

# Functional Requirements Catalogue in the Context of Virtual Classrooms for Blind Users

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**Abstract:** An increasing number of developers of virtual classrooms offer keyboard support and additional features for improving accessibility. Especially blind users encounter barriers when participating in visually dominated synchronous learning sessions. The existent accessibility features facilitate their participation, but cannot guarantee an equal use in comparison to non-disabled users. This paper summarizes a requirements analysis including an evaluation of virtual classrooms concerning their conformance to common accessibility guidelines and support of non-visual work techniques. It concludes with a presentation of a functional requirements catalogue for accessible virtual classrooms for blind users derived from a user survey, the requirements analysis described and additional findings from literature reviews.

## 1 Introduction

Over the last few years, e-learning has become an inherent part of instruction. For people with disabilities it facilitates access to educational material, supports individual learning rates and allows for location independent learning. Virtual classrooms transfer traditional learning scenarios to virtual learning environments in which learners and instructors meet to communicate, collaborate, learn and teach synchronously over the Internet. Virtual classrooms are applications which allow participants to interact using functionality like text chat, audio and video conference, dynamic whiteboard, shared desktop, participant list and file transfer. The dynamic, interactive and visual character of virtual classrooms can be an inspiring factor for learning but also poses new barriers for learners with disabilities. Especially the use of synchronous communication and live generation of visual elements, for example on dynamic whiteboards, poses barriers for blind users because of parallel events, graphical content, unclear spatial relations and quick changes (see [Kö12]). Due to their broad functionality, virtual classrooms work best with a high resolution. Non-disabled users register changes immediately due to a general visual overview. Using assistive technology like screen readers, only one line of text is available. Thus, as blind users register only few details at a time, the recognition of changes and correlations between elements can cause difficulties [Kö12]. Furthermore the paral-

lel audio output of the screen reader, the audio conference and audio signals of the virtual classroom can collide and require the user to switch to braille displays for the screen reader output resulting in possible additional deceleration of information reception.

Accessibility evaluations of virtual learning environments mostly concentrate on asynchronous communication (see for example [Po10]). Developments for improving accessibility include, for example, a Moodle plug-in for checking the accessibility of uploaded PDF documents [Ka14]. Only few evaluations analyze how synchronous communication and collaboration can be facilitated for people with disabilities. Research towards accessible collaborative platforms includes, for example, a wiki-based system [Me11] and an accessible whiteboard including a human translator [Fr10]. Furthermore, software providers of leading virtual classrooms strive to make their products accessible. Accessibility features include, amongst others, full keyboard support, a customizable interface, screen reader support and the possibility to include closed captions (see [B113, Ta08]). Nevertheless, none of the solutions analyzed provides satisfactory conformance to accessibility guidelines [KS13].

Following this introduction, the paper discusses common accessibility guidelines. Afterwards, a requirements analysis of virtual classrooms in terms of accessibility for blind users is presented. The collected data herewith was obtained by performing a product analysis of virtual classrooms. The goal of this analysis is to identify the most accessible and adaptable solutions aimed at developing and evaluating new concepts for accessible virtual classrooms. The paper closes with a requirements definition for accessible virtual classrooms derived from the results obtained from the analyses conducted.

## 2 Accessibility guidelines

The World Wide Web Consortium (W3C)<sup>1</sup> defines, for example, standards and guidelines for accessible Internet applications. Commonly known are the Web Content Accessibility Guidelines (WCAG) 2.0 [Wo08] which define guidelines for the design of accessible web pages. The Authoring Tool Accessibility Guidelines (ATAG) 2.0 [Wo13a] describe guidelines for designing accessible web content authoring tools. The User Agent Accessibility Guidelines (UAAG) 2.0 [Wo13b] define guidelines for designing user agents that promote accessibility and enable communication with assistive technologies. None of these guidelines are solely suitable for the definition of accessible virtual classrooms, as neither all important barriers are covered, nor are all criteria applicable (see [KS13]). Virtual classrooms combine the characteristics of all three guidelines:

- **web content** through the presentation of information using web applications,
- **authoring tools** allowing the users to create content and
- **user agents** that retrieve and render web content.

The IMS Guidelines for Developing Accessible Learning Applications [IMS04] describe accessibility challenges of online education and provide information and recommenda-

<sup>1</sup> World Wide Web Consortium (W3C): <http://www.w3.org/>

tions in addition to existing standards and guidelines. Section 7 describes Guidelines for Developing Accessible Synchronous Communication and Collaboration Tools addressing common problems and best practices.

Even though the IMS guidelines exactly cover the characteristics of virtual classrooms, they contain problem definitions and recommendations rather than specific guidelines. Thus, they complement rather than overlap the guidelines mentioned before defined by the W3C.

The ETSI Guide describes guidelines for “multimodal interaction, communication and navigation guidelines” [Eu03]. It advises developers to design for consistent multimodal presentation and interaction. Furthermore, the guide emphasizes that different presentation modalities need to be available according to the users’ special needs and that they should, whenever possible, contain the same information.

### 3 Product analysis

In the following we describe a product analysis of virtual classrooms with the aim of determining the most accessible and suitable virtual classroom for additional accessibility enhancements (see Figure 1). The criteria catalogue applied for the product analysis comprises a feature catalogue (see 3.1), a guideline conformance review (see 3.2), an analysis of support of non-visual work techniques (see 3.3) and an analysis of programmatic availability (see 3.4). This criteria catalogue will serve as basis for a requirements definition for virtual classrooms (see section 4). The analysis of programmatic availability is work in progress – but as it has no direct relevance for the requirements definition, it doesn’t compromise the results discussed. A preliminary user survey with visually impaired concerning the experience with e-learning and collaborative learning served as a basis for collecting user requirements for computer supported collaboration [Kö12], but is no direct part of this product analysis. The user requirements include

- UR1. generally accessible materials and software
- UR2. a clear structure
- UR3. reduction of visual elements
- UR4. sufficient time for the perception of information
- UR5. sensitization of developers and fellow users
- UR6. standardization of solutions available

The product analysis focuses on the license model, software functionality, accessibility and programmatic availability. The information given on the platform’s websites and tests with demo versions served as a data basis. In the beginning of the analysis, 16 virtual classroom solutions were selected according to a minimal feature catalogue (chat, audio and video conference, shared desktop and dynamic whiteboard) [KS13]. This product range A was reduced during the analysis process dependent on the fulfillment of minimal requirements for each step of the analysis (see Figure 1). In the following, the steps of the product analysis are discussed.

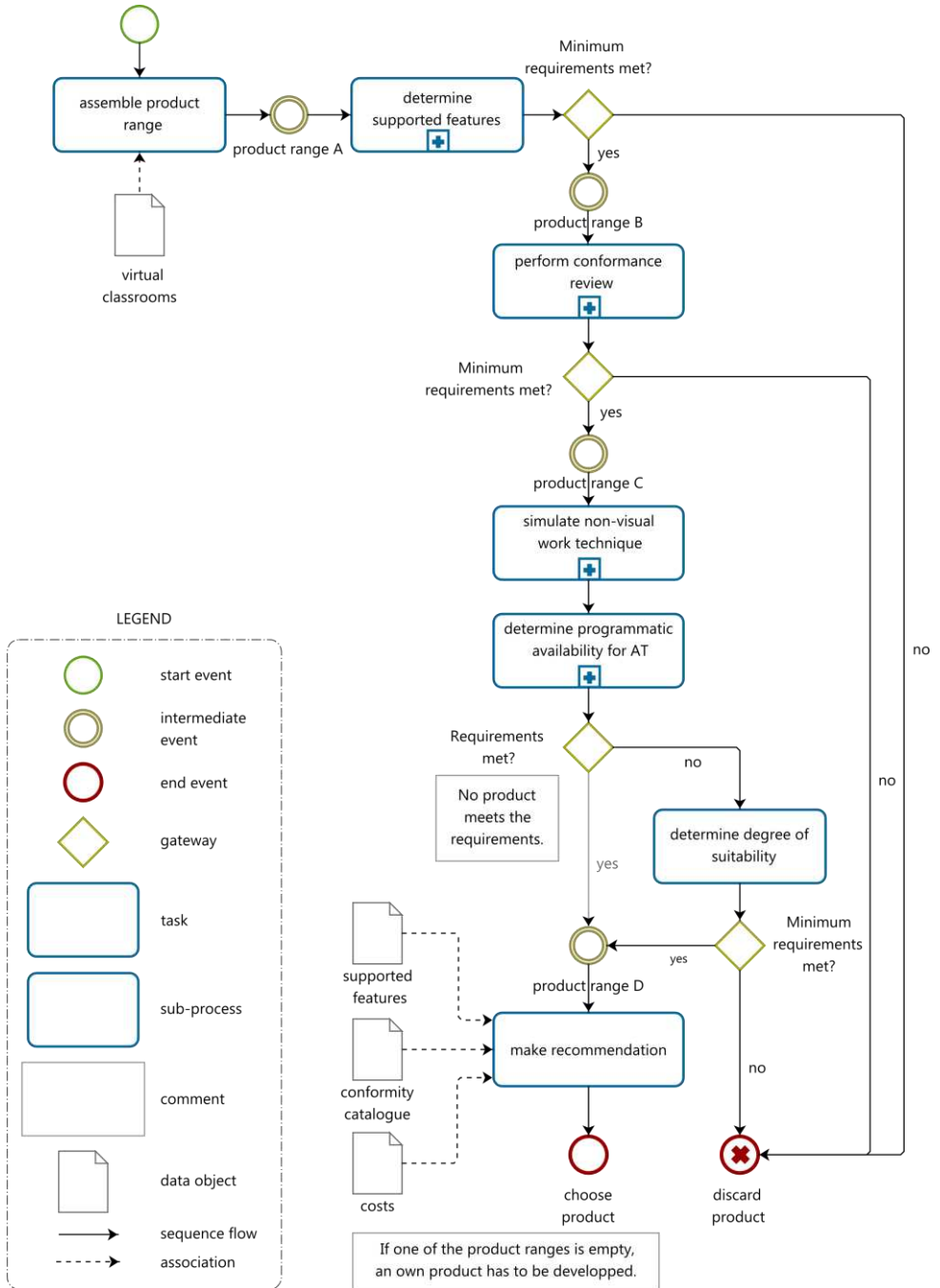


Figure 1: Product analysis process including feature catalogue, conformance review, support of non-visual work techniques and programmatic availability.

### 3.1 Feature catalogue

The first analysis step determine supported features catalogues the functionality supported of product range A, adding up to over 50 features [KS13]. The features supported were counted for each case and the highest percentage of features available from each solution was used in order to select the eight most promising platforms forming product range B<sup>2</sup>. Due to the open source code, the free/open source solutions are expected to offer a better programmatic availability than proprietary solutions. Though, proprietary virtual classrooms offer a wider feature range than free/open source solutions. Thus, thresholds of 40 % for open source solutions and of 45 % for proprietary solutions were chosen so that a similar number of both types of solutions could be considered. In the following, some accessibility features offered by Talking Communities (TC) [Ta08] and Blackboard Collaborate (BC) [B113] are listed:

- AF1. Customizable shortcut settings (TC) and user interface (BC)
- AF2. Screen focus selection for quick navigation (TC)
- AF3. Possibility to hide or display desktop elements for simplicity (TC)
- AF4. Configurable audio notifications of key events in session (BC, TC)
- AF5. Text-to-speech self-voicing (TC)
- AF6. Possibility to add closed captions (BC, TC)
- AF7. Text-based timeline of all session activities (BC)
- AF8. Scalable whiteboard content (BC)
- AF9. Screen reader support (BC)
- AF10. Configurability for maintaining compatibility with assistive technology (TC)

### 3.2 Guideline conformance review

The following guideline conformance review [KS13] was performed with product range B<sup>2</sup> evaluating the conformance to the WCAG 2.0 and IMS guidelines (see section 2). The WCAG consider the accessibility of the platform in general in contrast to the IMS guidelines which focus on the functionality of virtual classrooms in detail. The conformance to both guidelines was summarized in an overall score, the highest only amounting to 53 %. For product range C<sup>3</sup> the minimal requirement was a conformance of 45 % for proprietary and 28 % for free/open source virtual classrooms.

The conformance review showed that no virtual classroom provides text alternatives for all non-text content or time-based media. Most solutions support tabbing but only some solutions offer a comprehensive set of shortcuts. A self-determined control over focus changes, for example to new messages, is not supported. None of the virtual classrooms offers real time text transcripts for audio or video conferencing but some allow the integration of external tools.

<sup>2</sup> Product range B includes the following proprietary solutions: Adobe Connect (v. 8), Avilano (v. 4181), Blackboard Collaborate (v. 11), Talking Communities (v. 8.4), WebEx (v. WBS28); and free/open source solutions: BigBlueButton (v. 0.8 Beta 2), OpenMeetings (v. 1.9.0), YugmaFree (v. 4.1.5.1).

<sup>3</sup> Product range C includes Blackboard Collaborate, Talking Communities, WebEx, BigBlueButton, OpenMeetings.

### 3.3 Analysis of non-visual work techniques

In order to be able to evaluate product range C concerning the accessibility with non-visual work techniques (see Figure 2), typical use cases were developed mapping the most important features [Kö14], for example, gaining and maintaining an overview, using the chat and contributing to the whiteboard. Existing use cases for (collaborative) e-learning, supported features of virtual classrooms and conformance to accessibility guidelines (see [KS13]) served as a data basis.

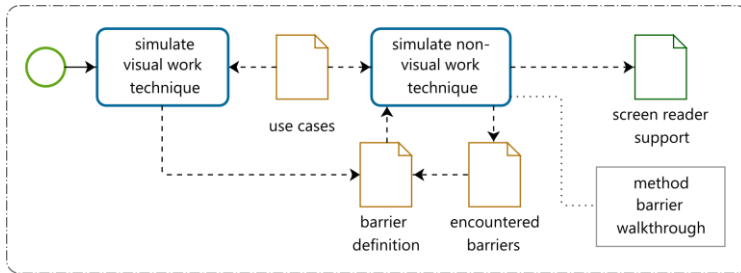


Figure 2: Subprocess simulate non-visual work technique of Figure 1

To analyze the extent of support of non-visual work techniques by virtual classrooms, the method barrier walkthrough [Br08] was applied. In order to identify possible barriers, all use cases were tested preliminarily using visual work techniques [Kö14]. In the following, the most severe barriers are listed:

- B1. Graphical content is not accessible
- B2. Interface element descriptions are not available
- B3. Interface element cannot be focused via keyboard
- B4. Changes are not perceived
- B5. No feedback if command was successfully executed
- B6. Visual feedback/indication is not focusable
- B7. Unclear focus position/focused window
- B8. Missing connection between contents (e. g. chat and whiteboard)
- B9. Lack of control over transmitted audio/video
- B10. Missing control over video transmission
- B11. Time-consuming window/focus change

In the subsequent evaluation of non-visual work techniques using screen reading software, the use cases were tested documenting the predefined barriers encountered. The analysis showed, that none of the solutions of product range C met all requirements: “The main barriers encountered were due to non-accessible interface elements and presentation of content as well as a limited overview of status, events and related content” [Kö14].

### 3.4 Programmatic availability

Following the investigation of non-visual work techniques, an analysis of programmatic availability of product range C according to “Principle 4.1: Facilitate programmatic access to assistive technology” of the UAAG 2.0 is projected. This work in progress includes the analysis of virtual classrooms using inspection tools like Microsoft Inspect<sup>4</sup> or Java Ferret<sup>5</sup> in order to ensure that the solutions provide adequate information about their interface elements and events. The goal is to rate the programmatic availability to assistive technology like screen readers and to assess the possibilities for improvements of the programmatic access and the implementation of alternative concepts.

### 3.5 Product selection

The support of non-visual work techniques is as important as programmatic availability. Therefore the pending decision if a virtual classroom meets the requirements for product range D depends on both factors. Regarding the results of the previous analysis steps, it is improbable that a solution will meet the requirements. Thus, the degree of suitability has to be assessed checking minimum requirements before a solution can be added to product range D. It is possible that solutions may reach the same score. In this case, all aspects and potential costs considered previously have to be taken into consideration again for the selection of a virtual classroom for further adaptations en route to equal access for all.

## 4 Functional requirements catalogue

The results of the requirements analysis form a criteria catalogue for the product analysis. For the data collection process, a variety of methods were used in order to increase the amount of discovered types of accessibility problems (as shown in [MFT05]) and to overcome limitations of conformance reviews [A110].

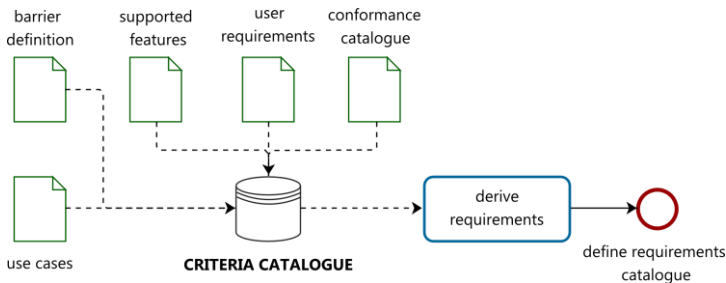


Figure 3: Criteria catalogue derived from the requirements analysis is used to define the requirements catalogue

<sup>4</sup> Microsoft Inspect: <http://msdn.microsoft.com/en-us/library/dd318521%28v=vs.85%29.aspx>

<sup>5</sup> Java Ferret: [http://docs.oracle.com/cd/E17802\\_01/j2se/javase/technologies/accessibility/docs/jaccess-1.3/doc/Ferret.html](http://docs.oracle.com/cd/E17802_01/j2se/javase/technologies/accessibility/docs/jaccess-1.3/doc/Ferret.html)

Table 1: Requirements catalogue for accessible virtual classrooms for blind users with related criteria: accessibility features, IMS guidelines, WCAG 2.0, UAAG 2.0 and encountered barriers.

No.	Requirements	Related criteria				
		Accessibility features	IMS <sup>6</sup>	WCAG	UAAG	Barriers
1	Perception	AF5, AF6, AF8	2.1/3.2, 2.2/3.4, 3.1, 4.1, 4.3	1.1, 1.2, 1.4	1.1, 1.10, 2.1, 2.11, 3.4	B1, B2, B4
2	Navigation	AF2	1.3/2.3/3.5/4.2, 1.4, 1.5	2.1, 2.4	1.9, 2.3, 2.4, 2.5, 2.11.6	B2, B3, B7, B11
3	Orientation	AF2, AF3	1.2, 1.5, 1.6	2.4	1.3, 1.8, 2.4, 2.5	B7, B8, B11
4	Interaction	-	1.4, 1.7/2.4/3.6	3.3	2.6, 2.9	B2, B3, B4, B5, B10
5	Semantics	AF4, AF7	2.1/3.2, 3.1, 4.1	3.1, 3.2	1.10, 2.11.7	B4, B5, B8
6	Speed	AF7	1.6, 1.7/2.4/3.6	2.2	2.9, 2.11	B8, B11
7	Social Presence	AF4, AF5	-	-	-	B6, B9, B10
8	Configurability	AF1, AF3, AF4, AF8, AF10	-	1.4	1.4, 1.5, 1.6, 1.7, 2.7, 2.8, 2.11.8	-
9	Help mechanisms	AF5, AF6, AF7	1.2, 1.4, 2.1/3.2, 2.2/3.4	3.3	1.2, 1.8, 2.4, 3.1, 3.2, 3.3	B5, B10
10	Assistive technology	AF9, AF10	-	4.1	2.12, 4.1	-

The functional requirements catalogue (see Figure 3) defines requirements for accessible virtual classrooms for blind users on the basis of features supported, user requirements, guideline conformance, use cases and barrier definition. Table 1 gives an overview of defined requirements listing related criteria derived from the analysis described above. Thereby, the same criteria may be applicable to multiple requirements. The ATAG 2.0 are not taken into consideration because its focus is on the authors who produce accessible content rather than on users with disabilities.

Requirements concerning, for example, keyboard support and alternatives for non-text elements can probably be found in every guideline for accessible learning applications, whereas criteria focusing on semantics, social presence or the demand for mechanisms enabling equal participation of disabled and non-disabled users are not as widespread. Therefore, this requirements catalogue is not intended to replace but to complement existing guidelines. It summarizes important accessibility requirements for virtual classrooms in order to assist developers as well as users in increasing the accessibility of their virtual classrooms. In the following, the requirements defined are described.

#### 4.1 Requirement 1: Perception

- 1.1. Make interface and content perceivable and predictable for all users (consistent design and events).

<sup>6</sup> The IMS guidelines [IMS04] are numbered 7.1 Synchronous text chat, 7.2 Audio conferencing etc. each containing best practices. The numbering in Table 1 is based on the second digit and numbered best practices: 1.1 for the first best practice of 7.1.



- 1.2. Provide alternatives or description mechanisms for all non-text content and time-based media (e. g. real time text transcript, real time text-to-speech, closed captions).
- 1.3. Use vector formats instead of pixel-based content (e. g. for whiteboard elements).
- 1.4. Provide mechanisms to perceive changes (concerning e. g. interface, new content or events).
- 1.5. Provide mechanisms to avoid interference of audio output (e. g. screen reader, live conferencing, audio signals).

## **4.2 Requirement 2: Navigation**

- 2.1. Provide keyboard support for all mouse functions.
- 2.2. Provide keyboard shortcuts to switch between and to activate important elements and windows.
- 2.3. Provide mechanisms to identify and easily change the focus position.
- 2.4. Allow for navigation of time-based media by time.

## **4.3 Requirement 3: Orientation**

- 3.1. Provide a clear interface structure.
- 3.2. Provide orientation aids (e. g. for keyboard focus, current activities, structural information and text search).
- 3.3. Provide mechanisms for determining relations between contents (e. g. links in an activity protocol).
- 3.4. Provide mechanisms for manual focus change or display refresh and avoid automation.

## **4.4 Requirement 4: Interaction**

- 4.1. Enable all users to participate equally (e. g. full keyboard support for the whiteboard including element creation and manipulation).
- 4.2. Provide (input) assistance through context sensitive instructions and feedback (e. g. about successfully executed commands, information about events).
- 4.3. Differentiate between composition (active) and monitoring (perception) mode.

## **4.5 Requirement 5: Semantics**

- 5.1. Provide mechanisms to determine dependencies and relations between contents (e.g. activity protocol with tags, timestamps and linked content).
- 5.2. Provide mechanisms to identify the authors of (textual, auditory, visual) contributions.
- 5.3. Allow for navigation of time-based media by semantics (e. g. through chapters or scenes).

- 5.4. Present content in an adequate manner for different user groups without altering the meaning or information conveyed.

#### **4.6 Requirement 6: Speed**

- 6.1. Enable users to recapitulate sessions and contents at their own speed and with their own assistive technologies (e. g. session recording, saved whiteboard, snapshots of the user interface, set indexes, referenced elements using ids).
- 6.2. Provide sufficient time for the perception of information (e. g. activity protocol including all content).
- 6.3. Provide mechanisms for quick navigation and orientation aids.
- 6.4. Provide individual control of time-based media.
- 6.5. Allow for time independent interaction (e. g. assignment of tags for traceable contributions).

#### **4.7 Requirement 7: Social presence**

- 7.1. Provide assistance for the usage of time-based media (e. g. assistance for correct video captures).
- 7.2. Provide mechanisms to keep track of the participants' status (e. g. accessible status messages).
- 7.3. Build awareness for special needs of developers and fellow users.

#### **4.8 Requirement 8: Configurability**

- 8.1. Support profile-based adaption of the interface, content presentation, interaction modalities and notification mechanisms (e. g. configuration of resolution, text, whiteboard, volume, synthesized speech, display of graphical controls, display of windows and elements).
- 8.2. Provide standardized settings according to different user groups.

#### **4.9 Requirement 9: Help mechanisms**

- 9.1. Provide input assistance and orientation aids (e. g. status info when sharing desktop, feedback on successfully executed commands, assistance with configuration of time-based media).
- 9.2. Document the user interface including accessibility features.
- 9.3. Enable all participants to provide assistance and peer review content (e. g. provide alternative descriptions/closed captions for elements and content).

#### **4.10 Requirement 10: Assistive technology**

- 10.1. Maximize compatibility with current and future user agents<sup>7</sup> and facilitate programmatic access to assistive technology.
- 10.2. Offer configurability for maintaining the compatibility with assistive technology (e. g. audio output, keyboard shortcuts).

### **5 Conclusion and outlook**

Existent assistive features of virtual classrooms help to make solutions usable for people with disabilities. But the major accessibility problems, the perception of visual elements and synchronous activities, remain unsolved.

This paper describes a product analysis of virtual classrooms and defines a requirements catalogue for virtual classrooms for blind users. In order to achieve an equally beneficial learning situation for both sighted and blind participants, the existing graphical and synchronous features preferably need to be preserved while offering adequate alternatives for non-visual usage as advised in the ETSI Guide [Eu03]. Additionally, the awareness and helpfulness of fellow users and the preparation of accessible materials is vital for inclusive virtual classrooms. Due to the synchronous and collaborative character of virtual classrooms, the requirements catalogue may also be applicable to related social web applications.

Future research will concentrate on the analysis of programmatic availability and the development, implementation and evaluation of alternative concepts. These concepts have to conform to accessibility guidelines, solve barriers encountered (see [IMS04, Kö14]) and fulfill the defined requirements catalogue in order to improve the access of blind users to virtual classrooms.

The main achievement of this work is the combination of guidelines, user requirements and evaluations forming a functional requirements catalogue for accessible virtual classrooms for blind users, which will serve as a sound basis for future research.

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<sup>7</sup>“User agents include browsers, media players and applications that retrieve and render Web content.” [Wo13b]

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