as browsers. 2.) desktop PCs and notebooks with Ubuntu, Debian and Suse Linux together with Opera and Firefox. 3.) Apple computers with Mac OS X (>V10.6), Safari and Firefox. 4.) Apple iPad with iOS (>V5) and diverse Android Tablets (>V4.0). 4.) Apple iPhone (V4) and diverse Android Smartphones (>V2.0), and 5.) Blackberry and Apple iPod. This was considered a comprehensive selection.

## 5.2 Practical Experiences

In the years 2010-2013, teaching materials were created for TIO in Frame Maker, LearnDSL and Open Office Writer. This happened for the education in Technical Informatics, Computer Organization and Computer Networks at the Universities of Hamburg and Clausthal. Additionally, some video recordings of the lectures, simulations and animations are added to the teaching materials. After every semester, feedback from the students was collected in written form and evaluated. According to that, parts of the software and the didactic presentation of the teaching material were improved.

## 6 Conclusion and Future Work

A web-based software platform called TIO for mobile learning with emphasis on study courses in mathematics, informatics, natural sciences and technology was created. It was tested for numerous software and hardware configurations users may have and proved to be technically working. TIO consists of a modified version of the open-source E-learning system ILIAS and the TIO tool set. The ILIAS extensions were made to improve its usability for mobile devices and MINT subjects. While ILIAS is for students, TIOWA is for the authors for content creation, uploading and converting. It stores the teaching material in a xml schema definition out of which several output streams can be generated that depend on the end-user device and its screen size (single-source-publishing). Teaching material can contain texts with formulas, audios and videos, animations and visualization of simulation results. Finally, the xml4tio data structure also allows remote access to experimental labs located in a university for practical training. We believe that some of our implemented features will be useful for the generation of 'digital natives' that must prosecute life-long learning.

The general experience is that mobile learning is useful for MINT subjects provided that diverse end user devices are supported because they differ a lot in their capabilities. Furthermore, it proved to be important to support various text systems such as Frame Maker, Open Office Writer and a variant of LaTeX because otherwise not enough authors can be found to develop teaching material. Furthermore, we found that mobile learning is especially useful for professionals because they can learn now in a flexible way in empty times slots such on train trips between work and home. Finally, an emotional component should be existent in mobile learning that makes it a deeper and more lasting. Thus chat rooms and other features with which clients can communicate with each other in the style of a social media were integrated. As a recommendation, we suggest to combine mobile learning with classroom presence of approx. 10% of the study time to make the emotional component optimal.

In the future, TIO must be approbated, tested and checked in practice over a longer period of time. Therefore, it will be used for online teaching a Master course in Technical Informatics and for training and certifying of professionals for the purpose of life-long learning. These real-world applications will allow to conduct a pedagogical evaluation of the benefits and disadvantages of M-learning for MINT subjects. From

that experience, recommendations can be given to teachers and organizations about M-learning in general. The TIO tool-set is the technical prerequisite for that.

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