https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Jupyter Book as an open online teaching environment in the geosciences: Lessons learned from Geo-SfM and Geo-UAV

Peter Betlem[1, 2], Nil Rodes[1], Sara Mollie Cohen[1], and Marie Vander Kloet[1, 3]

[1]The University Centre in Svalbard, Longyearbyen, Svalbard, Norway
[2]Department of Geosciences, University of Oslo, Oslo, Norway
[3]Department of Education, University of Bergen, Bergen, Norway

Correspondence: Peter Betlem (peterbe@unis.no)

Abstract. Together with our students, we co-created two open-access geoscientific course modules using the Jupyter Book environment that formed part of one undergraduate-level and one open-ended (undergraduate - professor) geology course that comprised both field and classroom teaching. The modules covered the acquisition of drone data and subsequent processing of 3D models and were iteratively revised over a four-year period. Each module implemented an in-line collection of videos, animations, code snippets, slides, and interactive material to complement the main text as a diverse open learning environment. Behind the scenes, Github was used to facilitate content version, co-creation and open publishing of the resources. We found that students were favourable to the framework and especially valued the framework's accessibility, inclusivity, co-creation capabilities, and interactivity. Collaboration certainly helped cultivate an interest in revising the source materials and updating information where it was deemed outdated or unclear, regardless of the contributor's background, affiliation or level of experience. However, effective co-creation relied on students to be able to use the tools at their disposal, plus be given the opportunity to contribute in their own ways. Through our combined efforts, we succeeded in providing lasting, up-to-date and open course materials to a campus with a small department that does not have significant experience nor capacity in developing and maintaining open educational resources. Work remains to establish optimal playtime durations for integrated animations and videos, as well as the translation of the modules into different languages. Finally, our efforts are an important step in the development of open educational geoscientific content co-created with input from technical experts, social scientists, and students alike.

1 Introduction

The concept of openness and sharing has become a core value and commitment across many disciplines and fields.
The open-source and FAIR (findable, accessible, interoperable, reusable) data (Wilkinson et al., 2016) stewardship movements share common principles with open pedagogy (OP) (Rocca-Serra et al., 2023; Wiley and Iii, 2018). Through open-source tools, FAIR data, and open educational materials, OP provides a more democratised, accessible, and affordable learning environment wherein neither students nor educators are bound by expensive software licences, proprietary data, or the limited perspectives of individual textbooks (Abernathy, 2023). Specifically, OP is an educational approach that emphasizes transparency, collaboration, student-driven learning, and the use of open educational resource (OERs) (Hegarty, 2015; Wiley and Iii, 2018). Specifically, it is defined as any type of educational teaching that is in the public domain or accessible with an open

licence (Audrey Azoulay, 2019). Unlike conventional, proprietary educational materials and practices, OP encourages educators and students to actively engage in the creation, adaptation, and sharing of educational materials. In so doing, it encourages transparency in teaching practices and makes learning materials accessible to a broader audience, enhancing the visibility of educational content and allowing for wider participation (Jhangiani and Biswas-Diener, 2017).

Despite the increasingly wide adoption, OP remains far from a formalised and recognised standard, but rather a loose set of aspirational guidelines that are "essentially impossible" to reconcile (Wiley and Iii, 2018; Tietjen and Asino, 2021; Christiansen and McNally, 2022; Weller, 2014). (McNally and Christiansen, 2019) suggest OP openness can be evaluated based on the eight primary factors, including copyright, accessibility, language, support costs, assessment, digital distribution, file format, and cultural considerations. None of these are binary "open", underlining the difficulty of defining what is and is not open (McNally and Christiansen, 2019). The OER-enabled pedagogy (OER-P) subset of OP implements many of these factors and is governed by a set of five specific rights, the so-called 5 Rs of OER that regulate openness and reduce the problem of disposable assignment (Wiley, 2013). These consist of the right to retain, reuse, revise, remix and redistribute educational content (Tietjen and Asino, 2021; Wiley, 2013; Wiley and Iii, 2018).

OER-Ps can be seen as an extension of the knowledge-building framework, which values students' work primarily for what it contributes to the community, and secondarily for what it reveals about individual students' knowledge (Bereiter and Scardamalia, 2014; Tietjen and Asino, 2021). After all, having the right to freely distribute materials with the broader outside world inherently increases the value of the work (Wiley, 2013), and it is this key element that sets OER-P apart from other forms of OP and teaching practices, whilst still benefiting from the OP framework (Andrade et al., 2011).

Open distribution and access further saves money and reduces cost, for instance, by minimising duplication and the generation of disposable material, and extend the usability of resources (Wiley and Iii, 2018). As a subset of OP, OER-P benefits from the participatory nature of OP while acknowledging the role of open licensing: OER-P welcomes participation and contributions, regardless of location and background, and conceptualises the learner as a peer contributor to a broader community that tries to address a particular need or problem. Herein the 5 Rs foster a culture of collaboration that facilitates community-supported growth and innovation (Tietjen and Asino, 2021). One only has to recall the COVID-19 pandemic to see the added potential of such an approach (Tietjen and Asino, 2021): Where small departments or single lecturers with little experience in online teaching may struggle to hybridise a class, a community of (networked) OER-P practitioners with complementing expertises have far better chances to update and revise educational materials and courses, especially when aided by student-led co-creation. Co-creation by students has the benefit of increasing diversity in teaching materials, thereby enhancing engagement and improving learning outcomes of individuals who are otherwise underrepresented in education (Biddle and Clinton-Lisell, 2023; Lambert, 2018; Kelly et al., 2022; Nusbaum, 2020).

Today, OP and OER-P can draw upon a rich ecosystem of (open) tools designed to document and distribute software and data, such as Project Jupyter. Project Jupyter promotes open standards and is an open-source project for interactive computing that is widely used in data science, machine learning, and scientific computing (Project Jupyter, 2023; Granger and Pérez, 2021). While Jupyter is often viewed as a means to solve complex, technical work, Jupyter itself solves problems that are fundamentally human in nature. Namely, Jupyter helps humans to decompose problems, think and tell stories with code and

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

data (Granger and Pérez, 2021). The Jupyter Book environment extends Project Jupyter and the underlying Sphinx documentation generation to the narrative environment and provides a hybrid environment in which narrative content can be seamlessly integrated with multimedia and executable content (Executable Books Community, 2020), akin a user-editable and annotatable "unbook" that is not subject to the dramatic inflation of traditional textbooks (Woodworth, 2011; Harrison et al., 2022; Matkin, 2009) and can be easily integrated with co-creation and version/source control solutions such as git. With a strong focus on the collaborative development, creation, and expansion of documentation, along with open licencing options, we decided to test whether Jupyter Books can indeed act as an diverse, equitable and inclusive learning environment that embraces the three pillars of "open" social justice (i.e.., redistributive, recognitive, and representational) described by Lambert (2018) and Biddle and Clinton-Lisell (2023).

This article documents the implementation of Jupyter Books and GitHub in two geoscience undergraduate modules on data acquisition and processing as part of a transition to OER-P teaching. The two integrated, interactive online textbooks cover and detail best practices in the acquisition and processing of unmanned aerial vehicle (UAV)-based data (Geo-UAV) and the subsequent multi-view stereo (MVS) structure-from-motion (SfM) photogrammetry processing (Geo-SfM). Our design was informed and inspired by existing textbooks and tutorials published using Sphinx and Jupyter Book (Henrikki Tenkanen et al., 2023, 2022; Lehmann, 2011; Executable Books Community, 2020; Rhoads and Gan, 2022) that showcases the ease of integrating interactive components within narrative course content. Animations and animated gifs are an important design-choice to increase engagement and lower the barriers for participation (Bakhshi et al., 2016). Because of their capacity to capture short animations, and generally small file sizes, gifs have become a key communication tool on par with other visual media (Miltner and Highfield, 2017; Bakhshi et al., 2016). The adoption of gifs for commercial purposes illustrates the adaptability of the format, and gifs are increasingly used to illustrate points, provide information, advertise, and even augment news and information (Miltner and Highfield, 2017). It is thus not surprising that gifs have been previously used in educational settings (e.g., Altintas et al., 2017; Talati et al., 2020; Russell, 1999; Brisbourne et al., 2002). In this contribution, we apply these and other pedagogical learnings and discusses the implementation of the Jupyter Book environment, including the integrated use of animations and traditional course content, as a tool for enhanced geoscientific learning. We demonstrate the applicability of the environment and assess student learning experiences of using and contributing to the course modules.

2 Methods and data

2.1 Context and participants

This study was conducted as part of two geology courses at a small public research university centre in Norway over 4 years. Both courses were taught asynchronously during a one-week interval by the same instructors, with all course material openly provided through an online portal. Classroom sizes were generally small, with typical participation numbers between 10 and 20 participants with a variety of Earth Science backgrounds. Course 1 was an annual (typically spring) undergraduate geology course focusing on the use of geoscientific digital techniques (n=13 (2021), 19 (2022), 15 (2023), 15 (2024); n~_total~=62). Typical activities included the use of digital field notebooks, the digital acquisition of data, the generation of digital geological

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

models, and the harvesting and integration of multi-physical data across scales. Course 2 was a multi-disciplinary short-course (n=10) that served as an introductory course to UAV-based data acquisition (e.g., legal framework, flight design, etc.) and processing in summer 2023. The participants in Course 1 typically represented the demographic diversity of the university centre (primarily western European and Scandinavian students). Course 1 required at least 60 ECTS within general natural science, of which 30 ECTS within the geosciences. Enrolments in Course 2 featured more diverse educational backgrounds, given that the course was open to scientific and technical staff as well as undergraduate and graduate students from other relevant STEM fields.

The Geo-SfM module (Betlem and Rodes, 2024) was designed with Course 1 in mind and was added to its syllabus in 2021, when the module was first taught, albeit digitally due to COVID-19. The Geo-SfM module introduces structure-from-motion multi-view stereo photogrammetry processing and provides a detailed recipe or cookbook with best practices to follow, including the use of softwares, which parameters to apply, and buttons to click. In subsequent years, Course 1 and the Geo-SfM module were taught in person. Small revisions and upgrades were made to implement feedback provided in the previous year.

The Course 2 syllabus solely comprises the Geo-SfM and Geo-UAV modules, the latter of which was specifically designed for the course. Course 2 was designed to enable students to explore and learn the full chain of UAV-based data acquisition and processing. Development of Geo-UAV (Rodes et al., 2024) accounted for many of the insights gained from the development of the Geo-SfM module; this time focusing on providing self-explanatory recipes for the geoscientific acquisition of UAV-based data sets, in particular, RGB and imagery data. In particular, the Geo-UAV module provides tutorials on the legal framework of UAV-use and covers many aspects related to the piloting of UAVs and UAV-based data acquisition. Like Geo-SfM, the Geo-UAV module was developed as a teaching-aid based on experiences and best-practices acquired through the Svalbox project and its spin-offs (Senger et al., 2021; Betlem et al., 2023).

2.2 Module and course design

The Geo-SfM and Geo-UAV modules modules were designed to facilitate a learning environment that is inclusive, accessible, and diverse in terms of representation of information, learning styles and perspectives. The Jupyter Book environment was implemented as the framework of choice, facilitating the integration of all course content within the modules (Fig. 1). Both modules consist of a series of sessions of increasing difficulty and depth. Each session begins with an introduction to a common theme, which is followed by supporting and background information, multimedia content, session-specific tutorials, and tasks or assignments. Interspersed throughout the sessions are mini-lessons on project management, how to structure and archive data sets, automation, and other topics that support scientific documentation and best-practices.

Following an introduction to the layout of the modules, sessions and key learning outcomes, students were introduced to the GitHub platform (i.e., the backend) and requested to sign up and raise a simple welcome/“hello world” issue through one of the on-page menu bars at the start of the respective courses. This was done to facilitate optimal use of the collaborative framework and allow the students to familiarise themselves with the GitHub backend, including issue tracker and online feedback solutions. The students were then asked to work through the course modules in pairs, applying the concepts of pair learning to further enhance collaborative learning (Nagappan et al., 2003; Drey et al., 2022).

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

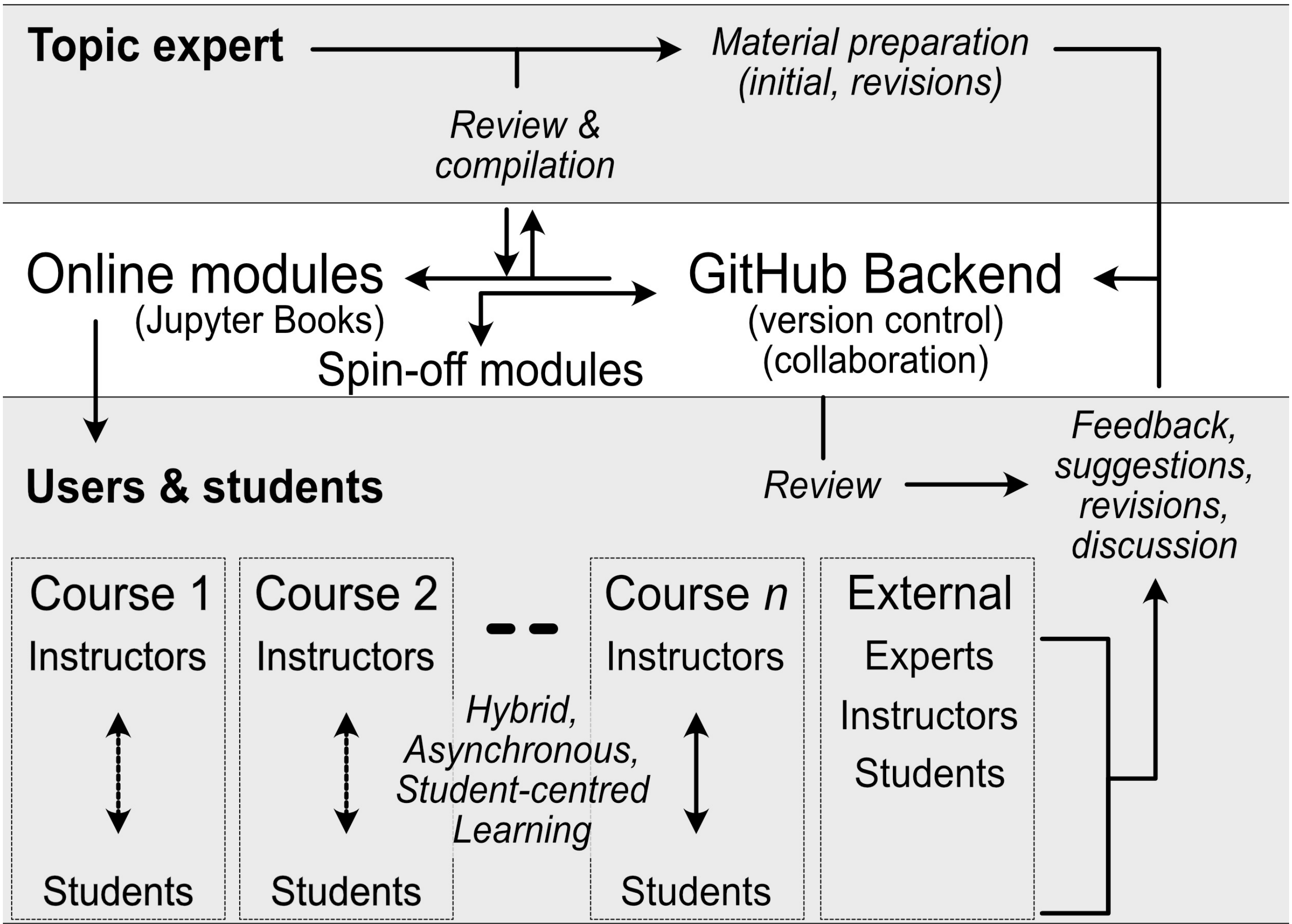

Figure 1. Instructional approaches of Geo-SfM and Geo-UAV integrating the GitHub backend for co-creation.

The GitHub platform, including its Classroom tools, has previously been shown to improve the educational experience for students and teachers (e.g., Zagalsky et al., 2015; Fiksel et al., 2019), and facilitates open hosting of documentation. The use of GitHub allowed detailed tracking of suggestions and corrections proposed by the students and other participants, thus forming the backbone to the co-creation and cooperative learning framework. This detailed log of "improvable" sections (e.g., changes in course content, more accessible phrasing, and additional/revised visual and multimedia assets) was used to further diversify the teaching material and adapt content to the styles and needs of the students. As instructors, we held few in-person lectures and were mainly present to facilitate discussions, guide asynchronous learning and provide technical support.

The GitHub platform provided an alternative venue to ask questions and students were encouraged to seek and receive feedback through the platform as well as from instructors. Online (issue) participation on GitHub, discussions and physical presentations replaced graded assessments and exams. Classroom teaching further implemented the colloquial sharing of results and experiences, with feedback mostly provided by other working groups. In Course 2, the shared assessment for the individual

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

sessions was certified and documented in a course certificate, listing the accomplished learning objectives, and stating their equivalent.

Both shorter and longer animations and videos were implemented in addition to detailed plain-language summaries and static figures to improve the accessibility of learning materials. Specifically, we were interested in determining student reception to the multimedia environment, as well as in assessing optimal playback times versus student retention to optimise the use of animation versus videos in future module designs. We used the LICEcap library (Frankel, 2023) for simple animated screen captures because it is a lightweight, intuitive, and flexible application that supports both Windows and OSX operating systems. The library supports custom capture windows, intermittent recording, and on-screen text messages and information. In total, 31 looping animations were incorporated with durations of between 3.8 and 78 seconds (Table A1). Videos were mainly recorded through the Open Broadcaster Studio (OBS) software package (Kristandl, 2021; Bailey et al., 2017). OBS Studio is a free and open-source software that is a reliable tool for the recording of screens, (instructional) videos and online streams and is easily used without formal training (Basilaia et al., 2020). OBS Studio supports screen, window and camera recording with configurable audio input and output. In total, 11 videos were incorporated with runtime durations of between 39 seconds and 6:28 minutes (Table A1). Students were also shown how to use the software, to lower the barrier for co-creation of multi-media assets.

During the development stages, we particularly appreciated the rich documentation provided by the Jupyter Book project pages (Executable Books Community, 2020) that offer a detailed tutorial of what is possible with the Jupyter Book framework and provide an extensive step-by-step guide on how to get started. This easy-to-follow guide further details various options for sharing the dynamic pages, which are optimised for both mobile and desktop use, and even allowed module participants to make more sophisticated changes to the modules. The runtime environment needed to compile the modules can be easily installed using the standard Python package managers pip, conda or mamba, and contains a set of command-line utilities for the compilation of textbooks from Markdown text (.md), Jupyter Notebook (.ipynb) or reStructuredText (.rst) files – all of which open formats. The implementation of the Markedly Structured Text (MyST) syntax, an extension of Markdown, provides simplicity while still being powerful enough to create rich content pages with text, figures, automatically-generated citations, executable and in-line code-cells, slide-shows, and embedded files (e.g., three-dimensional [3-D], interactive environments) and videos (Chen and Asta, 2022; Executable Books Community, 2020). Although not explored in the Geo-SfM and Geo-UAV modules, pages can also integrate with cloud-providers such as JupyterHub (Project Jupyter, 2023) and Google Colab (Bisong, 2019) to facilitate executable and programmable content without having to install libraries locally.

2.3 Open Pedagogy study

The pedagogy study can be divided into two distinctive phases, i.e., the initial and testing phase (based on the testing method). During the initial phase, i.e., the design phase of the Geo-SfM module in 2021 and 2022, mostly qualitative data were collected from course evaluations and in-class feedback sessions (n=32). Students' feedback was used to optimise the Geo-SfM module for the following year and fed into the design of the Geo-UAV module in early 2023. At the start of 2023 (year 3), we created

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

and distributed a student questionnaire to gather quantitative and qualitative data about students' experiences of the module and perceived impact on their learning in the course.

Participation in the survey was voluntary, data was collected anonymously, and no rewards were offered for participation. Students completed the survey online via Nettskjema, accessible through a link that was only available via the Jupyter Book modules. Further feedback was collected from external participants (independent module users not affiliated with the university), who accessed the online modules independently throughout 2023. Survey questions primarily targeted the user and learning experience of the platform, its accessibility, multimedia and content-diversity design choices, and the options for student (co)creation. Students were asked about their educational/scientific backgrounds, prior experiences with programming, the use of Jupyter Project tools (e.g., Jupyter Notebook/Lab), and the use of online documentation, video hosting platforms (e.g., YouTube), and animated gifs. Students were then provided with quantitative (5-point Likert scale) and qualitative questions on the learning and user experience of the integrated Jupyter Book and GitHub platforms. Fig. 2, Fig. 3 list several questions and statements from the survey along with quantified student feedback.

Implementing feedback from the 2023 courses, the class of 2024 was provided with a more extensive, preparatory three-hour tutorial on how to contribute through so-called forks and pull-requests. Forks and pull-requests allow more sophisticated changes to be made to the content pages but require a (documented) review by other participants and course instructors prior to integration into the live module pages. Herein each interaction is documented and the process automatically attributes co-creators. Assessment of the class of 2024 thus in addition focussed on what can be done to lower the barrier to co-creation as well as its apparent value to participants.

3 Results

In 2023 and 2024, students were asked to take part in the questionnaire during dedicated timeslots directly after the Geo-SfM module was taught in Course 1 (n = 30) and at the end of Course 2 (n = 10). Of the 40 students surveyed, 36 responded. Four external participants (n=4) independently responded to the survey, resulting in a total of 40 responses. The initial coding scheme applied to qualitative feedback was created through the screening of all the responses for common themes and the level of understanding of the assignments (Taylor et al., 2015). The coding scheme and examples of each category are listed in Table 1.

Table 1: Qualitative student feedback with descriptions and examples, grouped by category.

Code categories	Code	Description	Example
Accessibility, content and language	Constructive criticism	Responses that critisised the navigation and design of the modules. N=18	Instructions were sometimes not 100 % clear If there would be a search tool, it might be easier to find information on the page. Other languages than English Maybe sometimes background information and instructions are a bit mixed up. Sometimes the background context was lacking, meaning the tutorial was very helpful itself but it required prework that was not explained. Some tricks and tips were not in the Compendium

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Code categories	Code	Description	Example
Accessibility, content and language	Positive feed-back	Responses that positively referred to the accessibility, content and language of the modules. N=26	While the tutorial explained exactly what to click it also explained why, which was helpful and gave context. I liked how open and accessible everything was, all the supportive python codes etc., just there to use and make life easier. I really liked how clear and step-by-step the instructions were, as it made it easier to move forward (and go back) in my own pace. The use of alternative/multimedia learning resources makes it inclusive.It is a very useful resource. I will always use it when working with photogrammetry.
Co-creation	Constructive feed-back	Responses that independently referred to aspects of co-creation. N=8	It is good that changes can be put in very easy by the user. I liked that it was interactive and that you could change or add anything to improve it for next year. Also, being able to make small changes to the actual site felt inclusive. Some of the instructions used words/names from previous versions of Agisoft, but then again we were encouraged to edit this ourselves (a good thing).
Technical aspects: Naviga-tion and design	Constructive criti-cism	Responses that critisised the navigation and design of the modules. N=16	Navigation is not intuitive. The flow of the page is not great. Links referring to other compendiums was confusing in the beginning Sometimes a bit too much text and therefore loss of structure.
Technical aspects: Naviga-tion and design	Positive feed-back	Responses that positively referred to the navigation and design of the modules. N=28	Flows really well. Clear and logical breakdown of processes and steps are well explained I liked that the processes had been broken down into bitesize chunks and the exercises were logical to follow.
Technical aspects: Multime-dia integration	Constructive criti-cism	Students were specifically asked about the things they disliked about the use of multimedia in the compendiums. N=30.	In some of the videos the text was so zoomed out that it was hard to see what exactly what was being done Videos were too slow Sometimes not text to describe the step, only GIF. Provide text alongside animations/videos. Not able to pause gifs Gifs do not have a clear start/end Some gifs were a bit too long, so if you missed something in the beginning you had to re watch
Technical aspects: Multime-dia integration	Positive feed-back	Students were specifically asked about the things they liked about the use of multimedia in the compendiums. N=39.	The use of videos throughout and along with the instructions was good. Provide quick overview. Made things easy to follow, findable in menus. GIFs are short and therefore show the information very effectively. I did not watch as many YouTube videos but they can show more complex things. As I am a visual learner, the animated gifs helped me a lot throughout the week as it helped to navigated what needed to be done.

The quantitative results are presented as stacked box-plot charts (Fig. 2, Fig. 3), and examples of student responses from the open-ended questions are included in the following results and discussion. The results do not make a distinction between the internal versus external evaluations in the analysis of the feedback. Neither are the results divided between the courses, instead dividing the statistics per module.

3.1 Student perceptions on the learning environment

Student perceptions of the Geo-SfM and Geo-UAV modules were measured using Likert-scale questions developed specifically for this study, with feedback largely similar between the two modules. Overall, students reported agreement that that they were excited about using the online modules, that the modules met their needs, and that the content was clear and easy to navigate. Students also indicated agreement that they would recommend the modules to others, as well as use them as reference works in the future.

Answers to the open-ended questions largely reflected the positive learning experience and showed that the combined Jupyter Book/GitHub platform was valued for its modernness and clear structure, even as only few had noted a previous familiarity

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

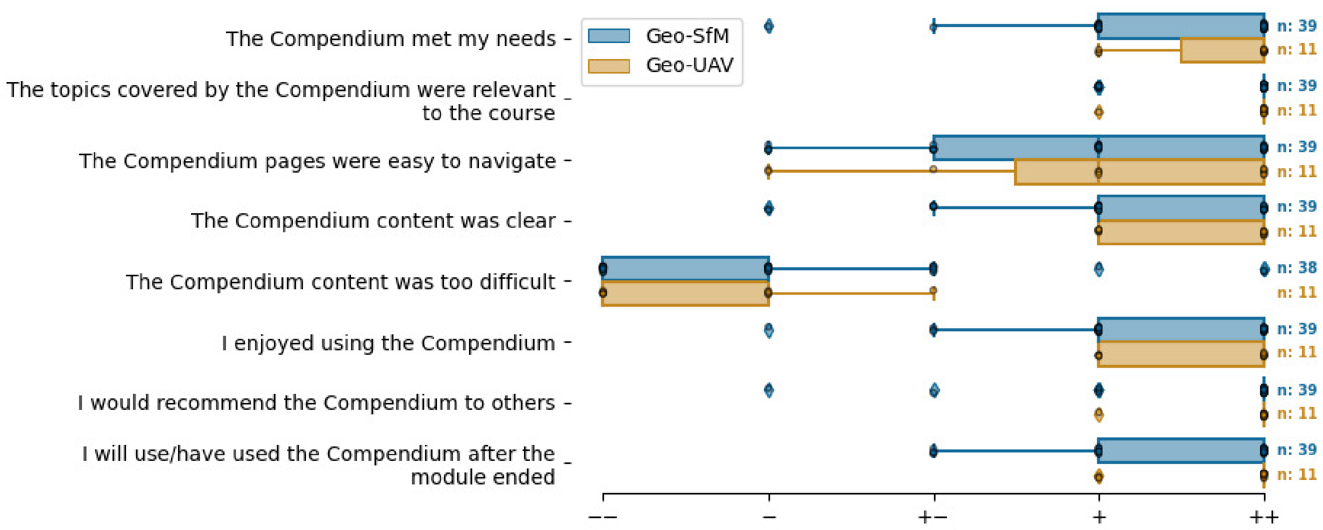

Figure 2. Quantitative student feedback on the Geo-SfM and Geo-UAV modules, here referred to as Compendiums.The bars, boxes and whiskers indicate the mean, one standard deviation and two standard deviations, respectively. Individual scores are separated for clarity.

with either, nor with typical documentation platforms such as e.g., Sphinx and Read The Docs. Students indicated that the open online nature of the platform facilitated diverse and asynchronous learning at one's own pace.

For Geo-UAV, examples of student responses included claims that the module provided a "very good overview of a complex topics and integration of different sources" and that they "liked how open accessible everything was", appreciating "that the processes had been broken down into bitesize chunks and the exercises were logical to follow". One student even referred to the modules "as a 'bible' of tutorials throughout the course", while another reflected that the platform worked well "to consolidate a large amount of information that, if it had purely been communicated verbally, would have been overwhelming to absorb".

Similar student reflections were recorded for the Geo-SfM module, with students noting that "all the supportive Python codes etc., [are] just there to use and make life easier" and that they "liked that pictures and GIFs were used in the tutorials", though not all students were equally excited about the use of lengthy animations.

3.2 Student perceptions on integrated multimedia use

As instructors, we had hoped to create a diverse and accessible learning environment through use of multimedia integration and student-led content creation, thus, students were asked specifically about their previous experiences with multimedia and how they perceived the multimedia use in the modules. The open-ended remarks on the use of animations and videos within the modules resonated well with the quantitative feedback given by the students. Overall, students reported agreement that the use of animations and videos greatly supplemented the main text, and that the quality of animations and videos was high. Indeed, many students reflected that the playtime of animations, in particular, was long and that the medium would benefit from being able to be paused. Similar reflections were mentioned in the open-ended responses, including that students did not like having

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

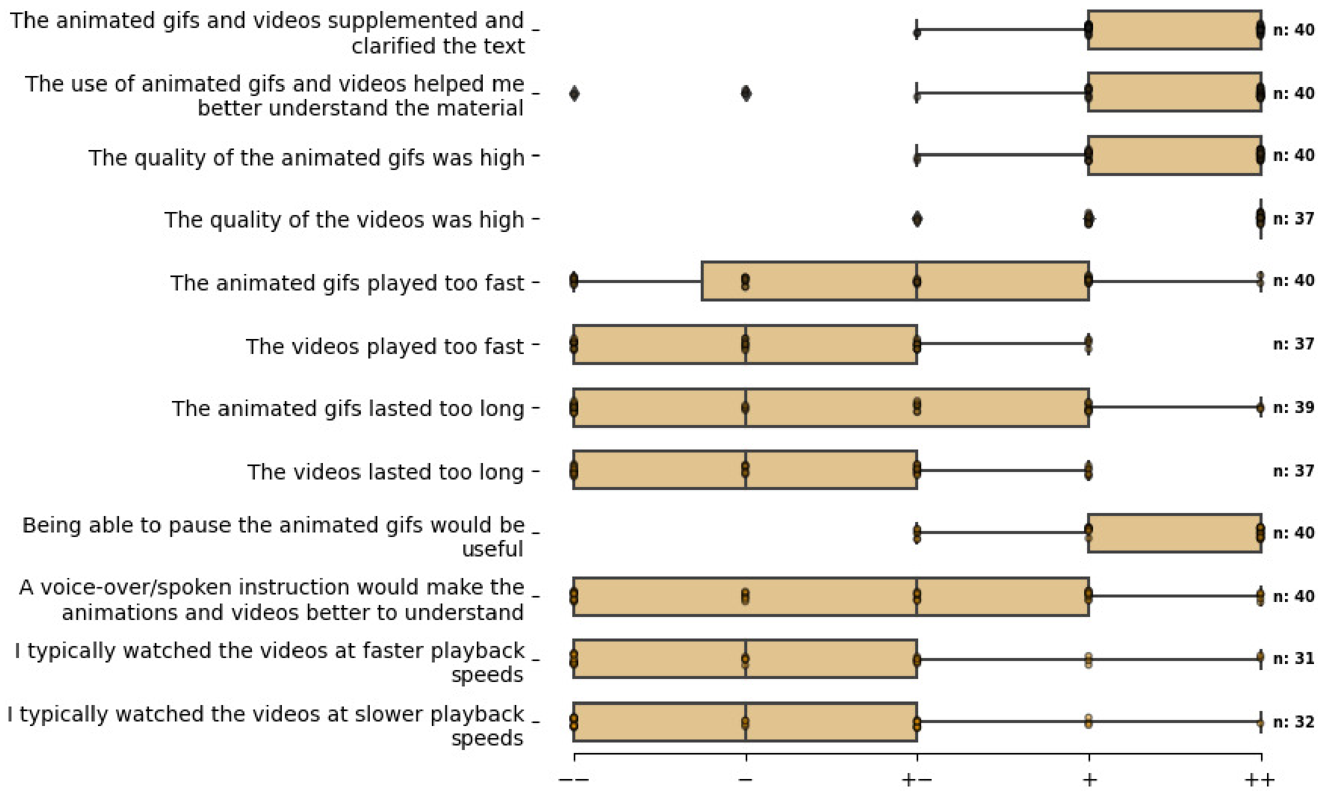

Figure 3. Student feedback on how well they experienced the inclusion of animations and video assets. The bars, boxes and whiskers indicate the mean, one standard deviation and two standard deviations, respectively. Individual scores are separated for clarity.

"to wait for the loop to end to see again the info [they] wanted to see" and that they "had to play it [animations, videos] several times to identify all steps" (as also indicated by playtime statistics in Table A2). Nonetheless, the use of GIFs was perceived as "useful to assist with processes and to reduce the amount of learning through reading".

For both modules, a selection of students reflected on a perceived information disparity between the main body text, multimedia elements, and instructions. This included occurrences of (outdated) animations that were recorded for a previous version of the software, content displayed in multimedia but not the main text body (and vice versa), and the extent of operations covered by the modules versus more advanced usage.

3.3 Student perceptions on co-creation possibilities

Although student perception on co-creation was not quantitatively assessed, eight students independently reflected on it through the open-ended survey questions. Students noted that "being able to contribute to it [the modules]" and "also see other's contributions was helpful in filling in gaps". Students actively contributed to the modules to extend functionality, improve clarity, and replace outdated animations and figures. This is evident from the 39 pull requests to the Geo-SfM module by 10

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

individual students of the 2024 class, which benefited from the extended introduction into GitHub. Unsurprisingly, a subset of students in previous years reported agreement that they were "a bit confused … when it came to using GitHub" as they were not fully introduced to the platform's possibilities at the onset of the courses. The differing levels of introduction, however, did not change student-reported inclusiveness in content creations, or their overall learning experience. Both cohorts reported that it felt inclusive to learn from student-proposed changes from previous years and to be able to further revise and improve the resources for future use, thus becoming part of the community. The "use of GitHub/git to enable community contributions" was noted as an important factor that set the modules apart from previous learning experiences.

4 Discussion

Unlike proprietary lecture materials and technologies, the entry barriers to entry for students learning with open-source resources such as Jupyter Book can be very low (Barba et al., 2019). For many of the students in our courses, the Geo-UAV and Geo-SfM modules were their first foray into the large and growing ecosystem of such tools. Like open-source software (Khan and UrRehman, 2012), OERs have the unique opportunity to deliver inherently collaborative, transparent workspaces that extend beyond the original authoring institution (Caswell et al., 2008).

The present study explored students' perceptions of two Jupyter Book-based modules that were designed with the explicit goals to increase openness, diversity, and student co-creation in creating OERs in OP. In the discussion that follows, we use students' survey responses to assess these and other pedagogical factors and summarise our findings through an *Open Enough* rubric (Christiansen and McNally, 2022) (Table 2; treating *Harvestability* as a *Technical* rather than *Pedagogical* factor). Both Geo-UAV and Geo-SfM (and the Jupyter Book/GitHub framework as a whole) rank high on openness, outranking many of those rated by Christiansen and McNally (2022).

Table 2. Openness as evaluated against the *Open Enough* considerations outlined by Christiansen and McNally (2022).

	Technical Factors			
Course Module	**Copyright/OL**	**Discoverability**	**File Format**	**Harvestability**
Geo-UAV	Mixed (CC-By-NC)	Most Open	Most Open	Most Open
Geo-SfM	Mixed (CC-By-NC)	Most Open	Most Open	Most Open
	Pedagogical Factors			
	Language	**Material costs**	**Assessment**	**Accessibility**
Geo-UAV	Closed	Mixed	Mixed	Most Open
Geo-SfM	Closed	Mixed	Mixed	Most Open
	Other considerations			
	Diverse users	**Culturally inclusive**	**Easy to navigate**	**Responsive design**
Geo-UAV	Yes	Yes	Yes	Yes
Geo-SfM	Yes	Yes	Yes	Yes

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

4.1 Learner-centred design - Co-creating accessible and diverse resources

Overall, students perceived the modules as useful for supporting their learning, while also expressing some concerns about some of the design choices, many of which have been systematically addressed during the 4-year runtime of the project. Student feedback helped to meaningfully revise the modules. Importantly, the course design was strengthened to better support co-creation and curation of content with students, which results in a more learner-centred course design.

Open-source curricula have been shown to facilitate participation, discussion and co-ownership amongst students and the broader community, inviting all to participate in the collaborative development of educational resources (Chen and Asta, 2022; Kim et al., 2021). Analysis of feedback provided by the students indicated as much and highlighted several advantages of using the Jupyter Book/GitHub framework, in particular. Although interactivity, exposure to code (snippets), and integrated multimedia use provided a rich and diverse learning experience certainly helped demystify the abstract notions of scientific data acquisition and processing, the availability of co-creation examples and introductions to the unformatted code of the teaching resources lowered the barrier to become contributors. Students affirmed as much and specifically noted the efficacy of step-by-step instructions that were provided in various formats, different voices, and different levels of interactivity. Students also affirmed what we had hypothesised – that for students to become contributors, they first need to be comfortable using the tools and be given ample opportunity and freedom to revise content, with the side note that it is reviewed and fact-checked by other students and course instructors prior to implementation. The latter, however, must not stand in the way of students to think about what else can be built into the tool to support their learning and that of others. Indeed, students agreed that the exposure to code, programming and the backend was beneficial to the learning experience, not least because co-creating cohesive content follows aspects of (scientific) problem solving: Decomposition, Pattern recognition, Abstraction, and Algorithm design (Barba et al., 2019).

Given that the modules are openly available on the internet and provide accessibility by supplementing multimedia and user-interactions, it is not surprising that the students rated the Geo-UAV and Geo-SfM modules favourably in terms of accessibility, clarity, and ease of use. Both modules generally rated positively on diversity of content, navigation, and their modern design, though would benefit from being translated into additional languages. Perhaps the most important reflections came on the use and integration of animations and videos in addition to the rich text descriptions, which were stated to greatly benefit the diversity and accessibility of the course content. Where shorter animations of up to a few seconds were preferred to explain single steps, students seemed to prefer pausable videos for content with longer playtimes that covered multistep processes. During plenum discussions, students largely agreed with our hypothesis that videos form a higher participation-barrier for co-creation, especially given the ease with which short animations can be re-recorded and updated, and higher cost of videos in terms of time, IT skills, and storage requirements. Thus, in addition to being low-bandwidth, animated gifs were found to be ideally suited as long as the content was sufficiently decomposed into digestible chunks. Further studies are, however, needed to ascertain these findings and find optimal playtime durations for animated and video content.

Indeed, some of the technologies and software being used were nascent and unfamiliar to students, though this was easily overcome through active facilitation, concise foundational work, and hands-on guidance by instructors. For example, the in-

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

troduction to the GitHub backend, alongside a brief tutorial on how to revise the Jupyter Book files, in particular, cultivated an interest in revising the source materials and update information where it was deemed outdated or inconclusive - a recurring student feedback theme. Students easily identified and raised issues, which were then curated and patched by themselves and others, who then also became contributors and co-owners of the content. In addition, the collaborative experience resulted in enhanced collaboration, where multiple student pairs worked together to put more extensive revisions together, including multimedia. Students described the practice as increasing their feeling of belonging, with one student reflecting that the ability "to make small changes to the actual site felt inclusive" and another mentioning the benefits of seeing student contributions from past years. Co-creation also led to pedagogic improvements in the resources. Through student-led revisions, the language and content gradually became clearer and better aligned with students' perspectives and level of understanding.

4.2 Design choices - lessons learned and future directions

Simultaneously building comprehensive teaching materials and designing pedagogical feedback processes can be a challenging task, and one that can only be accomplished through an interdisciplinary collaboration between scientists, social scientists, and students. Over these past four years, we learned a lot from the iterative development of the modules and courses, as well as from the design of the pedagogics framework itself. Where the initial focus in years 1 and 2 lay primarily on assessing the technical usability of the modules and learning-potential of multimedia and animations, qualitative student reflections in years 3 and 4 emphasised the potential for co-creation, as well as the noted inclusivity, diversity, and accessibility benefits of the Jupyter Book/GitHub framework. These lay the groundwork for future activities that are needed to quantify student perceptions of these and other aspects, which we only briefly touched upon in the current study. Still, our results provide valuable insight into how to design and co-create future OER-P content.

From the perspective of instructors, we are excited to see that open-source software and infrastructure has matured to the point where open-source curricula can be easily created, shared, adapted, and, importantly, used and found. Like us and our students, other educators have access to and can remix different compendium versions for their course-specific needs. These adaptations can be easily tracked through the GitHub backend and reintegrated where applicable. Indeed, such adaptations often find their way back to the original modules and contribute to a community-driven development of OERs (e.g., Kim et al., 2021).

At the time of submission, a simple search-engine search for *structure from motion photogrammetry tutorial* shows the Geo-SfM module among the top-listed results, with a similar outcome for the Geo-UAV module. Both modules are thus findable, in the practical sense. External contributions to both Geo-UAV and Geo-SfM are evidence of this, as are the four external participants that independently provided valuable survey feedback to the modules. External findability, however, remains a possible point of concern, with students and practitioners often unaware of existing modules developed elsewhere (e.g., Python GIS; Henrikki Tenkanen et al. (2022)). The need to better address resource availability also became evident from student responses that requested additional compendiums on GIS and programming, as well as feature requests such as the implementation of a search bar - all of which are already readily available either within the modules, or through other open modules elsewhere.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

A key objective of the digital compendiums was to provide lasting, up-to-date course material to a campus with a small department that does not have significant experience nor capacity in developing and maintaining OERs. Another important objective was to create an interactive environment that promotes active learning (Barba et al., 2019; Freeman et al., 2014) and facilitates learning at one's own pace and interest, which are key to learner-centred and asynchronous learning (Georgiadou and Siakas, 2006).

Interactivity drives engagement, interest, and exploration of concepts, which is crucial to both learning and scientific thinking. Both Geo-UAV and Geo-SfM were designed with that in mind, and both were tailored bottom-up to support courses where students have a wide range of experience and ability. Extensive narrative content, examples and code templates help those in need of support, while more-experienced students can modify and adapt examples to independently explore more advanced scenarios.

The iterative and open development of educational content indeed demands considerable effort to create an initial environment that is suitable for students to contribute to. This workload is, however, not unlike the creation of other course content such as lecture slides, and, once established, the OERs benefit inherently from remaining accessible and adaptable to future needs with only minimal time required for student-led (decentralised/co-created) revisions. Version control further allows the documentation of changes, and instructors and students alike can easily visualise changes made to the modules over time, and even reinstate previously removed content. The latter was deemed particularly useful in the development of Course 2, as we were able to build upon the Geo-SfM module's history tracking and transfer previously removed side-notes on data acquisition to the more appropriate Geo-UAV module. It is important to note, however, that cross-linking between different modules should be done with caution, as reflected on in Course 2 evaluations by students. Extensive cross-linking between the Geo-UAV and Geo-SfM modules was often mentioned as a point of confusion, and it may thus be better to integrate, rather than link, corresponding materials in the correct pedagogical structure.

Course 2 also illustrated that the chosen JupyterBook/GitHub framework worked well for both in- and outdoor settings. The Geo-UAV module with its field days, in particular, showcased the possibility of having interactive and portable documentation that can easily be taken into the field and integrated into field-based teaching. Given this success, we are planning on developing additional modules that target field instruments such as differential positioning and various geophysical imaging tools, some of which are already available through a dedicated module portal.

With students actively co-creating and maintaining learning resources, we experienced a significant drop in preparatory workload and instead enabled work on more in-depth resources and specific content requested by students. We also observed that this shifted lectures from a teacher-centric to a learner-centric model that revolved around student-led discussions of findings and design choices. Both aspects simultaneously freed up time and allowed instructors to step in only when really needed. As noted from a student's remark, this was greatly appreciated and provided a unique sense of inclusivity and resulted in a hands-on approach that lectures on a similar topic elsewhere had lacked. The asynchronous and hybrid nature of the modules thus seems to have lowered the participation barrier which may also benefit non-traditional learners and students from underrepresented groups who may have less initial experience with either of the topics covered by the modules.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

In closing, we hope that by documenting our approach to co-creating OER-P content, we have set an important first step in a community-wide effort to catalogue, develop and co-create educational content, and make these openly available to users. However, it must be emphasised that such an effort can only succeed through an interdisciplinary approach in which scientists, social scientists and students co-create teaching resources and assess course design and learning in parallel.

5 Conclusion

This study designed and explored students' attitudes towards learning UAV-based data acquisition and processing with Jupyter Books and GitHub as a backend. The open-source curricula can be easily created, shared, adapted, remixed, and, importantly, are very user friendly. Quantitative survey responses indicated a positive student perception to the learner-centric learning environment as well as the co-creation possibilities provided by the Jupyter Book/GitHub framework. The interactive multimedia environment facilitated asynchronous and active learning, driving engagement, interest, and exploration of concepts that benefit both learning and scientific thinking. Work remains to establish optimal playtime durations for integrated animations and videos, as well as the translation of the modules into different languages. The collaborative nature of the modules was instrumental in cultivating an interest in revising the source materials and updating information where it was deemed outdated or unclear, regardless of the contributor's background, affiliation or level of experience. Co-creation can decrease the workload to maintain and expand up-to-date course content, thus accomplishing one of our key objectives: to provide lasting, up-to-date course material to a campus with a small department that does not have significant experience nor capacity in developing and maintaining OERs. These elements, along students' positive assessment of the framework's inclusivity, diversity, and accessibility, contribute to the *mostly open ranking* both modules attained within the *Open Enough* framework of ranking open pedagogics openness.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Data availability. The source material for the Geo-UAV and Geo-SfM modules, as well as that of Geo-MOD (Course 2) is freely available from their respective Zenodo repositories (Betlem et al., 2024; Rodes et al., 2024; Betlem and Rodes, 2024).

Author contributions. PB: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Writing – Writing & Reviewing, Visualization, Project administration, Funding acquisition, Project administration. NR: Methodology, Software, Investigation, Resources, Writing – Writing & Reviewing, Visualization, Funding acquisition, Project administration. SMC: Resources, Writing – Writing & Reviewing, Funding acquisition, Project administration. MVK: Conceptualization, Methodology, Writing – Writing & Reviewing, Supervision.

Competing interests. The authors declare that they have no conflict of interest.

Ethical statement. The data used in this study were collected on a voluntary and anonymous basis. Identification of individual participants in the questionnaire is impossible. The questionnaire was developed with the Norwegian National Ethics Committee's Guidelines for Research Ethics in the Social Sciences and Humanities in mind. Further, the project was internally reviewed through the University Pedagogy Programme at the University Centre in Svalbard, i.e., the host institution.

Acknowledgements. Foremost, we thank the participating students for constructive feedback and their eagerness to participate in and co-create the modules. We also thank UNIS colleagues Kim Senger, Aleksandra Smyrak-Sikora and Thomas Birchall for feedback during the first years of implementation. We also acknowledge funding and support from the Norwegian Centre for Integrated Earth Science Education iEarth (Norwegian Agency for International Cooperation and Quality Enhancement in Higher Education grant #101060) and additional funding provided by the Norwegian CCS Research Centre (NCCS; industry and partners and the Research Council of Norway grant #257579). Similarly, we keenly acknowledge the close collaboration with the Svalbox project (co-finanded by the University of the Arctic, the Research Council of Norway and the University Centre in Svalbard). We appreciate the academic licenses of Metashape provided by Agisoft as well as the UAVs and other hardware made available through Svalbox. We also thank Henrikki Tenkanen and Vuokko Heikinheimo and their Automating GIS-processes documentation for introducing us to the world of Jupyter Book and open course documentation.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

References

Abernathy, D. R.: The next Layer: Towards Open Pedagogy in Geospatial Education, Transactions in GIS, 27, 1467–1478, https://doi.org/10.1111/tgis.13081, 2023.

Altintas, E., Iigun, S., and Kucuk, S.: Evaluation of Use of Graphics Interchange Format (GIF) Animations in Mathematics Education, Educational Research and Reviews, 12, 1112–1119, 2017.

Andrade, A., Caine, A., Carneiro, R., Ehlers, U., Holmberg, C., Kairamo, A.-K., Koskinen, T., Kretschmer, T., Moe-Pryce, N., Mundin, P., Nozes, J., Reinardt, R., Richter, T., and Silva, G.: Beyond OER – Shifting Focus to Open Educational Practices: OPAL Report 2011, 2011.

Audrey Azoulay: Certified Copy of the Recommendation on Open Educational Resources (OER), 2019.

Bailey, JH. et al.: Open Broadcaster Software, Software, OBS Project, 62, 2017.

Bakhshi, S., Shamma, D. A., Kennedy, L., Song, Y., de Juan, P., and Kaye, J. J.: Fast, Cheap, and Good: Why Animated GIFs Engage Us, in: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, CHI '16, pp. 575–586, Association for Computing Machinery, New York, NY, USA, ISBN 978-1-4503-3362-7, https://doi.org/10.1145/2858036.2858532, 2016.

Barba, L. A., Barker, L. J., Blank, D. S., Brown, J., Downey, A. B., George, T., Heagy, L. J., Mandli, K. T., Moore, J. K., Lippert, D., Niemeyer, K. E., Watkins, R. R., West, R. H., Wickes, E., Willing, C., and Zingale, M.: Teaching and Learning with Jupyter, in: Chapter 2 Why We Use Jupyter Notebook, pp. 1–77, 2019.

Basilaia, G., Dgebuadze, M., Kantaria, M., and Chokhonelidze, G.: Replacing the Classic Learning Form at Universities as an Immediate Response to the COVID-19 Virus Infection in Georgia, International Journal for Research in Applied Science and Engineering Technology, 8, 101–108, 2020.

Bereiter, C. and Scardamalia, M.: Knowledge Building and Knowledge Creation: One Concept, Two Hills to Climb, in: Knowledge Creation in Education, edited by Tan, S. C., So, H. J., and Yeo, J., Education Innovation Series, pp. 35–52, Springer, Singapore, ISBN 978-981-287-047-6, https://doi.org/10.1007/978-981-287-047-6_3, 2014.

Betlem, P. and Rodes, N.: Geo-SfM: Teaching Geoscientific Structure-from-Motion Photogrammetry Processing, Zenodo, https://doi.org/10.5281/zenodo.11173239, 2024.

Betlem, P., Rodés, N., Birchall, T., Dahlin, A., Smyrak-Sikora, A., and Senger, K.: Svalbox Digital Model Database: A Geoscientific Window into the High Arctic, Geosphere, 19, 1640–1666, https://doi.org/10.1130/GES02606.1, 2023.

Betlem, P., Rodes, N., and Cohen, S. M.: Geo-MOD: Teaching Geoscientific Photogrammetry-Based Data Acquisition and Processing, Zenodo, https://doi.org/10.5281/zenodo.11172855, 2024.

Biddle, A. M. and Clinton-Lisell, V.: "The Pictures Allowed Me to Connect to the Material More": Student Perceptions of a Diversity-Focused Open Pedagogy Assignment., Scholarship of Teaching and Learning in Psychology, 9, 405–418, https://doi.org/10.1037/stl0000385, 2023.

Bisong, E.: Google Colaboratory, in: Building Machine Learning and Deep Learning Models on Google Cloud Platform: A Comprehensive Guide for Beginners, edited by Bisong, E., pp. 59–64, Apress, Berkeley, CA, ISBN 978-1-4842-4470-8, https://doi.org/10.1007/978-1-4842-4470-8_7, 2019.

Brisbourne, M. A., Chin, S. S.-L., Melnyk, E., and Begg, D. A.: Using Web-Based Animations to Teach Histology, The Anatomical Record, 269, 11–19, https://doi.org/10.1002/ar.10054, 2002.

Caswell, T., Henson, S., Jensen, M., and Wiley, D.: Open Educational Resources: Enabling Universal Education, International Review of Research in Open and Distributed Learning, 9, 1–11, https://doi.org/10.19173/irrodl.v9i1.469, 2008.

Chen, E. and Asta, M.: Using Jupyter Tools to Design an Interactive Textbook to Guide Undergraduate Research in Materials Informatics, Journal of Chemical Education, 99, 3601–3606, https://doi.org/10.1021/acs.jchemed.2c00640, 2022.

Christiansen, E. G. and McNally, M. B.: Examining the Technological and Pedagogical Elements of Select Open Courseware, First Monday, 27, 1–24, 2022.

Drey, T., Albus, P., der Kinderen, S., Milo, M., Segschneider, T., Chanzab, L., Rietzler, M., Seufert, T., and Rukzio, E.: Towards Collaborative Learning in Virtual Reality: A Comparison of Co-Located Symmetric and Asymmetric Pair-Learning, in: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems, CHI '22, pp. 1–19, Association for Computing Machinery, New York, NY, USA, ISBN 978-1-4503-9157-3, https://doi.org/10.1145/3491102.3517641, 2022.

Executable Books Community: Jupyter Book, Zenodo, https://doi.org/10.5281/ZENODO.2561065, 2020.

Fiksel, J., Jager, L. R., Hardin, J. S., and Taub, M. A.: Using GitHub Classroom To Teach Statistics, Journal of Statistics Education, 27, 110–119, https://doi.org/10.1080/10691898.2019.1617089, 2019.

Frankel, J.: Justinfrankel/Licecap, 2023.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., and Wenderoth, M. P.: Active Learning Increases Student Performance in Science, Engineering, and Mathematics, Proceedings of the National Academy of Sciences, 111, 8410–8415, https://doi.org/10.1073/pnas.1319030111, 2014.

Georgiadou, E. and Siakas, K. V.: Distance Learning: Technologies; Enabling Learning at Own Place, Own Pace, Own Time, in: Learning and Teaching Issues in Software Quality, Proceedings of the 11th INternational Conference on Software Process Improvement - Research into Education and Training, edited by R. Dawson, Georgiadou, E., Linecar, P., Ross., M., and Staples, G., pp. 139–150, The British Computer Society, Southampton, UK, ISBN 1-902505-77-8,, 2006.

Granger, B. E. and Pérez, F.: Jupyter: Thinking and Storytelling With Code and Data, Computing in Science & Engineering, 23, 7–14, https://doi.org/10.1109/MCSE.2021.3059263, 2021.

Harrison, M., Paskevicius, M., Devries, I., and Morgan, T.: Crowdsourcing the (Un)Textbook: Rethinking and Future Thinking the Role of the Textbook in Open Pedagogy, The Open/Technology in Education, Society, and Scholarship Association Journal, 2, 1–17, https://doi.org/10.18357/otessaj.2022.2.1.30, 2022.

Hegarty, B.: Attributes of Open Pedagogy: A Model for Using Open Educational Resources, Educational Technology, 55, 3–13, 2015.

Henrikki Tenkanen, Christoph Fink, and Håvard Wallin Aagesen: Automating GIS Processes 2022, https://autogis-site.readthedocs.io/en/latest/index.html, 2022.

Henrikki Tenkanen, Vuokko Heikinheimo, and David Whipp: Python for Geographic Data Analysis, https://pythongis.org/index.html, 2023.

Jhangiani, R. S. and Biswas-Diener, R.: Open: The Philosophy and Practices That Are Revolutionizing Education and Science, Ubiquity Press, ISBN 978-1-911529-02-6 978-1-911529-03-3 978-1-911529-00-2 978-1-911529-01-9, https://doi.org/10.5334/bbc, 2017.

Kelly, A. E., Laurin, J. N., and Clinton-Lisell, V.: Making Psychology's Hidden Figures Visible Using Open Educational Resources: A Replication and Extension Study, Teaching of Psychology, p. 00986283221108129, https://doi.org/10.1177/00986283221108129, 2022.

Khan, M. A. and UrRehman, F.: Free and Open Source Software: Evolution, Benefits and Characteristics, International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), 1, 1–7, 2012.

Kim, S., Bucholtz, E. C., Briney, K., Cornell, A. P., Cuadros, J., Fulfer, K. D., Gupta, T., Hepler-Smith, E., Johnston, D. H., Lang, A. S., Larsen, D., Li, Y., McEwen, L. R., Morsch, L. A., Muzyka, J. L., and Belford, R. E.: Teaching Cheminformatics through a Collaborative Intercollegiate Online Chemistry Course (OLCC), Journal of Chemical Education, 98, 416–425, https://doi.org/10.1021/acs.jchemed.0c01035, 2021.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Kristandl, G.: "All the World's a Stage" – the Open Broadcaster Software (OBS) as Enabling Technology to Overcome Restrictions in Online Teaching, Compass: Journal of Learning and Teaching, 14, https://doi.org/10.21100/compass.v14i2.1241, 2021.

Lambert, S. R.: Changing Our (Dis)Course: A Distinctive Social Justice Aligned Definition of Open Education, Journal of Learning for Development, 5, https://doi.org/10.56059/jl4d.v5i3.290, 2018.

Lehmann, R.: The Sphinx Project, Universität Potsdam, Project Documentation, 2011.

Matkin, G. W.: Open Learning : What Do Open Textbooks Tell Us About the Revolution in Education?, Working Paper, University of Californa at Berkeley. Center for Studies in Higher Education, 2009.

McNally, M. B. and Christiansen, E. G.: Open Enough? Eight Factors to Consider When Transitioning from Closed to Open Resources and Courses: A Conceptual Framework, First Monday, 24, 2019.

Miltner, K. M. and Highfield, T.: Never Gonna GIF You Up: Analyzing the Cultural Significance of the Animated GIF, Social Media + Society, 3, 2056305117725 223, https://doi.org/10.1177/2056305117725223, 2017.

Nagappan, N., Williams, L., Wiebe, E., Miller, C., Balik, S., Ferzli, M., and Petlick, J.: Pair Learning: With an Eye Toward Future Success, in: Extreme Programming and Agile Methods - XP/Agile Universe 2003, edited by Maurer, F. and Wells, D., Lecture Notes in Computer Science, pp. 185–198, Springer, Berlin, Heidelberg, ISBN 978-3-540-45122-8, https://doi.org/10.1007/978-3-540-45122-8_21, 2003.

Nusbaum, A. T.: Who Gets to Wield Academic Mjolnir?: On Worthiness, Knowledge Curation, and Using the Power of the People to Diversify OER, Journal of Interactive Media in Education, 2020, 2020.

Project Jupyter: JupyterHub, https://jupyter.org, 2023.

Rhoads, S. A. and Gan, L.: Computational Models of Human Social Behavior and Neuroscience: An Open Educational Course and Jupyter Book to Advance Computational Training, Journal of Open Source Education, 5, 146, https://doi.org/10.21105/jose.00146, 2022.

Rocca-Serra, P., Gu, W., Ioannidis, V., Abbassi-Daloii, T., Capella-Gutierrez, S., Chandramouliswaran, I., Splendiani, A., Burdett, T., Giessmann, R. T., Henderson, D., Batista, D., Emam, I., Gadiya, Y., Giovanni, L., Willighagen, E., Evelo, C., Gray, A. J. G., Gribbon, P., Juty, N., Welter, D., Quast, K., Peeters, P., Plasterer, T., Wood, C., van der Horst, E., Reilly, D., van Vlijmen, H., Scollen, S., Lister, A., Thurston, M., Granell, R., and Sansone, S.-A.: The FAIR Cookbook - the Essential Resource for and by FAIR Doers, Scientific Data, 10, 292, https://doi.org/10.1038/s41597-023-02166-3, 2023.

Rodes, N., Betlem, P., and Cohen, S. M.: Geo-UAV: Teaching Geoscientific Drone-Based Data Acquisition, Zenodo, https://doi.org/10.5281/zenodo.11173399, 2024.

Russell, D. A.: Animations for Teaching More Advanced Acoustics Topics, The Journal of the Acoustical Society of America, 106, 2197, https://doi.org/10.1121/1.427457, 1999.

Senger, K., Betlem, P., Birchall, T., Buckley, S. J., Coakley, B., Eide, C. H., Flaig, P. P., Forien, M., Galland, O., Gonzaga, L., Jensen, M., Kurz, T., Lecomte, I., Mair, K., Malm, R. H., Mulrooney, M., Naumann, N., Nordmo, I., Nolde, N., Ogata, K., Rabbel, O., Schaaf, N. W., and Smyrak-Sikora, A.: Using Digital Outcrops to Make the High Arctic More Accessible through the Svalbox Database, Journal of Geoscience Education, 69, 123–137, https://doi.org/10.1080/10899995.2020.1813865, 2021.

Talati, I. A., Choi, H. H., and Filice, R. W.: Cinebot: Creation of Movies and Animated GIFs Directly from PACS-Efficiency in Presentation and Education, Journal of Digital Imaging, 33, 792–796, https://doi.org/10.1007/s10278-020-00325-1, 2020.

Taylor, S. J., Bogdan, R., and DeVault, M. L.: Introduction to Qualitative Research Methods: A Guidebook and Resource, John Wiley & Sons, ISBN 978-1-118-76721-4, 2015.

Tietjen, P. and Asino, T. I.: What Is Open Pedagogy? Identifying Commonalities, International Review of Research in Open and Distributed Learning, 22, 185–204, https://doi.org/10.19173/irrodl.v22i2.5161, 2021.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Weller, M.: The Battle for Open, Ubiquity Press, ISBN 978-1-909188-34-1 978-1-909188-36-5 978-1-909188-33-4 978-1-909188-35-8, https://doi.org/10.5334/bam, 2014.

Wiley, D.: Defining the “Open” in Open Content and Open Educational Resources – Improving Learning, https://opencontent.org/definition, 2013.

Wiley, D. and Iii, J. L. H.: Defining OER-Enabled Pedagogy, The International Review of Research in Open and Distributed Learning, 19, https://doi.org/10.19173/irrodl.v19i4.3601, 2018.

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., Gonzalez-Beltran, A., Gray, A. J. G., Groth, P., Goble, C., Grethe, J. S., Heringa, J., ’t Hoen, P. A. C., Hooft, R., Kuhn, T., Kok, R., Kok, J., Lusher, S. J., Martone, M. E., Mons, A., Packer, A. L., Persson, B., Rocca-Serra, P., Roos, M., van Schaik, R., Sansone, S.-A., Schultes, E., Sengstag, T., Slater, T., Strawn, G., Swertz, M. A., Thompson, M., van der Lei, J., van Mulligen, E., Velterop, J., Waagmeester, A., Wittenburg, P., Wolstencroft, K., Zhao, J., and Mons, B.: The FAIR Guiding Principles for Scientific Data Management and Stewardship, Scientific Data, 3, 160 018, https://doi.org/10.1038/sdata.2016.18, 2016.

Woodworth, E. D.: Being the Unbook, Being the Change: The Transformative Power of Open Sources, The Journal of the Assembly for Expanded Perspectives on Learning, 17, 7, 2011.

Zagalsky, A., Feliciano, J., Storey, M.-A., Zhao, Y., and Wang, W.: The Emergence of GitHub as a Collaborative Platform for Education, in: Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing, CSCW ’15, pp. 1906–1917, Association for Computing Machinery, New York, NY, USA, ISBN 978-1-4503-2922-4, https://doi.org/10.1145/2675133.2675284, 2015.

https://doi.org/10.5194/gc-2024-6
Preprint. Discussion started: 16 May 2024

Appendices

Table A1. Multimedia counts and playtime statistics.

Module	Feature type	Feature count	Internal/External	Playtime (min)	Playtime (mean)	Playtime (max)	Playtime (std)
Geo-SfM	Animated gifs	17	17/0	8.4 s	23.7 s	78.0 s	17.9 s
Geo-UAV	Animated gifs	14	14/0	3.8 s	8.1 s	13.0 s	2.3 s
Geo-SfM	Video	4	1/3	130 s	171.8 s	206 s	32.9 s
Geo-UAV	Video	8	2/6	39 s	178.6 s	388 s	101.4 s

Table A2. Feedback on the average number of times an animation or video was replayed and paused.

Frequency	Ani. rewatch	Vid. rewatch	Vid. pause
0	6	18	18
1-3	21	23	17
4-6	12	0	4
7-10	2	0	2