iWeaver: Towards 'Learning Style'-based e-Learning in Computer Science Education

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Abstract

Although learning style theory is widely accepted amongst educational theorists in the context of traditional classroom environments, there is still little research on the adaptation to individual styles in an e-learning environment. In particular the possibility of fluctuations in a learning style with changing tasks or content has not yet been addressed. The described PhD project named *iWeaver* was designed to provide a flexible, yet manageable environment for the learner by implementing adaptive hypermedia techniques. *iWeaver* draws upon the widely recognised Dunn & Dunn learning styles model and derived learning strategies. It uses database-driven JavaServer Pages, which generate 'media experiences' (e.g. interactive Flash animations or streaming audio) and other specifically developed 'learning tools' to teach the Java programming language. This paper describes the system architecture of *iWeaver* and gives technical details on the implementation of specific media experiences and learning tools. An approach to predict and accommodate fluctuations in a learning style profile that will be integrated in a future version of the environment is discussed.

Keywords: e-Learning, Adaptive Learning, Adaptive Hypermedia, Multimedia Learning, Individual Learning Styles, Learner Modelling, User Modelling, Learner-Centred Design

1 Introduction

This paper describes the technical and educational aspects of a PhD project in progress. The aim of the project is to accommodate individual learning styles in an adaptive e-learning environment that teaches the Java programming language.

The trend to focus on e-learning to supplement training at many universities and companies opens up new opportunities to personalise the learning experience. The teaching method in a traditional classroom environment is usually one (teacher) to many (students). In such a setup it is usually challenging to provide each student with an individual learning experience. This problem can be addressed by e-learning environments, which are capable of supporting a one (server) to one (learner) communication. E-learning with dynamically adapted digital content is therefore an effective medium for personalised learning.

The increasing availability of fast, multimedia capable computers and the progressive penetration of broadband Internet connectivity in Australia (Pearce 2002) open up new opportunities to deliver rich media content via the Internet.

Accommodating learning styles has proven to be effective in many classroom-based research scenarios (Felder and Silverman 1988; McCarthy 1990), yet few researchers have explored the possibilities of using multimedia representations in conjunction with a learning style-based approach in e-learning.

The *iWeaver* project aims to bridge this gap by offering a tailored and dynamically adapting environment to the learner. The question underlying the project asks if matching learner preferences assists performance. Additionally, does the opportunity to learn instructional content that is continually adapted, assist performance any further than the use of a static but nevertheless adapted environment? As well as differences in performance, the variables of understanding and motivation are also going to be explored.

1.1 Background Research

iWeaver is a multidisciplinary research project, which draws upon prior work in 'multimedia learning theory', 'cognitive load theory', 'adaptive hypermedia environments', and 'learning styles research'.

Mayer (2001) proposed a 'cognitive theory of multimedia learning' (p. 41) following experimental results, which showed that particular combinations of media promoted learning whereas others had a detrimental effect. Mayer also found that media overload could inhibit learning: in his 'redundancy principle' for instance, he states that 'students learn better from animation and narration than from animation, narration, and text' (p. 147).

Chandler and Sweller (1996) conducted extensive research on the cognitive load for users in computer environments. When learners (in particular novice learners) had too many options to choose from, it increased their cognitive load and decreased motivation. A major concern in the design of the *iWeaver* environment was to keep a balance between the cognitive load for the learner, the accessible navigation options and the learning content.

Brusilovsky (2001) proposed a taxonomy for adaptive hypermedia environments in which he divided existing research into ‘adaptive presentation’ and ‘adaptive navigation’ approaches. *iWeaver* implements several established adaptation techniques, including link sorting, link hiding and conditional page content.

This project builds on the theory that each learner has an individual learning style profile. A learning style is described by James and Blank as

> ‘the complex manner in which, and the conditions under which, learners most efficiently and most effectively perceive, process, store and recall what they are attempting to learn’ (1993:47).

iWeaver uses the Dunn & Dunn learning styles model (Dunn, Dunn and Freeley 1984). This model is based on 30 years of research (Dunn, Thies and Honigsfeld 2001) and is used internationally. A number of learning strategies have been derived from this model and were successfully implemented in traditional classroom scenarios. In the *iWeaver* project, a selection of these strategies was transferred into an e-learning environment by using multimedia representations and specifically developed learning tools.

1.2 Related Work

Several educational hypermedia systems that adapt to learning styles have been developed over the past few years (Carro, Pulido and Rodríguez 1999; Martinez and Bunderson 2000; Corso, Ovcin, Morrone et al. 2001), but it still remains unclear what aspects of a learning style profile are worth modelling and which is the most effective approach for a particular style.

The adaptive response of existing environments is restricted to pictures and text instead of multimedia representations, with some exceptions like the computer systems course CS383, developed by Carver, Richard and Edward (1996). Also, the adaptive response is usually based solely on an initial assessment of the learning style profile, which is then expected to remain stable.

However, research indicates that learning styles can vary with a different task or different learning content (Snow 1989; Kozma 1991). Hence it seems counter-productive to lock the learner into a fixed learning style profile after the initial assessment. To allow for these possible fluctuations in a learner’s profile, a predictive statistical model will be used in a future version of *iWeaver*. This model is discussed in the ‘Future Work’ section of this paper. It will attempt to anticipate the most likely choices and adapt the interface of the learning environment accordingly.

2 The *iWeaver* Approach

When learners enter the *iWeaver* environment for the first time, they complete the standardised ‘Building Excellence Inventory ®’ (Rundle and Dunn 2000). The inventory assesses their initial learning style and creates a profile using 118 multiple choice questions according to the Dunn & Dunn learning styles model. The learners receive an analysis of their learning style profile with personalised recommendations based on the ‘Guide to Individual Excellence ™’ (Rundle and Dunn 2000). Subsequently they enter the actual learning environment and are given a choice of different variants of the learning content. These variants are referred to as ‘media experiences’ in this paper.

The choices offered to the learner represent a subset of two out of the total number of four available media experiences. This reduces the cognitive load and prevents the urge of some learners to cover all material available as described by Carver, Richard and Edward (1996).

The screenshot in figure 1 shows the user interface design of an exemplary learning unit about the switch-statement.

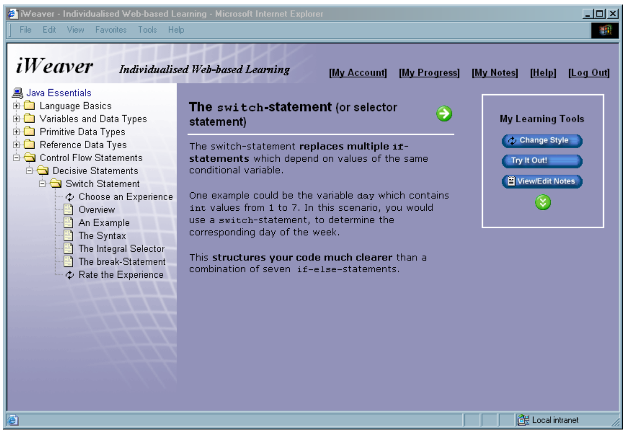

Figure 1: Layout of the user interface

A menu with user-related options is located on the top of the screen, whereas the content navigation is situated on the left. The main space in the centre is occupied by the media experience, supplemented by a selection of learning tools on the right.

In accordance with the policy that determines available choices of media experiences, only the two most likely chosen learning tools are initially visible. All other tools are hidden, but still accessible via an expand-button.

The learning content is divided into modules which are again divided into learning units. After going through one learning unit, the learner can choose to repeat the unit and try out a different media experience. Alternatively, the learner can choose to proceed to the next unit. However, before they can proceed, a rating of the encountered media experiences has to be given with regards to their perceived subjective effectiveness. The learner is also asked to rate their impression of their current learning progress and overall satisfaction with the learning environment. Multiple choice tests are conducted after each module for comparative studies with a static environment.

2.1 System Architecture

The following diagram illustrates the schematic system architecture of the *iWeaver* learning environment:

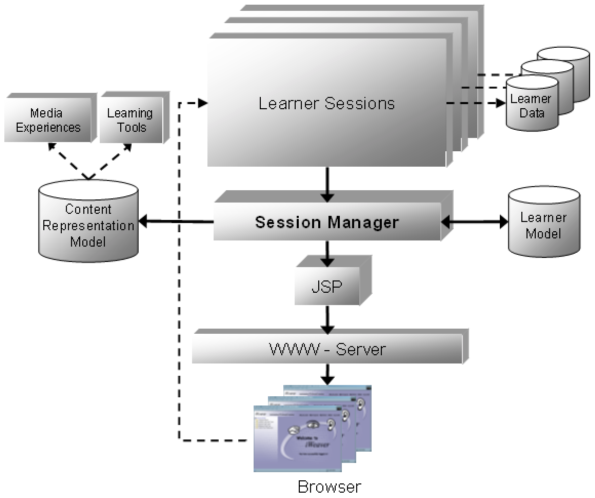

Figure 2: System architecture of *iWeaver*

The learner logs on via a standard web browser. A learner session is initiated that stores all relevant data (e.g. learning style profile, navigational choices, usage pattern of learning tools, etc).

The session manager is a server-process that constantly gathers updated data from the learner session. The learner model is refined and compared with the content representation model. Subsequently, the best matching combination of media experiences and learning tools is calculated and recommended to the learner. This combination is then rendered as a JavaServer Pages (JSP)-generated HTML page and sent to the learner's web browser.

The learner model used by *iWeaver* is solely based on the user's learning style profile. Other factors such as prior knowledge or personal learning objectives as outlined in the learner model standardisation draft by the Institute of Electrical and Electronics Engineers (IEEE 2000) are not taken into consideration for the reason of simplicity and specific focus of this study. This simplification is made possible by restrictions in the selection process of participants: only participants with no prior knowledge in object-oriented programming are going to be recruited.

2.2 Media Experiences – The Approach

iWeaver offers four different media experiences that are tailored towards the perceptual domain of the Dunn & Dunn learning styles model. This domain relates to how we like to perceive information with our senses.

The simplest media experience is 'visual text', which caters for learners who remember material best by reading it. It comprises rich text formatting, for instance annotated source code sections and highlighted key concepts.

Figure 3 shows an example of a 'visual pictures' experience that is designed to accommodate learners who prefer information represented in a pictorial fashion. This is achieved by supplementing text with illustrations, diagrams, flowcharts or non-interactive animations.

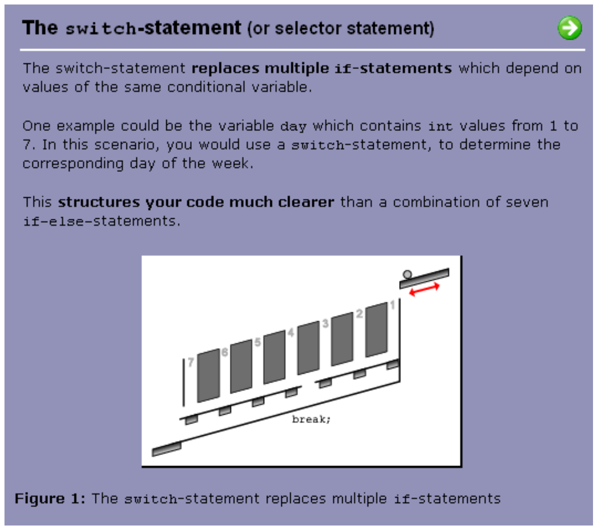

Figure 3: Visual pictures – media experience

Visual learners often create 'mental images' according to what they hear or see. The example in figure 3 supports this process by explaining the Java switch-statement with an animated metaphor: the ball falls into a different chute, depending on the position of the platform it travels on. The position of holes (i.e. break-statements) in the intermediate level determines which shaded areas (i.e. program code) the ball touches on its way down.

'Tactile kinaesthetic' learners experience an interactive version of this content that explains the switch-statement. This strategy accounts for their preference to physically interact (in a computer-based environment with the mouse or the keyboard) with what they learn. These interactive animations are referred to as 'interactivelets'. In the example of the switch-statement, tactile learners can *manually* set break-statements (i.e. move or open holes in the intermediate level) and *manually* adjust the position of the platform. Other ways implemented to approach tactile kinaesthetic learners are drag & drop puzzles, where source code fragments have to be arranged in the right order or 'fill in the gaps' exercises.

Auditory learners have a preference to listen to instructional content. The 'auditory' experience therefore presents the content in an audible style, similar to playing back a recorded PowerPoint presentation.

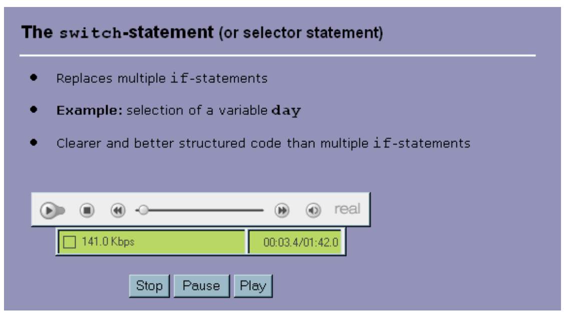

Figure 4: Auditory – media experience

The content is read to the learner whilst the key concepts are shown in bullet-point style on automatically changing HTML pages. The learner can pause the audio output, scroll back and forth or click on the table of content headings in the navigation tree to navigate within the audio stream.

2.3 Media Experiences – The Technology

From a technical point of view, the HTML pages with the adapted learning content are dynamically generated using a MySQL database. Animations and interactivelets are developed using Macromedia Flash. The Flash format was chosen over Shockwave and Scalable Vector Graphics (SVG) because of its small file sizes and its built-in ‘Advanced ActionScripting’ capability. Action-Scripting allows the development of more sophisticated animations and interactivelets.

The auditory components are recorded in the compressed MP3-format. In the current prototype, progressive downloading (via TCP-protocol) is used as streaming technology to deliver the auditory content. The advantage, progressive downloading offers over real-time streaming (via UDP-protocol) is that it causes no re-buffering delay if the learner decides to scroll or skip backwards in the audio stream. This re-buffering delay can take from 3 to 7 seconds, depending on the connection speed.

The disadvantage of progressive downloading is the problem of ‘bandwidth-hogging’. This means that learners with a broadband connection use a lot of the available server bandwidth to quickly download the complete audio file, which might disrupt the audio stream delivery to modem users. A pilot study will assess the impact of re-buffering as a confounding factor for the field study. This will be compared with the detrimental effects of bandwidth-hogging on the media experience of modem users.

The linking of HTML content pages with corresponding trigger points in the audio stream is done with the Synchronised Multimedia Integration Language (SMIL) (W3C 2001). A comparison of the three most popular SMIL players, Microsoft Media Player (in conjunction with the Microsoft Internet Explorer), Apple Quicktime Player and the RealOne Player from RealNetworks revealed that the RealOne Player was most suited for this project.

The most important criteria for the player selection were firstly SMIL 2.0 support, as it offers more programming options and flexibility than SMIL 1.0. Secondly, Macintosh support was important, because this hardware platform is relatively common for the targeted audience (Internet/web developers). A progress bar to visualise the download progress of the audio file was also desirable. Unfortunately, the RealOne Player was not embeddable with a progress bar, but it was still the best option out of the three players in question.

The following table shows the comparison of the different players:

Selection Criteria	**Real One**	**MS Media**	**Quick time**
Embedded player has Macintosh support	yes (OS X)	**no**	yes
SMIL version support	2.0	2.0 (subset)	**1.0**
Embeddable with progress bar	no	yes	yes

Table 1: Comparison of SMIL players

SMIL 2.0 is a recommended W3C standard, which is specifically suited for the timely synchronisation of different media types. It is an XML-based language that is stored in simple text files. As opposed to using a static video file, the modular approach of SMIL is to loosely combine separate media elements in a flexible fashion. This facilitates content maintenance and guarantees the future scalability of the learning environment.

2.4 Learning Tools – The Approach

iWeaver offers a number of learning tools (figure 5) as an addition to the described media experiences.

These tools are tailored towards the different learning styles in the psychological domain of the Dunn & Dunn learning styles model. This domain covers preferences relating to how we process information and solve problems.

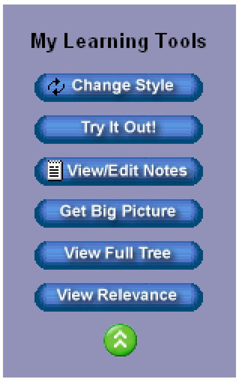

Figure 5: Learning tools menu

The toolbar is located on the right side of the screen, with each tool represented as an individual button. All learning tools are launched in a pop-up window so they can be used concurrently (i.e. without losing the content shown in the main window underneath).

A context-aware note-taking tool is offered to learners with reflexive preference. Reflexive learners prefer to sit back, think about and reflect upon new material. This tool is also potentially useful for visual text learners, who tend to take notes as well. It allows note-taking on the level of each learning unit. These notes can be accessed either globally from the top navigation bar or locally in the learning unit where they were taken. The existence of pre-taken notes is indicated to the learner by a slight visual difference in the tool button.

Impulsive learners, who like to jump into new material immediately, are offered a 'Try It Out' button. With this button, they can access an online Java compiler that allows the immediate trial of a newly learnt programming concept.

Global learners prefer to get the big picture first, before going into the details. To cater for this preference, an advance organiser in the form of a mind-map diagram (figure 6) is made available. The mind-map highlights where the learner currently resides in the content structure of the module, how they got there and what they are going to encounter next. Global learners can also view the full content tree to get the big picture of the module.

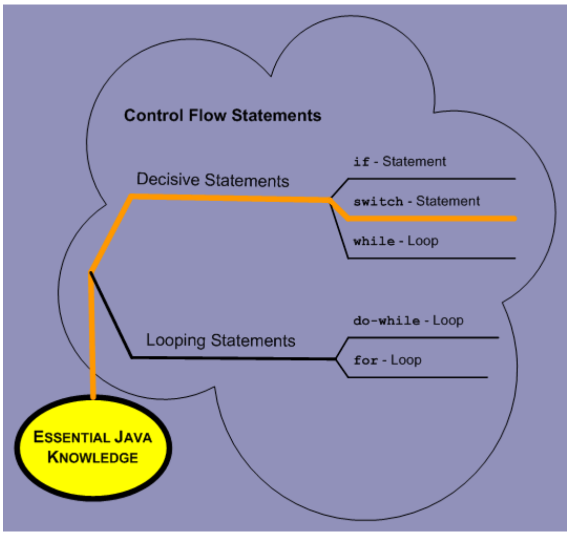

Figure 6: Mind map for global learners

Internal kinaesthetic learners like to make connections and want to know how the learnt content personally affects them. A 'View Relevance' button is offered to these learners. This button displays additional examples for the introduced concept, thus increasing the availability of connective stimuli for the learner.

2.5 Learning Tools – The Technology

An interesting learning tool to describe in more detail is the 'Try It Out' button that launches the online compiler. This tool was originally developed for impulsive learners, but a preliminary survey suggests that it may also be popular among other learner types.

A click on the 'Try It Out' button opens a new window with a text box that contains a source code example. It contains an example for the currently presented programming concept that can be altered freely. Another variation of the tool is to provide the learner with incomplete source code with the task to complete it.

Submitting the content of the text box hands the source code over to a Java bean on the web server. This bean writes the code into a java-file on the server's hard disk. The file is then compiled and an applet is created which displays the output of the class. If the compilation process returned no error, the bean returns a URL to an applet, which is then embedded into a JSP page. If an error occurred during the compilation process, the erroneous source code is displayed along with the error message. The affected line numbers where the error occurred are highlighted. The learner has then the opportunity to correct the error and to compile again.

A specific problem with this scenario was the behaviour of the applet cache of the browser, respectively the classloader of the Java Plug-in. Neither of these caching mechanisms was built to handle dynamically changing applets. Hence once an applet is loaded, it is permanently cached. The learner would have to manually empty the cache (or restart the browser) in order to force a reload of the applet. Naturally, this extra step is potentially overlooked or forgotten by learners. This leads to frustration and confusion, because code changes seem to have no effect.

An automated solution was found: every time an applet is compiled, it is written into a newly created and uniquely named directory. This forces the Java runtime mechanism to reload the updated applet, because its URL has changed (but not the class name). The deletion of outdated applet classes is coupled with this process to avoid the accumulation of unneeded data on the server. The described approach appeared to be the simplest and most effective solution to the caching problem.

The online compiler has several benefits for the learner over the use of an integrated development environment:

- It does not need to be installed, nor launched on the client side.
- It can be used on any computers with just a web browser installed and restricted access (e.g. at university or in a public library).
- It is context-aware: it launches with a source code example that demonstrates the currently presented programming concept.

2.6 Adaptive Behaviour

The current version of *iWeaver* implements a combination of adaptive navigation and adaptive content presentation techniques as described by Brusilovsky (1996).

Adaptive link ordering, which has been shown to improve selection time and to reduce cognitive overhead (Bollen 1999), is used to guide the learners to their best-suited media experience.

Adaptive link hiding is implemented by hiding links to experiences that are unlikely to be chosen. These experiences are still accessible via an expand-button, similar to the 'smart menus', in Microsoft Office and Windows.

Another application of the link hiding/expand-button method is the learning tools menu. The learner is given a short version of the learning tools menu first, tailored for their initial learning style profile. The individual usage pattern of the learning tools is analysed to determine further additions or omittances of tool buttons:

When the learner clicks the expand-button, more items appear within the menu, but the overall order stays the same. Studies conducted by Debevc, Svecko, Donlagic and Meyer (1994) on their version of an adaptive toolbar showed that a changing order of menu items can be confusing, especially for novice users.

When the learner selects a previously unused item, that item is from then on included in the short version of the menu. On the contrary, if the learner does not use an item for a certain time, it eventually disappears from the short version of the menu.

The content navigation (figure 7) is also designed in an adaptive manner. The navigation is based on the familiar Windows Explorer tree metaphor with expandable / collapsible submenus and content leaves.

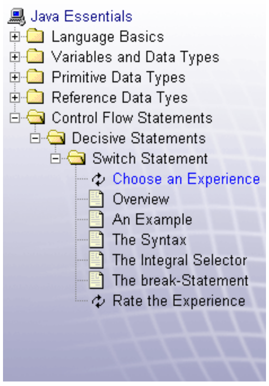

Figure 7: Cumulative tree navigation

This explorer navigation is implemented using a dynamically generated, cumulative JavaScript tree (Wang 2002). The more learning units and modules the learner covers, the more complex the tree becomes. This concept is called 'progressive disclosure' and was recommended by Hix and Hartson (1993) for information-rich user interfaces. The progressive increase in complexity of menu items is beneficial because the learner is not likely to experience cognitive overload effects, as all accessible content has been visited before.

The described mechanisms provide the learner with an adaptive, configurable, yet easily manageable user interface that provides rich learning options.

3 Future Work

Research indicates that learning styles can vary with a different task or different learning content (Snow 1989; Kozma 1991). Adaptive learning environments that allow for these fluctuations, predict them and derive tailored media recommendations for learners are not existent at present.

A future version of *iWeaver* will implement a predictive statistical model to recommend a media experience that is most likely to be chosen in the current learning context by the current learner. This extension of the recommendation mechanism is attempting to accommodate possible fluctuations in a learner's learning style profile.

The targeted statistical model will use a combination of content-based and collaborative approaches, which are defined by Zukerman and Albrecht as follows:

> 'In the content-based approach, the behaviour of a user is predicted from his/her past behaviour, while in the collaborative approach, the behaviour of a user is predicted from the behaviour of other like-minded people' (2001:2).

The following variables will feed into a mechanism that calculates the order in which media experiences are recommended:

- Content-based approach
    - Initial personal learning style profile
    - Past choices of media experiences
    - Past ratings of the perceived adequacy of these media experiences
- Collaborative approach
    - Ratings of learners with a similar profile

As described by Zukerman and Albrecht, Bayesian Networks (Pearl 1988) are particularly suited for this combined content-based and collaborative approach. These networks were assessed as being more flexible, extensible and accurate than other predictive models such as neural networks.

4 Summary

This paper presented the implementation of key ideas for strategies to accommodate different learning styles in an e-learning environment. These strategies are based on the Dunn & Dunn learning styles model and encompass two dimensions: media experiences and learning tools.

Media experiences are targeted towards the perceptual domain of the model. 'Visual text' learners experience content in a rich text format, whereas the content for 'visual pictures' learners is supplemented by additional illustrations, diagrams and animations. 'Tactile kinaesthetic' learners are accommodated by interactivelets and 'auditory' learners encounter a PowerPoint style presentation of the learning content. The technical details of the implementation of these four experiences are described with a focus on the SMIL implementation of the auditory experience and its benefits.

The described learning tools aim to accommodate different psychological styles. Global learners can access mind-map diagrams to understand the sense of the big picture; learners who like to make connections can access additional examples. Reflective learners have the opportunity to take notes and answer reflective questions with a note-taking tool. Impulsive learners can immediately try out example code with the help of an online compiler. The advantages and the technological background of this compiler mechanism are discussed and a solution for the caching problem of dynamic applets is described in more detail.

Furthermore, the adaptive features of *iWeaver* are described: specific media experiences and learning tools are recommended for an individual learning style profile and then ordered according to their likelihood to be used. Unlikely choices are hidden to reduce the cognitive load of the learner, but they are still accessible via an expand-button. The content navigation adapts by progressive disclosure: it grows with the progress of the learner in the environment.

At current stage, *iWeaver* is still a project under construction. Future work on the prototype will include implementing a Bayesian Network to predict learner choices based on the current learning context. The production of a complete content module to carry out a pilot study is in progress.

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