Using the Open Source Collaborative Model for Digital Educational Content

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Abstract: Computer-aided learning has recently seen significant adoption among learners. Automated tools that offer online courses, artificial intelligence assisted tutoring, practice items, etc. have been developed and are available for use. On the other side of the spectrum, educators are offered little improvement for the process of curating the educational materials that are to be used in the classroom. Worse, even though in most cases the curriculum for one field is similar, different educators create different hand-out materials, homework, practice items, and tests. The preparation for the above is significant and the educational content produced is created, used, and reviewed by a small number of people. In this paper we propose a novel methodology for using the open-source collaborative model to create, use, and deliver high-quality educational content. Educational content developed following our methodology guidelines is easy to use, modify, and remix. Educators who want to use the content may easily select the topics of interest from a proposed set and all of the educational materials, such as reading materials, assignments, practice items, and even exam items, will be generated. Some of the content is made available to learners via a generated website, whereas other parts of the content (such as exam items or assignment solutions) may be hidden. Additionally, all of this content is public and usable by anyone, including learners of all types (self-educated or following a formal programme). Therefore, the content may be reviewed and updated by multiple educators and learners alike. We use the proposed methodology to create educational materials for multiple university courses and present the impact of using such materials from both educator and learner perspectives.

1 INTRODUCTION

Educational computer programs have been used with great success to stimulate and deepen the learning process. Examples of such tools are: online courses for most of the disciplines of study (from beginner to expert levels), websites that offer exercise banks that are automatically evaluated, tutoring programs that leverage the artificial intelligence capabilities to incrementally provide explanations and exercises for learners(Benigno and Trentin, 2000)(Tallent-Runnels et al., 2006).

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Although these tools may be used to some extent individually by learners, ideally, they would be integrated by educators in their methods. However, given the vast amount of tools and resources available on the Internet, educators often use exorbitant amounts of time to search, select, adapt, and provide educational materials in various forms: slides, practical items, exams, homework, projects, etc.(Judith Harris and Koehler, 2009).

To make matters worse, each educator does their own due diligence for a specific class, thus duplicating the effort of other educators from the same field. Although presentation materials such as slides may be adapted for one's needs, other content such as practical items and exam questions may be shared among educators to facilitate reuse and collaboration.

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Ideally, the learning materials for each field of study would be stored in a public location where any educator or learner can access it. Additionally, the content should be easy to understand, browse, select, adapt and be published to learners. In this case, any educator can access the content and use it according to one's needs, thus minimising the effort of producing class materials. As an added benefit, the content would be used by more educators and therefore could be improved collaboratively. Content development, use and curation are a challenge for both learners and educators(Kebritchi et al., 2017).

To that end, in this paper we propose a novel methodology for creating, using and curating high quality educational content by using the open-source collaborative model. Additionally, we provide a set of tools that may be used to either create educational content or to directly customise and use it. The content produced using our methodology is available to the general public and anyone with an Internet connection may access it. All of the educational materials are easily modifiable since we provide all of the content in an editable format that may be used to generate immutable content (such as *.pdf* or *.png* files). Educators may easily select a subset of the topics presented and the tools we provide will manage the deployment of the content that contains all of the required materials: slides, reading materials, exam items, practice items, etc. Additionally, we strive to automate educational tasks that require a lot of effort such as: the evaluation of practice items, assignments, and exams as much as possible.

Besides making it easier for educators to discover and use educational content, the added benefit of our approach is represented by the fact that the content may be shared among multiple educators. Having multiple entities using the same content will create a community around it which is incentivised to maintain a high standard for it.

We have applied our methodology to the development of educational materials for multiple university courses from a computer science programme. We show that using the collaborative model for educational content is beneficial not only for educators but also for learners, considering the different types of interaction(Moore, 1989). In our particular case, students have benefited from having automatic evaluation of most of their tasks and by actively contributing to the educational content.

In short, the main contributions of this paper are:

- We propose a novel methodology for creating, using and curating high quality educational content by using the open-source collaborative model.
- We propose a range of open source tools that may be used to create and use high quality educational content.
- We use our methodology to create educational content for multiple university courses.
- We present the impact on both students and teaching assistants on using the proposed methodology.

The remained of this paper is organised as follows: Section 2 presents an overview of the methodology. Section 3 presents the current state of using technology in the process of learning. Section 4 details the actual methodology, as sections dealing with content development, use and curation. Section 5 is an evaluation of the methodology. Section 6 and Section 7 conclude the paper.

2 OVERVIEW

The proposed methodology aims to provide answers to common questions related to educational content, such as:

- How do I develop / create a digital educational content repository?
- How do I use (as an educator) a digital educational content repository in an actual implementation (course, training)?
- How do I contribute to a digital educational content repository?
- How do I curate / manage a digital educational content repository?

By providing answers to these questions, the methodology offers uniform guidelines that are followed by different content types. New content repositories that follow the same guidelines will present a comfortable and familiar view to content developers, users and maintainers, improving the effectiveness of teaching flows.

To this end, the methodology revolves around three key concepts:

- **content aspects:** These are classes of actions related to digital content in the educational process.
- **roles:** These are roles of stakeholders in the educational process. There is a one to one mapping between roles and content aspects.
- **infrastructure:** These are digital components that are used throughout the educational process.

Figure 1 presents the connection between the three concepts. The digital infrastructure serves as a common point for three roles and three teaching aspects. Each of the three teaching aspects, and so each of the

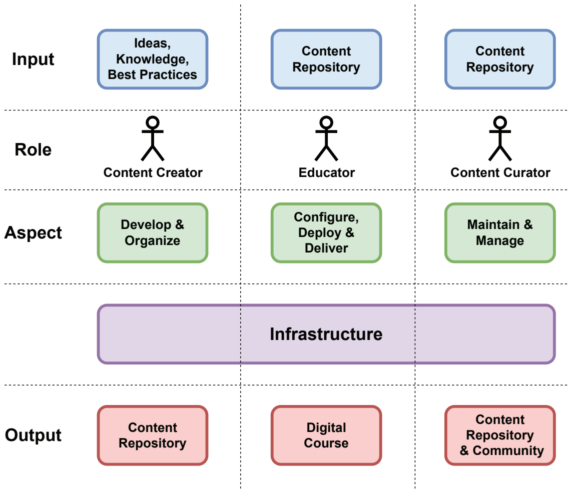

Figure 1: Methodology Concepts.

three roles, relies on the infrastructure and generates a type of output from a type of input. These three flows are detailed below:

Content creators develop and organise high quality learning materials that respect the 5 Rs of open educational resources(Hylén, 2006): Retain, Reuse, Revise, Remix, Redistribute. They use **ideas, knowledge and good practices** as input to produce **content repositories** as output. The infrastructure employed consists of open source tools for storing, reviewing and validating digital content. For content creators, the methodology provides the guidelines for creating, organising and storing educational resources.

Educators configure, deploy and deliver these materials to learners. They use the **content repositories** as input to produce actual **digital courses** as output. The infrastructure employed consists of engines to format the content to learners and to automate teaching workflows. For educators, the methodology provides guidelines on how to use reuse, modify and remix the existing educational content provided by content creators.

Content curators maintain and manage the existing content. They use the **content repositories** and the **digital courses** as input to improve the **content repositories** and to create **communities** around that content. The infrastructure employed consists of the same tools for storing, reviewing and validating digital content, together with communication and collaboration tools to include educators using the content. For content curators, the methodology provides guidelines on overseeing the use of the content, incentivising contributors, managing modification requests and organising discussions around the existing content.

Figure 2 provides another view of the flows, focused on infrastructure components and connection between inputs and outputs.

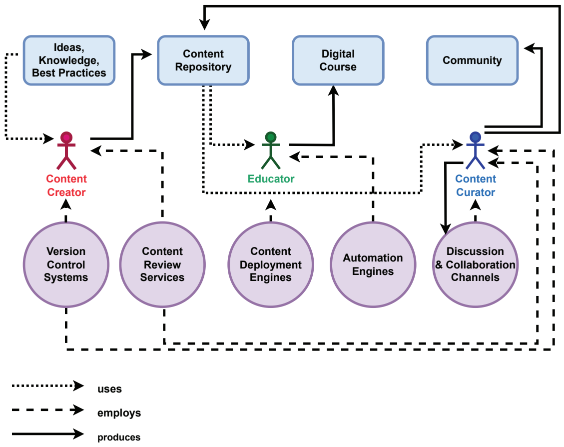

Figure 2: Methodology Flows.

The methodology consists of detailed practical guidelines for the three flows. Section 4.3 details the flow related to content creators and the developing and organising of content. Section 4.4 details the flow related to educators and the deployment and delivering of content in actual courses. Note that we use the term *course* as a placeholder for any instance of delivering content to an audience. Section 4.5 details the flow related to content curators and the maintenance and management of existing content.

The methodology itself is organised inside a content repository that follows its own guidelines. This makes the methodology the target of its own flows, including its continuous improvement. The repository provides actionable items in the form of guides, examples, references to existing content and pointers to infrastructure components. These are to be followed by the person acting as a content creator, educator, or curator to provide a collection of high quality, continuously improved digital educational content repositories.

Note that one person could be filling multiple roles. For example, someone can choose to fill only the educator role and use and deliver existing content as part of their own digital course. In the absence of existing content, someone can initially fill the role of content creator to develop required content, then the role of educator to deliver it, and finally the role of curator to maintain the community around the project.

Overall, the methodology, as detailed in Section 4, structures the common flows related to educational content. It answers questions of the form "How do I …?", thus providing the focus for effective content-related aspects: development, delivery, and maintenance.

3 BACKGROUND

Web-based learning environments have grown significantly in usage and popularity over the past couple of decades (Chirikov et al., 2020), (Mathias Decuypere and Landri, 2021), (Chen et al., 2020). Some of these are open and free to use, others commercial products. These digital platforms, ranging from comprehensive Learning Management Systems (LMS) like Moodle and Canvas to Massive Open Online Courses (MOOCs) platforms such as Coursera and edX, offer diverse and customizable learning experiences. For those focusing on technical skills, interactive coding platforms like Codecademy provide hands-on coding exercises, while a platform like DataCamp offers courses in data analysis. Also, there are specialized platforms such as Duolingo for language learning and the tutor-web, an open-source learning environment designed to teach mathematics and statistics (Jonsdottir and Stefansson, 2014), (Jonsdottir et al., 2017). Many of these platforms offer features beyond simple content delivery. For instance, there are features for interactive assessments, forums for discussion, tools for peer review, and mechanisms for instructors to provide feedback, a key element in student learning. As stated in (Black and Wiliam, 1998), several studies have shown firm evidence that innovations designed to strengthen the frequent feedback that students receive about their learning yield substantial learning gains. Providing students with frequent quality feedback can be time consuming for educators but by using these available tools students can get feedback on their work that does not require marking by teachers.

There is no doubt that web-based learning environments have increased accessibility to learning, allowing students from diverse backgrounds and geographic locations to access high-quality educational resources, and breaking down traditional barriers (Zi-Yu Liu and Korobeynikova, 2020), (Puggioni et al., 2021), (Eleftheria et al., 2013), (He et al., 2022). From the teacher's standpoint, however, there is often a limitation to these platforms; they are not easily contributable, meaning that an educator does not have the possibility of selecting subsets of topics or organising entire courses tailored to their learners' needs.

To address these issues, attempts have been made to use version control systems (Angulo and Aktunc, 2019), such as Github [1], to store educational resources and share them with students. GitHub is a good choice for storing open educational resources, promoting collaboration and version control, it makes it easier for educators to work together on course materials, track changes, and offer resources that can be accessed and improved by everyone, even by the students (Glassey, 2019), (Bhasin et al., 2021). It offers free hosting using GitHub Pages, making it easier to create a website.

Multiple course repositories exist, however, each implements its own structure and deployment options. Since the resources don't have a standard structure it's hard to reuse that content, making the contribution from other communities less likely. In fact, there are databases of courses on GitHub where each course follows a different structure. This makes it difficult for educators to discover and navigate the content that they need. Another problem with the already present courses on GitHub is that the content is stored in PDF format. While PDFs are widely used for document sharing, they have several limitations in the context of open education resources. PDF format is typically non-editable, making it difficult for educators to modify the content for their specific needs or to contribute improvements.

Our methodology addresses this limitation, by creating a generic repository structure that is easy to navigate, contribute to and reuse even by non-technical educators. To the best of our knowledge, there are no other proposed methodologies on organising and using educational resources for the open source environment.

4 METHODOLOGY

The methodology that we propose offers guidelines for all levels of interaction with a course repository. In this section, we describe the main aspects of how users are going to interact with a potential repository depending on their needs.

Versioning systems fundamentally group information into **repositories**(Santos-Hermosa Gema, 2017). As such we consider that all of the educational resources pertaining to a particular course or field of study are going to be organised into a repository.

4.1 Content Types

Educational resources come in various forms and sizes. Examples of such resources are represented by books, wikis, videos, computer learning games, and multiple choice questions - just to name a few. To be able to easily navigate the content from an educational repository it is imperative that a wide range of content types be supported.

We group educational resources into 6 broad categories that are representative of most (if not all) types

[1] www.github.com

Table 1: Types of content.

Content Type	Examples
Reading	books, wikis, articles
Media	images, recordings, videos, games
Slides	.pptx files, .ppt files
Guides	tutorials, demonstrations
Drills	quizzes, problems, essays
Projects	assignments

of content. Table 1 highlights these categories which are detailed below.

The **reading** content type is the most common form of storing educational materials (or information, in general). As the name suggests the content is developed to be read, therefore it comes in the form of text. The reading content type is typically used standalone or in conjunction with other types of content to explain topics.

The **media** content type refers to audio, visual, or audiovisual educational materials. The media content type represents an easily digestible format for presenting information. As such, media is typically embedded within the text that is destined for reading, slides, guides, drills, and projects.

Slides are the main support material for live activities, such as lectures. They can also be used during practical sessions or talks (such as conferences). The main role of slides is to provide visual support material for presenting information and engaging participants in discussions.

Guides are pieces of content consisting of detailed steps that are commonly used in practice. Guides are to be used by learners as tutorials or by educators as demonstrations.

Drills are educational activities designed to reinforce learning through repetitive practice. Drills come in many forms such as multiple choice questions, essays, practice items, etc.

Projects are practice items that are larger in scope and require extensive time, effort, and resources to complete. When compared to drills, projects aim to present a comprehensive narrative that can be divided into smaller, coherent steps.

Each repository for educational content is going to contain a mix, if not all, of the above content categories. To make it easy to understand and reuse the educational content, we propose a specific structure for the repository.

4.2 Repository Structure

The structure of the repository needs to be easy to navigate so that educators intuitively find the resources that they search for, while also making it easy to select content at whatever granularity it is needed.

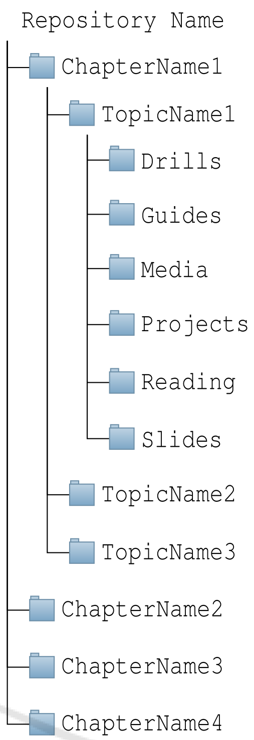

Figure 3: Repository Structure Sample - A repository contains any number of chapters. Each chapter contains any number of discussed topics. Each topic contains all of the content types defined for it.

To that end we have devised the repository structure presented in Figure 3. The resources of a course or field of study are grouped into a numbers of chapters. Each chapter is represented by a number of topics. For each topic, a number of content types (ideally, all) exist.

By using this form of organisation, educators can easily browse through the available resources and select whatever topics or chapters of interest. Once a topic is selected to be a part of the course, all of the resources pertaining to that specific topic will be included in the final presentation material. Essentially, all of the content that is needed for a lecture or a practical session is just one click away.

If some content needs to be excluded at a smaller granular level (some specific drills, or some specific assignments) that is also possible, but generally, topics should be treated as indivisible units.

Listing 1: Drill File Example. The drill information is stored as a list of key-value pairs of the form Title: ”Sample Question Name”, Difficulty: ”easy”, Tags: ”topic-1”, ”topic-2” etc.

```
# Sample Question Name

## Difficulty

easy

## Tags

- topic-1
- topic-2

## Question Text

Is this a sample question?

## Question Answers

+ Yes

- No

- Maybe

## Feedback

The question is self-reflecting
```

For content curators and content creators this form of organisation is advantageous because it lifts the burden of thinking about dependencies between topics. The topic is created and if prior knowledge is necessary, a simple link to a different topic (that the current one is depending on) or chapter may be inserted. It is the burden of the educator to establish the order in which different concepts are taught.

4.3 Developing Content

For content developers, the methodology provides guidelines on how to create interactive and attractive content that is easy to reuse, modify and publish. Therefore, content creators are given recommendations in two directions: (1) how to develop content that is valuable for learners and (2) how to create content that is easily usable by educators.

For creating attractive educational resources, the methodology provides recommendations regarding interactivity, using as much as possible media items instead of reading materials, how to create the layout of an educational activity etc.

For creating content that is easily usable by educators, the methodology offers guidance on what formats are to be used for the educational materials so that they are easily editable and the tools that may be used to achieve this.

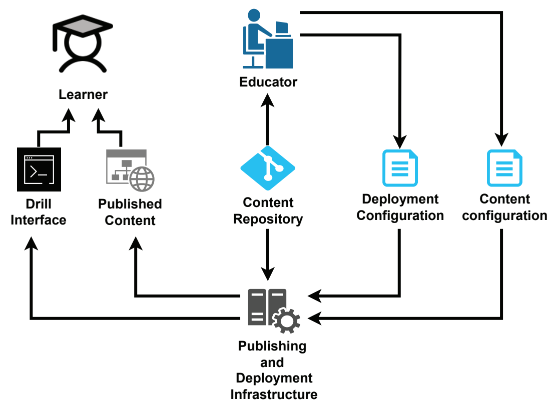

Figure 4: Flow for using the educational content: the educator browses the content and selects the topics of interest by providing a configuration file; additionally, a deployment configuration is provided that describes various deployment options referring to the publishing format. The publisher tool that we have developed then renders the course materials and updates the websites that host the drill interface.

We focus on the latter aspect, since the former is beyond the scope of this paper.

The easiest form in which information may be edited is text. As such, we strive to store all of the educational resources as text, in the form of Markdown files. We have chosen Markdown because it offers an easy way to format text by using specific annotations. Additionally, Markdown is used to nicely render text files in most versioning systems. Excepting media files, we use Markdown for all other content types.

Reading, projects, guides content types are easily stored in Markdown since these are essentially text-based resources.

Slides are also stored in Markdown and are rendered either in the browser or as a .pdf file by using *reveal-md*. *reveal-md* is sufficiently powerful to handle most of the situations that a graphical presentation tool such as PowerPoint can, however, it is text-based. In our experience, creating slides using Markdown and *reveal-md* is easier and has the added benefit of having the source easily editable.

Drills are also stored using Markdown, however, depending on the drill type and the publishing format, additional transformations may be used. Additionally, we want to also store the correct answer in the drill file, so that (1) educators understand what is the expected answer, (2) learners who solve the drill as part of a self-study session can check their answers and

(3) if the drill solution is automatically verifiable, a correct answer is needed.

As a consequence, we have developed a standard for representing drills in Markdown files. Listing 1 highlights a sample of such a drill file. Such files are parsed by a script we provide which creates a dictionary where each *##* preceded line represents the key and the following lines up to the next # represent the value. Some keys are mandatory, namely ”Title”, ”Question Text”, ”Question Answers” and ”Feedback” but the others are optional. The format is flexible enough to support any kind of question that targets any kind of publisher. All that needs to be done is that the drills are annotated with the proper metadata so that the publisher correctly supports them. Additionally, the format is simple enough that even a non-technical person may understand it and modify the drill content.

Media files come in various forms and each type has different properties. For example, images may be stored as .svg files which are easily modifiable and translatable to a different format such as .png, .jpg or .pdf using **draw.io**. However, videos, audio files or recordings are not easily editable. As a consequence, in these situations, we store the non-editable version since, typically, when this sort of content type mandates modifications, a new version is created from scratch. In the particular case of videos that are created out of static images, the images could be stored in .svg format alongside the script that creates the video.

4.4 Using Content

Using the content is designed to be as easy as possible. Figure 4 highlights the main aspects of using educational content that is developed using our methodology. The educator browses the existing content and selects the topics or chapters of interest. The selection is made via a graphical interface which then is translated into a content configuration file. Additionally, the educator may select deployment options such as: the format in which the materials will be published (*https* for rendering on a website, *.pdf* for presentations or other custom targets), and the target platform for drill hosting (so that appropriate pre-processing is done). The educator need not bother to create the deployment settings as the default option is to render and host everything on a public website. If the educator has a preference for a different flavor of end publishers, that may also be customised, however, in this case, the educator must have the knowledge to properly configure the deployment parameters. Additionally, the publishing and deployment infrastructure may easily be extended to support any kind of publishing format, as long as translators from Markdown to the targeted formats are provided. Once the deployment and content configuration files are extracted and handed over to the publishing and deployment infrastructure, all of the educational materials are translated to the appropriate formats and deployed on the provided targets. Once deployed, students may access and consume the educational materials.

By providing a simple selection interface, the educator may obtain educational materials for an entire course just by doing a few clicks. Additionally, both the educator and the student may propose changes to the materials.

Note that the educational materials developed following our methodology do not target a specific teaching activity (such as a lecture, seminar, workshop, practical session etc.). The content categories may be combined during different teaching activities as the educator sees fit. However, the methodology does provide a taxonomy of teaching activities and how each content type may map on it.

Table 2 provides the broad categories of teaching activities that we were able to identify given our teaching experience.

Lectures are teaching activities that typically take place with a larger audience and are asymmetrical: a lecturer mostly talks while the audience mostly listens. Interactivity is important but is limited by the larger audience: not all participants will be able to actively engage in discussions. Slides and media items are used most frequently during lectures, however, guides (in the form of demonstrations or tutorials) may also be employed. Drills may be used in the form of multiple choice questions to engage the audience and have instant feedback on whether the audience has understood the presentation.

Practical Sessions are represented by hands-on activities that learners perform in order to acquire experience. These activities are typically supervised by an educator who proposes the practical exercises and evaluates the learner’s performance. The purpose of the evaluation is to provide feedback as opposed to grading the learner. Instances of practical sessions are represented by lab sessions, seminars, or workshops. A practical session may employ, depending on educator preference, reading materials for short explanations, slides for educator presentations, media items to support the previous two, guides that assist the learner in learning, and drills that offer the possibility for hands-on practice.

Assignments are unassisted practical activities that learners undertake individually or in teams over a longer time span. Their primary objective is to provide learners the flexibility to work through tasks at

Table 2: Teaching activities mapped on content types.

Teaching Activity	Category	Content Type
Lecture	Learning	slides, media, guides, drills
Practical Session	Learning	reading, slides, media, guide, drills
Assignment	Learning + Assessment	projects, drills
Test	Assessment	drills
Self Study	Assessment	reading, media, drills, projects, guides

their preferred speed, allowing them to address gaps in their understanding as they progress. Assignments primarily use the project content type, however, they may also be generated as a series of drills. Although the primary purpose of an assignment is to deepen the understanding of one or a series of topics, they are usually graded, taking part in the assessment process. **Tests** are assessments designed to evaluate learners' understanding and application of the course material. Tests are comprised of a series of drills.

Self Study is the process of independently learning outside of structural classroom settings or formal instruction. Learners may individually access and consume the educational materials, therefore all content categories, except for slides, may be used for this activity. We have excluded slides as a learning material for self study because slides are typically used for presentation purposes, not self study.

Note that the teaching activities that involve skill assessment might require that some parts of the resources be private to the educator so that learners cannot cheat. This comes in contrast to the open nature of the educational content that is produced by using our methodology.

For tests, our perspective is that the examination should be done in a supervised environment to make sure that the learner does not access the online solution. As for knowing all of the answers in advance, we consider that the drill database should be sufficiently large so that if a potential learner memorises all the drills and their solution, then it can be considered that the learner has mastered the course.

For assignments, however, we have not come up with a solution. By their nature, projects are to be solved in an unsupervised environment, therefore, having a public solution makes it easy to cheat an assignment. We do not have a solution for this aspect, other than expecting that the educators will modify the project so that the public solution cannot be used.

4.5 Curating Content

Each repository of educational content is supervised, or curated, by one or several content maintainers. Our methodology describes the responsibilities of a content maintainer:

- Content management: to review and handle modification requests, to create tasks and organise the work that should be done on the repository, to establish contribution guidelines, and acknowledge the work of contributors.
- Community building: promote the content, encourage and organise discussions around it and build an ecosystem of content users and contributors.

Content maintainers are typically the persons that initially developed the educational materials, however, in time, prolific contributors may also take on this role.

4.6 Automation

Besides making it easy for educators to reuse existing content, another important aspect of our methodology is to design educational materials that alleviate as much as possible the need for manual effort. As such, we try to automate as much as possible content generation and evaluation. Although this may not always be possible (for example, philosophical essays still need to be graded by a human), most STEM fields are amenable to automatic evaluation.

Automatic evaluation may be used for:

- Lectures, for multiple choice questions that are engaging for learners. The result of a multiple choice question is available live for both the learner (to validate the understanding) and the teacher (to aggregate the results and understand whether a concept was understood or not).
- Practical sessions for drill categories such as multiple choice questions, fill-in-the-blanks, programs that need to be developed, etc. For engineering fields, this should be easily implementable, as we show in Section 5.
- Assignments, provided that the assignment is amenable to automated testing. In computer science fields, for example, assignments are typically in the form of computer programs therefore these

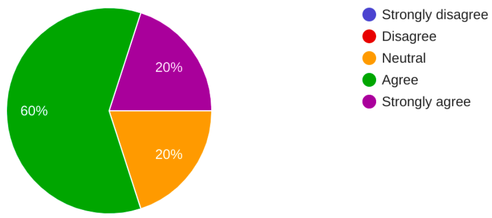

Figure 5: Content deliverers' level of agreement with the statement "The practical session materials were helpful in understanding the presented concepts".

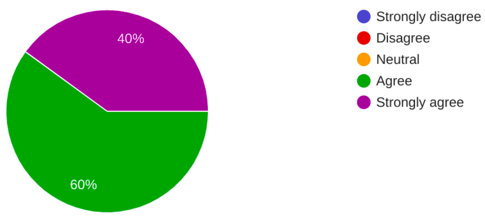

Figure 6: Content deliverers' level of agreement with the statement "The lecture materials were helpful in understanding the presented concepts".

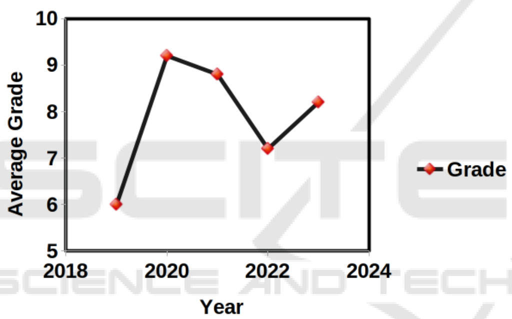

Figure 7: The evolution of exam grades over time for the Operating Systems class. In 2023 we have used the educational resources developed using our methodology.

can be easily testable. We also provide guidelines on how to set up a generic assignment testing framework that uses a versioning system.

- Tests, provided that the exam is in the form of multiple choice questions or a practical assessment (such as writing a computer program).

In our methodology, we provide guides on how to set up an infrastructure for automated testing of all of the above categories. In addition, our repository template already contains default configurations that aid in setting up the infrastructure. As such, content creators can easily set up the infrastructure when creating a repository from scratch, educators typically are not concerned with this (except for choosing content that is amenable to automated evaluation) and content curators only have to maintain the initially configured infrastructure.

5 EVALUATION

To apply our methodology we have created educational resources for 2 university courses - Operating Systems (OS) and Computing and Calculus for Advanced Statistics (CCAS) - and 2 university summer schools - Security Summer School (SSS) and D Summer School (DSS).

For the OS class, the materials were created from scratch, whereas for the rest the materials were "ported" to follow the methodology.

From this selection of courses, the OS class has the largest audience, roughly 600 students each year, and the largest team involved in maintaining and delivering the content. As such, we further present a series of metrics to showcase the impact of using our methodology for the OS class.

Figure 7 highlights the evolution of exam grades for the OS class. Prior to 2020, we employed a written exam and the average grade was around 6. In 2020, because of the pandemic, an oral exam was introduced, and since it was the first time we were using this type of exam, the examiners were very indulgent. The examination was calibrated so that it was comprehensive enough without being too easy. As a consequence, the average grade started decreasing. However, when we introduced the new learning materials in 2023, the average grade increased. We note that the team of examiners and the team of content deliverers were roughly the same starting from 2020. Although some of the persons who created the materials are also part of the examination team, the large majority of them are not content contributors.

Furthermore, we wanted to evaluate the perspective of content deliverers on the materials we developed for the OS class. For that, we have devised a feedback form and asked the content deliverers from our course to complete it. The questionnaire contained two statements and the respondents were asked to complete the level of agreement with them. Figures 6 and 5 present the perspective of content deliverers on the educational materials. As it can be observed, the majority of respondents (28 participants) consider that the materials help understand the presented concepts.

Note that the content deliverers were not involved in selecting the topics that were presented during the course and practical sessions. The materials were already organised for them, they simply had to deliver the content (in the form of lectures and practical sessions). As such, we do not have any evidence of whether the content that we provided is easy to configure. However, there were content deliverers who were not part of the content development team that

Table 3: Number of contributions for our Operating Systems educational materials.

	Total Number	Authored by Students	Resolved
Pull Requests	222	32 (14.4%)	220
Issues	112	18 (16.0%)	72

have made contributions to the content. Furthermore, we had student contributions to our educational content.

Table 3 showcases the number of "Pull Requests" (modification requests) that were made to our content repository. The number includes contributions from content developers, content deliverers, and students over the course of a year. A non-negligible percentage of those is made by students (roughly 14.5%), most of which were accepted. The "Resolved" column represents the number of requests, out of the total number, that have been processed. Processing a pull request means that it has either been integrated or closed without being merged. The majority of the pull requests have been merged after changes were requested by the content curators. A small fraction (25 pull requests) have been closed without being merged. For issues, the "Resolved" column signifies the number of issues that have been closed as a result of a pull request being merged.

This shows that once the content is publicly contributable, both learners and educators/content developers benefit from it: learners deepen their knowledge by proposing modifications, whereas educators/content developers get to have their content improved.

In short, we have validated that the content developed following our methodology is indeed of high quality, showing that educators appreciate it and learners benefit from it. Additionally, given the contributions we obtained, we consider that we demonstrated that the materials are also easy to contribute to. However, we have not yet proven that our materials are easily configurable.

6 NEXT STEPS

Currently, we are using the educational content that we have developed following our methodology, however, we do not know if other educators find it useful. Therefore, our next step is to create an ecosystem of educators around the content that has been developed so far. Once educators start using the developed resources, we will be able to obtain feedback outside of the community from our university.

At the same time, we are continuously looking for ways to improve our interfaces so that educators with a non-technical background are capable of using and developing materials for their courses.

Additionally, we want to create educational materials for more courses, ideally for non- technical fields of study (such as geography, philosophy, etc.). Breaking the barrier of non-STEM fields of study will enable us to better understand what are the needs for automation and usability for course materials that are not naturally amenable to our methodology.

7 CONCLUSION

The technological revolution has enabled new ways of learning and a multitude of tools have been developed that aid the learning process. These tools primarily target learners. No tools, to the best of our knowledge, have been developed to ease the process of gathering and organising teaching resources for educators.

To that end, we have presented a novel methodology that offers guidelines and recommendations on how to create high quality educational content that is easy to use, modify, and remix. Our methodology targets content creators, content deliverers, and content curators.

We have used our methodology to develop educational materials for two university courses and two university summer schools. We have presented metrics for one of the university courses that has been delivered that demonstrate the value of the created materials for both educators and learners. Further, we have shown that content that is developed by using our methodology can be easily contributed to.

We envision a future where educators, irrespective of the field that they are teaching, may easily access a platform and search for the topics they want to teach, select a few, and push a "publish" button, and all of the course materials will be made available to learners. Furthermore, all evaluation will be done automatically. Once the burden of searching, gathering, curating educational materials, and manual grading is lifted from educators, they will have more time to spend on mentoring and coaching learners.

We consider that this work is a first step towards that future.

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