WebWriter: A System to Author and Remix Explorables

Requirements & First Prototype

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Abstract: Active and personalized learning requires that teachers can remix a wide variety of sources into new learning resources, which in turn may be customized by students. While this is well-supported for paper-oriented resources, multimodal, interactive learning resources for digital use, called explorables, are much more difficult to author and remix. In this paper, we derive a set of requirements for a system to author such explorables from a workshop-based study. We further present a first prototype of such a system, called "WebWriter".

Keywords: educational technology, K-12, personalized learning, requirements, explorables

1 Motivation

Modern teaching concepts applied in schools emphasize active learning [Fr14]: The learner is not a passive listener, but an active participant in constructing his personal knowledge. Furthermore, in an increasingly diverse and inclusive classroom, personalized learning becomes ever more important: Learning experiences should be differentiated by teachers and allow for students to find their own, custom learning paths [SS20]. In practice, this is reflected in the process of creating worksheets: Teachers use existing sources to compose a worksheet, sometimes differentiating it for their specific learning group. These sources may be textbooks, websites, or any kind other kind of media available. Next, they distribute copies to their students who can interact with the worksheet individually and customize it. Research indicates that this process is very common, although it often happens in private, which can be called dark reuse [Be18].

Viewed in abstraction (compare Figure 1), this process can be called the *remix workflow* (as coined by Muuß-Meerholz for Open Educational Resources (OER) [Mu18], related to the 5Rs of OER [WH18]). Teachers' authoring of educational resources can be best understood not as creating something from scratch, but as a process of remixing existing sources to suit their needs. The simple process of distributing copies of learning resources

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then enables the final part of personalized learning, customization by learners.

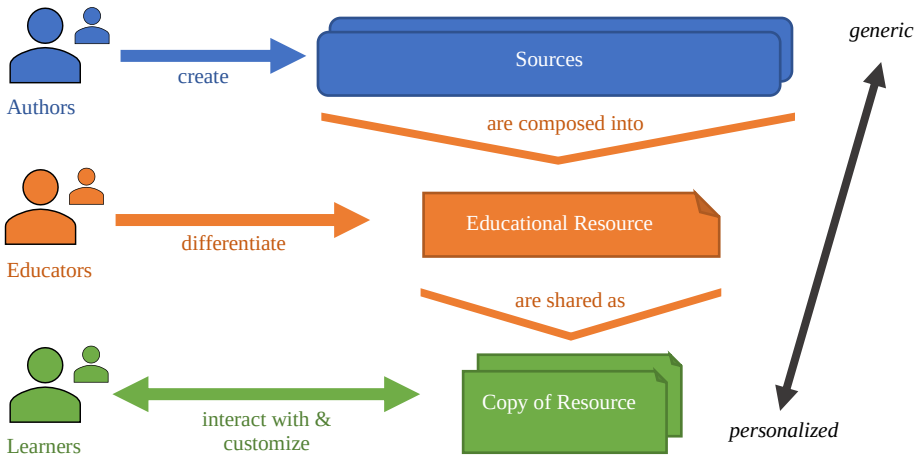

Figure 1: The Remix Workflow for Personalized Learning Resources

While the process of creating classic worksheets and similar paper-based media can be supported digitally with tools such as word processors (e.g. Microsoft Word), authoring learning resources made for purely digital use is more difficult. Resources for digital use can harness all the innovations of learning technologies, for instance:

1. *Multimodality & interactivity*: A large body of research has shown that mixing different types of media such as text and images is beneficial for learning outcomes [Ma20]. Specific types of media such as educational videos [Br16], serious games [Wo13] or simulations [WAP08] can be useful in certain settings.
2. *Connecting & quantifying learning*: Through techniques such as hyperlinking, learning resources can become interconnected parts of the web. They can consume data by calling on available APIs. They can also produce data about learning experiences, enabling learning analytics.
3. *Customization & accessibility*: As the learner can interact with his copy of the learning resource using his own digital device, they can make use of their own learning environment better tailored to their needs. For instance, visually impaired learners may access a worksheet-like resource with their web browser including a screen reader extension.

Overall, this kind of digital learning resource can be called an *explorable*, emphasizing the learner's active relationship with the resource, after a term first coined by Bret Victor [Vi11].

Observing the gap between classic worksheets and the possibilities of explorables leads to

this question: **How can the remix workflow be supported technically for explorables?**

2 Related Work

Hohman et al. [Ho20] provide a full history and overview of explorables, which they call interactive articles. They outline that explorables are successfully used in science communication, journalism, education, and policy making, arguing that explorables could help improve engagement, recall and learning. However, they state that "creating interactive articles today is difficult". They cite that "the act of creating a successful interactive article is closer to building a website than writing a blog post." As they explain, this introduces incidental complexity to the task of creating the actual explorable. That indicates a clear opportunity for research into the design of an explorable authoring system which can reduce this incidental complexity. In the current discourse of computer science education, there has been comparable work [Se19] focused on personalized digital worksheets, specifically in the context of computer science (CS) as a school subject. Serth et al. argue that teachers already use digital learning resources such as Massive Open Online Courses (MOOCs) but are unable to edit them to fit the students' needs (differentiation in our terms), mostly breaking the remix workflow mentioned before. Serth et al. interviewed 13 CS teachers, 2 headmasters and 3 students and found the interviewees criticized the lack of interactivity, lack of personalization and usability of existing solutions. By analysing worksheets created by teachers, they also noticed the issue of context switching between source code and other worksheet content. Our research can further validate these findings for a broader target group (not only CS and programming, but more general-purpose tools and resources).

Historically, learning objects (LO) represent a first attempt to solve the question of remixing educational resources. With a set of standards, learning resources were intended to become discoverable, reusable, and interoperable. Viewed from a personalized learning perspective however, LO had a central issue: "learning objects can be aggregated but not adapted" [Wi07]. The movement of OER inherits the goal of easily remixable educational resources. It can be summarized by the 5 activities related to OER: Retain, reuse, revise, remix, and redistribute [WH18]. These 5 activities already hint at functional requirements an explorable authoring system might have. An interesting general, technical solution to the remixing of interactive content is the recently implemented Web Component standard[2]. With Web Components, developers can define their own HTML elements using JavaScript. Implementation details can be hidden, and styles encapsulated using the Shadow DOM (Document Object Model).

Regarding state-of-the-art systems, there are several solutions that require programming expertise to author explorables: LiaScript [Di19] is a markup language for learning resources that allows interactivity with scripting. Jupyter[3], a system increasingly adopted

[2] https://www.webcomponents.org/, accessed on 14/10/2023.
[3] https://h5p.org/, accessed on 14/10/2023.

in teaching CS at the university level, is similar, allowing the creation of digital notebooks with both Markdown rich text cells and executable code cells. IdyllStudio [Co21] is another recent approach of an authoring tool for explorables, notably introducing a system of variables shared across the whole explorable, allowing for interactive elements affecting the content of the page. H5P[4] is the most comprehensive solution without programming, providing a more general and modular approach, enabling teachers to compose interactive multimedia learning resources out of a set of up to 50 content types such as quizzes, memory games, and so on. From a learning technology perspective, H5P can be seen as modernized approach to LO, facilitating reuse with OER-compatible rights management but foregoing learning object standards. H5P content is usually created via a plugin in Moodle, but the authoring tool Lumi[5] has emerged as another, unofficial way to create H5P content. Lumi is a desktop application wrapping H5P's editing interface. Specifically, it allows creating H5P content in a file-based manner (.html or .h5p files).

In summary: Some prior work hints at the requirements and design of an explorable authoring system, providing a foundation for further work, but there is no comprehensive solution yet. Also, Web Components provide a possible technical solution to the problem of reusable but customizable interactive elements that is worth investigating.

3 Requirements

Study Setup. For the collection and analysis of teachers' requirements on explorables, their creation and usage, we conducted a workshop-based user study with 19 teachers (11 male, 8 female) at different proficiency levels (8 teacher training students, 2 teachers in training, 8 teachers of various experience levels, and 1 former teacher working at a university). The study was constructed as an introductory workshop on H5P and Lumi, chosen as the closest approximation of system to author and remix explorables. It was advertised through mailing lists, social media, flyers, and in different teacher networks.

The workshop was structured through six phases (in 3,5 hours): (1) Exploration of prior knowledge and experience with tools for creating learning materials; (2) Introduction to explorables; (3) Introduction to Lumi and H5P; (4) Creation of a specified explorable; (5) Creation of a personal explorable; and (6) a closing session reflecting on the experiences and lessons learned. While the workshop was moderated by one person, another person was there to observe and record the participants' contributions.

In order not to prime the participants with the ideas and concepts behind explorables, H5P and Lumi, the initial phase of the workshop was used to get the participants talking and creative. As such, the participants were divided into four groups to discuss and collect answers to the following questions: Which digital tools have you been using to create learning materials? What do you consider important in a digital tool used for creating

[4] https://jupyter.org/. accessed on 14/10/2023.
[5] https://app.lumi.education/, accessed on 14/10/2023.

learning materials? What are the advantages of digital materials? What advantages do you see in non-digital materials (e.g., paper worksheets)?

Furthermore, the participants' opinions and experiences were discussed at the end of each phase to collect more requirements as well as critical viewpoints and feedback on Lumi and H5P, as both may serve as opportunities to provide a more suitable alternative, resolving issues and disadvantages. To quantify the usability of Lumi, we used the System Usability Scale (SUS). This will allow us to compare it to a new system in future studies.

Results. Based on the different phases of the workshop, we collected the participants' opinions and feedback on Lumi and H5P as well as their viewpoint on explorables compared to analogue learning materials. As such, the first phase was used to activate participants prior knowledge and let them share personal experiences and opinions. So far, teachers have been using a large variety of tools to create learning materials. Mentioned tools include text editing and presentation software as well as specialized tools like quizzes, audience response systems (e.g., Kahoot[6]) or simulations (e.g., PhET[7]). Also, school- and subject-specific applications were mentioned (e.g., BiBox[8], Geogebra[9]).

When it comes to the question of what participants find important in a digital tool for creating learning materials, expressed properties include interactivity, ease-of-use, intuitive design, compatibility to different operating systems, export functionality, personalization features and secure, privacy-preserving data handling. Participants argued that ease-of-use and intuitive design are relevant for both for the teachers authoring and the students learning with the explorable. The participants expressed that the authoring process for digital learning materials needs to be intuitive and suitable to existing workflows. A tool adding additional complexity and not integrating well into the teachers' workflow is considered a hassle and may be not successful among the majority of teachers.

In line with the advantages of explorables based on the literature, the participants argued that interactivity and adaptability are advantages of "going digital". Furthermore, motivational aspects and activation of learners were mentioned. For non-digital materials, the participants emphasized reliability and independence from the school's infrastructure, and the advantage of no required digital literacy skills. Also, the "learning through pen and paper" argument was discussed, as some of the participants argued that learning through handwritten notes is effective.

The overall workshop concept was well accepted and engaging for the participants, observable through the lively small group discussions and mingling participants during the different phases. The participants also gave positive feedback on the format and workshop content in the closing session. Lessons learned included positive but also critical

[6] https://kahoot.it/, accessed on 08/03/2023.
[7] https://phet.colorado.edu/, accessed on 08/03/2023.
[8] https://www.bibox.schule/, accessed on 08/03/2023.
[9] https://www.geogebra.org/, accessed on 08/03/2023.

perspectives on Lumi, as it was a bit crowded and easy to get lost in. The UI was criticized as being lengthy and needed a lot of scrolling through forms for different elements. However, Lumi was also considered more suitable to author H5P content compared to direct H5P authoring in Moodle. Furthermore, the different H5P content types were received positively, as they are a more uniform alternative to a large set of different tools that teachers use so far. In a closing survey, participants assessed the usability of Lumi using the SUS, resulting in a score of 70.2632, to be interpreted as a "C" letter grade.

Discussion. The goal of the evaluation was to derive teachers' requirements for an explorable authoring system. Tab. 1 presents a set of requirements and specific features that were either commonly used in the workshop already or frequently requested. A core strength of Lumi emerges from the results: Usable on any operating system, teachers can distribute authored content flexibly, either within or without an LMS, achieved by a file-based approach with different export formats. The results also suggest that mixing different content types from a broad selection is desirable, and H5P already provides many content types – yet the lack of usability features such as copy & paste or drag & drop of external resources hinders the remixing workflow. The evaluation identified multiple general usability issues, foremost the lack of a live preview, causing teachers to lose track of their current activity. Furthermore, the results align well with those of Serth et al., confirming the centrality of enabling the remix workflow for such systems.

The system should…	**Specific features from the workshop**
…allow creating interactive multimedia usable for students	mix of content types, making interactive videos, embedding simulations
…be usable for teachers in remixing workflows	live preview, undo/redo, appealing visuals, unlimited composition of content, copy/paste external resources
…support personalized learning	specific content customization options, theming, conditional branching
…enable reuse & retention	use on any operating system, import/export, usage within LMS, usage without LMS

Table 1: Explorable authoring system requirements (Specifics not fulfilled by Lumi underlined)

4 Prototype

Based on the existing research and the surveyed requirements, a first prototype of an explorable authoring system, named WebWriter, was implemented. From a technical perspective, it is a single page application with a Model-View-ViewModel architecture. The whole application is programmed in TypeScript, with key technologies being Lit[10] for

[10] https://lit.dev, accessed 14/10/2023.

UI elements, ProseMirror[11] for the editing logic, and Tauri[12] to wrap the application for desktop use. The resources authored are standalone HTML pages that include all dependencies and assets, making them usable on- or offline in many contexts, such as LMS, web servers, or even file-based cloud solutions. WebWriter makes use of established solutions such as Web Components, and NodeJS packages for the built-in (plugin) system.

Central to the user experience of WebWriter is a "What You See Is What You Get" (WYSIWYG) approach, fulfilling the requirement of a live preview. A basic set of features with this approach has been implemented. Rich text elements with formatting, including links, headings, lists, etc. can be added. Multimodal elements such as images, audio, video, etc. can be added, as well. Any kind of rich text including multimodal elements can be copied and pasted from other sources, being a key functionality in remixing content. Key "quality-of-life" requested by teachers such as undo/redo are supported. Some "common sense" features that were not explicitly mentioned in the requirements were also implemented, such as switching the language of the editor, editing the metadata of the explorables authored (title, author, license, etc.), or changing the assigned keyboard shortcuts. Printing or exporting an explorable to a PDF is also supported, although this obviously depreciates multimodal and interactive content and should be seen as a fallback.

A unique aspect of the prototype is the system of widgets, which are small interactive elements that can be added to the explorable like any other element. A teacher may dynamically install any widget he needs through the "Packages" interface. Widgets may be added, deleted, copied, pasted, undone, or redone like any other element of the explorable. Through students' final thesis, many widgets are available already or are in the process of being made. Examples include a computer network simulation similar to FILIUS[13], a widget to create flowcharts, and an executable code cell matching the functionality Jupyter provides. Developers may seamlessly implement widgets inside WebWriter with an automatically reloading preview of the widget being worked on.

[11] https://prosemirror.net, accessed 14/10/2023.
[12] https://tauri.app, accessed 14/10/2023.
[13] https://www.lernsoftware-filius.de/, accessed 14/10/2023.

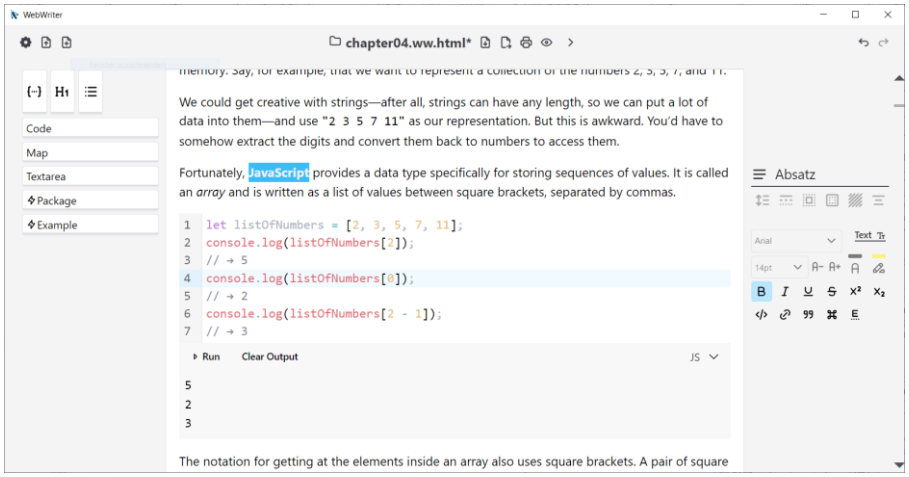

Figure 2: UI of WebWriter with programming-oriented example content

5 Conclusion

First, we introduced the remix workflow and the concept of explorables. Next, we outlined a set of requirements for an explorable authoring system, based on a workshop study conducted with teachers. The requirements match the "remix workflow" concept derived from the literature and further show that state-of-the-art solutions for authoring explorables cannot properly support this workflow. To this end, we presented WebWriter, a first prototype to better support the remix workflow for teachers.

The requirements could be validated with a survey assessing the specific requirements found. The prototype itself will be used in an iterative, design-based research design. Further workshops with conducted where they make use of WebWriter[14] to author and remix explorables. Through observation, surveys and evaluating the resources produced during the workshops, we can collect a set of qualitative data and analyse it, deriving design principles for explorable authoring systems. In turn, these design principles can be used rework the prototype, leading to a new iteration. This provides the opportunity to explore much of the feature space while making use of the wealth of experience educators provide. Features to be explored include…

- …embedding content from existing systems such as H5P content types or PhET simulations into explorables.
- …an optional server component to enable learning analytics via xAPI[15] and to enable sharing resources easily online.

[14] More information, the source code, and the current prototype can be found here: https://webwriter.app.
[15] https://adlnet.gov/projects/xapi/, accessed on 14/10/2023.

- …investigating the potential of large language models for the authoring process, providing suggestions, or generating content, including for widget elements.
- …providing a WYSIWYG interface for CSS styling of elements to enable teachers to visually personalize their explorables.
- …more advanced features for widgets such as nesting different widgets, internationalization, presets, custom xAPI events, or interaction with other widgets in the explorable (or even across distributed explorables).

The data collected from the teachers will most likely provide more possible features to include in the prototype and evaluate in later iterations.

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