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Open Educational Resources:
Too good to be true or the future of education?

O. Kavatsyuk, H.J.A. Beldhuis, F. Bianchi, M.B. Blikmans, M. Buist-Zhuk, V.E. Heininga, S.Hoekstra, J. Noel-Storr, W.S. Rossi, M. Seri, and M.K. van Vugt

Resources and links are listed in Appendix A

Open Educational Resources: Too good to be true?

There are many things students and instructors do not agree on, however, one thing they all concur with: study books are expensive. That is, while the debate about the negative effects of highly inflated study costs, and increased debt, on students' performance is ongoing: the students continue - perforce - to work with outdated editions or (illegally scanned or obtained) pdf versions of their required or recommended textbooks. Open Educational Resources (OER) are an alternative to expensive study books, and more arguments than just costs support this philosophy. For example, OER allow for easier collaboration and verification of teaching materials (with both student- and peer-review) and, most importantly, make teaching materials more uniform, better findable, and facilitate instructor's visibility. These characteristics give OER (potentially) an important role in the "Recognition and Reward" schemes for teachers and researchers.

The University of Groningen is promoting the use of OER through the University Library, and the Open Education pillar of the Open Science programme. For example, by organizing information and training sessions; exploring ways to incentivise the (re)use and creation of OER; implementing the technical infrastructure for hosting, sharing and creating OER; and by developing support services for Open Education. However, many instructors and students alike wonder: how can a free study book be of high quality, up-to-date, and reliable? In this opinion paper, we provide answers to these questions with a focus on Science, Technology, Engineering and Mathematics (STEM) subjects[1]. In addition to addressing the question of how open access/free materials can have high quality, and what support is required to achieve that, we review the different types of OER, including open textbooks, open interactive tools, open courses, MOOCs (Massive Online Open Courses) and open source assignment platforms.

Introduction

The United Nations Educational, Scientific and Cultural Organization (UNESCO) gives the following definition of OER:

"teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" [1].

[1] Disclaimer: mentioned platforms, tools and resources are suggestions of useful resources made by the authors based on their personal experience and courses they teach.

As underlined by the William and Flora Hewlett Foundation, OER can be full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge [2].

These definitions would not be complete without addressing the so-called 5R permissions proposed by David Wiley [3]:

- **Retain** – download, duplicate, store
- **Reuse** – use in a class, website or in a video
- **Revise** – adjust or modify content (e.g. translate into another language)
- **Remix** – re-order, combine or revise the original content, creating something new (e.g., mashup)
- **Redistribute** – share/re-post the original content, your revisions, or your remixes

Open Educational Resources are still less known than, for example, Open Source Software, the most famous being Mozilla Firefox (web-browser), Python (programming language), Linux (operating system) and Blender (3D animation).

Figure 1. Open Source Software is quite well-known nowadays, with the most famous being Mozilla Firefox (web-browser), Python (programming language), Linux (operating system) and Blender (3D animation).

University staff involved in teaching at top institutes make high-quality educational materials, such as lectures, textbooks and learning materials, publicly available at no cost at an increasing scale. These efforts enable educators to learn from and build upon each other's work, including teachers and enthusiasts from around the world including countries that have lower possibilities for economic commitments to education.

In the Netherlands, the importance of OER is underlined in the mission and vision of the Ministry of Education, Culture and Science aiming to make teaching and learning materials

as open as possible in the coming three years [4]: in the 2021-2025 Coalition agreement[2] that strives to make Open Science and Open Education the norm; and in the "Versnellingsplan Onderwijsinnovatie met ICT" [5] (specifically, the Zone "Towards digital (open) educational resources").

Quality matters

Contrary to the popular belief that free-to-use open resources - especially textbooks - cannot be of as good quality or as effective as more expensive commercial materials: research and surveys in the area of OER consistently portray a different picture.

In their latest research report and surveys, Bay View Analytics indicate that the ratings that faculty give required materials are higher for OER than for commercially published resources. Faculty tend to provide a higher overall rating of open resources; they also rate most of the specific aspects in OER (e.g.: coverage, accuracy, costs, etc.) as equally good or better than commercial materials. The only area where OER are still behind commercial alternatives is in the quality of supporting and/or supplemental materials [6].

A meta-analysis that summarises textbook studies examining the learning performance of over 100,000 students indicates an equivalent learning performance of students using open textbooks and those using commercial textbooks. A study by Clinton and Khan [7] reported that courses in which open textbooks were used had 29% lower withdrawal rates than courses taught with commercial textbooks. Other studies suggest that students perform equally well in courses using OER as in courses using traditional materials, and students generally seem to prefer OER to more traditional resources [8, 9]. Furthermore, other research shows that OER adoption can even increase student performance, compared to using traditional commercial resources [10, 11].

Another metric important to consider in terms of OER adoption and efficacy is the cost savings. According to data from the US, the prices of textbooks have grown more than three times the rate of inflation since the 1970s [12]. The lack of access to affordable course materials has been further exacerbated by the COVID-19 pandemic and subsequent university closures.

However, there are also concerns that teachers express. Open textbooks are often composed of chapters written by different authors without (or a very little) support of the professional editors and graphic designers. This can lead to different notation being used in chapters, compromised quality of figures and confusing formulations. Therefore, adopting an open textbook can require a lot of time (e.g. searching for a good quality text, making necessary changes).

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[2] https://www.government.nl/documents/publications/2022/01/10/2021-2025-coalition-agreement

Open textbooks

An open textbook is a textbook published under an open-copyright license (e.g. Creative Commons license; https://creativecommons.org/about/cclicenses), and made available online to be freely used by students, teachers, and members of the public. See, for example, the open textbook “Physics of Light and Optics”: https://optics.byu.edu/textbook. A great feature of this open textbook is that it enables the use of online discussion and collaborative reading of the textbook.

Open textbooks can be a creation of teachers, or a result of collaboration between teachers and their students (i.e., engaging in Open Pedagogy practices). A great example of such a collaborative open textbook development is the UG course “Biopsychology”: https://sites.google.com/rug.nl/biopsychologyinterdisciplinary/home. Some of the student content developed during this course will be incorporated by the teacher as a part of the upcoming open textbook on the subject.

OpenStax

One of the most known initiatives is OpenStax https://openstax.org/ [13], launched in 2012, that currently offers 42 textbooks for university and high-school courses, including physics, mathematics, biology, economics, psychology, and many more subjects. Each OpenStax textbook is free to view, download, and, if needed, also to modify (e.g., in order to choose chapters that fit your course).

OpenStax follows a traditional publishing route: it has an editorial company that hires best experts on a chosen subject to write a textbook, as well as recruiting several main reviewers, and typically around 100 peer reviewers per book [14]. The books are created at a typical level of cost to the publisher, however, they are distributed to universities and students at no cost – and can be obtained as print versions also at very low costs. This is because OpenStax relies upon philanthropic organisations and donors, such as the Bill & Melinda Gates Foundation [15].

In contrast to commercial companies that expect to make financial profit with their products, non-profit foundations expect a social return on investment: for example, student savings, and textbooks available for all (the most important profit). Therefore, OpenStax prioritises textbooks that can potentially produce the most “social return” on investment. One can find plenty of books for high-enrollment courses, mostly introductory courses in mathematics and sciences.

Figure 2. The popular open textbooks platforms are OpenStax, The Open Textbook Library and LibreTexts.

The Open Textbook Library

Another valuable resource of open textbooks is “The Open Textbook Library” [16]. This collection currently counts 952 [16] books, with 60% of their books reviewed by faculty members with expertise in certain subject areas (from institutions that have joined the Open Education Network https://open.umn.edu/oen). In addition, most of these open textbooks are reviewed during production [17].

LibreTexts

Another important player on the open textbook market is LibreTexts https://libretexts.org/ with 398 books and 223 millions students served [18]. Many LibreTexts texts contain interactive visualizations to improve learning and understanding. With so-called “dynamic figures”, students can manipulate 3D objects for interactive visualization. Figure 3 shows an example of such a figure for the 3D model of the protein Porin [19].

In addition to books and dynamic figures, LibreTexts also allows individual authors to host them publicly on a website for free (e.g., https://learningstatisticswithr.com). For more specific examples of such open textbooks, please see recommendations by the University Groningen Library [20].

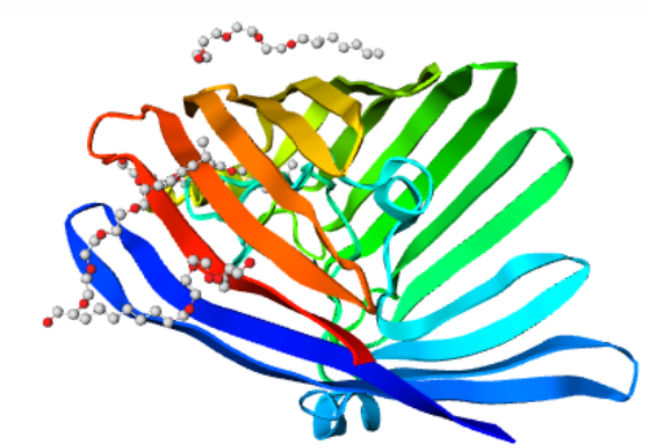

Figure 3. 3D model of the protein Porin, a part of the interactive visualization offered by the LibreTexts textbooks, see [19] for a moving figure.

Open Interactive Tools

For STEM courses, a number of valuable (according to our lecturers) open access tools are available that help students to get a better understanding of subjects through virtual experiments and figures that can be manipulated. Below we list some examples.

PhET interactive simulations

The PhET Interactive Simulations https://phet.colorado.edu/ project was founded in 2002 by the Nobel Laureate Carl Wieman, at the University of Colorado Boulder. The aim of the PhET interactive simulations is to allow all students to experience science and mathematical practices in a game-like, very intuitive environment [21], an example is given in Figure 4. Currently, there are 161 simulations (in 97 languages, including English and Dutch) and more than 3000 teacher-submitted lesson plans available.

CalcPlot3D

CalcPlot3D was created by Paul Seeburger, Professor of Mathematics at Monroe Community College, USA with NSF grant support [22]. It has many extended features, and allows students to explore 3D surfaces (Figure 5), vector and multivariable calculus topics, differential equations, and even prepare files for 3D printing.

GeoGebra

GeoGebra (the name made from two words ***Geo****metry* and *A****lgebra***) is an interactive tool to explore geometry, algebra, statistics and calculus [23-24]. The GeoGebra project was

started by Markus Hohenwarter in 2001 as part of his master's thesis at the University of Salzburg.

Desmos

Desmos [25], with its intuitive design, is an online alternative for a graphical calculator. It is easy to use in class for both teachers and students.

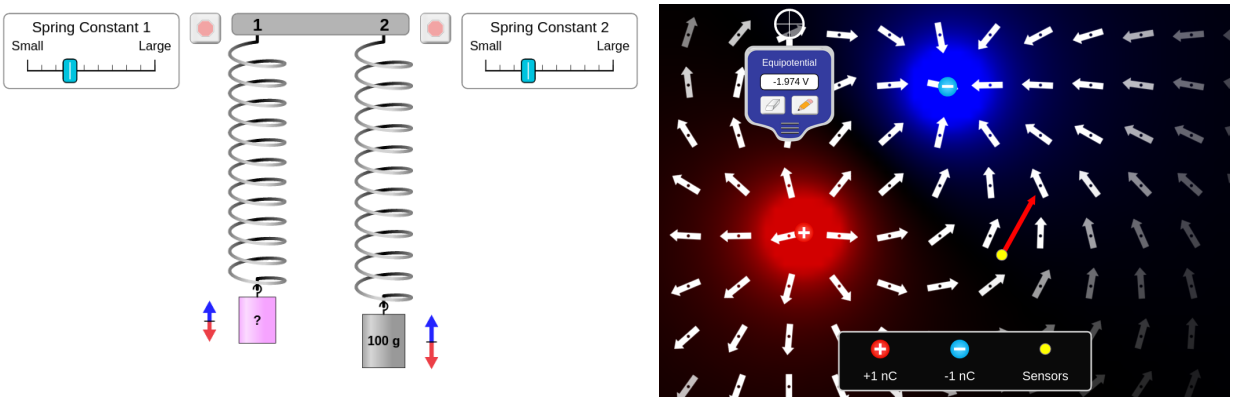

Figure 4: Examples of PhET interactive simulations: "Springs and Masses" and "Charges and Fields" [21].

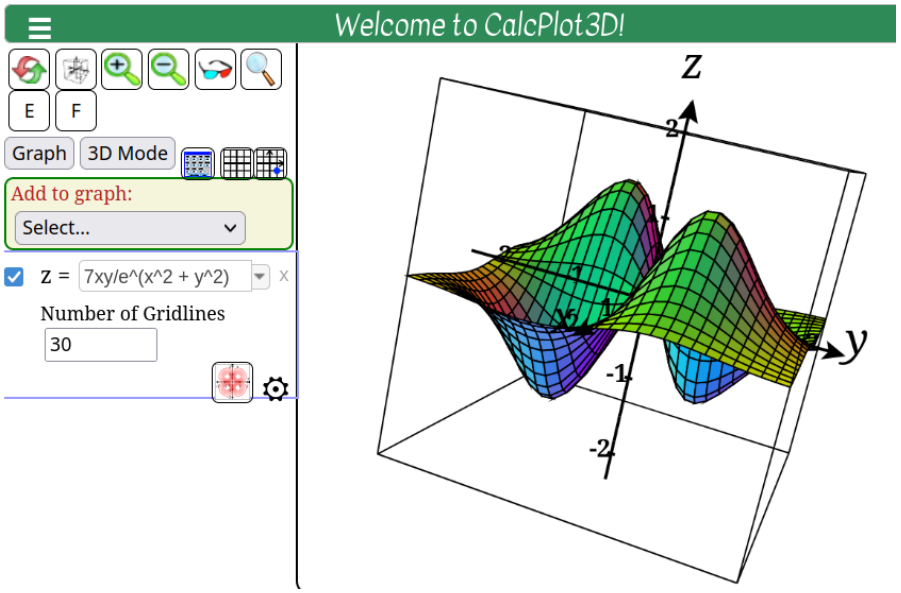

Figure 5: An example of graphing 3D surfaces with CalcPlot3D [23-24].

SageMath
SageMath [26] https://www.sagemath.org/ is a great free open-source mathematics software system licensed under the GPL. It builds on top of many existing open-source packages: NumPy, SciPy, matplotlib, Sympy, Maxima, GAP, FLINT, R and many more. One can access their combined power through a common, Python-based language or directly via interfaces or wrappers. The mission of SageMath is to create a viable free open source alternative to Magma, Maple, Mathematica and Matlab (commercial software).

And more
For teaching computer programming, there are a wide range of tools available online, e.g., Software Carpentry [27]. Software Carpentry is a volunteer project dedicated to teaching basic computing skills to researchers. All of their lesson materials are freely reusable under the Creative Commons – Attribution license.

The physics programme at the University of Groningen is often using Widgets from the following resource: https://www.falstad.com/mathphysics.html (it provides more advanced physics/mathematics examples (dynamic figures) than PhET simulations).

Open courses and MOOCs

MOOCs (Massive Open Online Courses) [28] are available for anyone to enroll. MOOCs are free online courses and provide a way to learn new skills, advance people's careers and deliver quality educational experiences at scale.
However, MOOCs are most often not "true" OER. Usually, they are free to access but are not licensed with an open license and, therefore, cannot be freely adapted, remixed or repurposed without violating licensing terms/IP laws. However, MOOCs could still be a great (and completely legal) educational resource to use if properly integrated into a course. Some MOOCs are openly licensed too and can be reused/edited/remixed with minimal restrictions, and therefore classified as OER.

Open Source Educational Software

WebWork
WeBWork [29] is an Open-Source online assignment system for mathematics and sciences courses with a large data-base of problems and a possibility to create ones' own exercises. The fact that problems are individualized (Figure 5) allows for collaboration between students, even online, without having one student to provide THE answer for the

whole group. Each individual needs to understand how the final result is achieved in order to apply their common method to their individual version of the assignment.
There are no subscription costs to Webwork, only hosting needs to be arranged (a single course can be hosted at the Openwebwork.org server [29]).

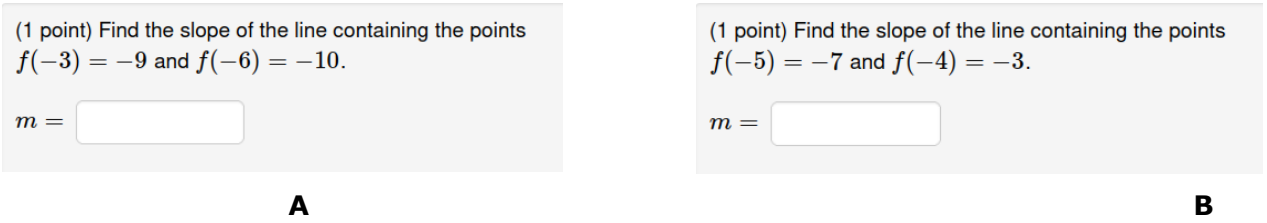

Figure 5: In WeBWork students get individual versions (A and B) of the same problem (the same task, numbers are different). Note: In this example, only two versions are shown out of many more possibilities.

WeBWork gives instructors a possibility to offer individual problems as often as needed, providing immediate feedback with a progress overview available for both faculty and students. Once instructors have a set of assignments that is aligned with their content and learning goals, they can reuse them infinitely, since they are individualized. Thus WeBWork not only reduces the workload for the instructors (re-usability), but increases the social interactions between the students (collaborative learning). The fact that WeBWork lends itself for remote collaboration (e.g. via Zoom or Google-meet) makes it suitable for all teaching formats (live/online).

In addition, WeBWork exercises can be integrated in Open Textbooks. A great example of it is Active Calculus project https://activecalculus.org/index.html. For example, see page https://activecalculus.org/single/2017/sec-2-1-elem-rules.html with the elementary derivative rule. After the explanation, there are exercises offered with Webwork.

FORRT
FORRT (https://forrt.org) is an open source collection of teaching tools for teaching reproducible research. This website collects resources, including exercises and lesson plans that make teaching really easy. Lecturers can also contribute their own resources.

Sharing developed resources

Apart from using existing resources, teachers may also develop their own resources. We think it would be good to have a central place where teachers can share their resources. A

promising development in the Netherlands is edusources search portal (https://edusources.nl/) with the accompanying repository SURFsharekit (https://www.surfsharekit.nl/). However, we also believe that the University of Groningen should consider its own OER platform. It will contribute to the visibility of our university in terms of educational innovations and high quality of education and research. Giving it a prominent place on the university webpages will attract prospective students and staff.

The role of OER in the "Reward and Recognition" initiatives

Creating, but also adopting and updating existing OER is a time consuming task. We think that universities should consider various reward schemes to promote the use of OER and stimulate and reward lecturers to use and create them.
For example, Portland State University offers a grant scheme [30] where lecturers are offered grants up to $5000 for creating an original open textbook for their course. It has the following award level:

- Level 1 - $1,000: Locate, evaluate, and adopt an existing Open Educational Resource
- Level 2 - $2,000: Adapt, update, or combine existing Open Educational Resources into a new resource
- Level 3- $5,000: Create an original Open Educational Textbook for your course

In addition to possible financial stimulation, OER should become a part of the "Reward and Recognition" scheme. Examples of existing schemes are:

- University of British Columbia: Guide to Reappointment, Promotion and Tenure Procedures at UBC [pdf] (pp. 16, 19, 48)
- University of Massachusetts Amherst: Provost Annual Promotion and Tenure Memo [pdf] (p. 5)
- Miami University: Guidelines for Second Promotion of TCPL Faculty Members

Peer review of open educational resources

Another point that may be added: it would be good to have a peer review system for resources so that teachers interested in OER can get reviews before investing in trying to use those. A significant challenge for peer review is the lack of time. To solve this issue, we suggest that peer review of educational materials should be recognized in academic evaluations, potentially through a system like Publons (https://publons.com/about/home/).

Conclusions

Creating and publishing a textbook is a very expensive process, as many players are involved: writers, editors, peer reviewers, designers, publishers and more. Notwithstanding that these are valid costs, all students, and especially those for whom textbooks are a painful expense for their modest budget or add up to their debt, can benefit from open textbooks. Although OER sounds like too good to be true, we think it is the future of education.

The idea of OER is to make education materials available to everyone. UNESCO sees OERs as means of promoting access, equity and quality in the spirit of the Universal Declaration of Human Rights [32], and, in line with these spirits, a large part of the early work on OER was funded by universities and foundations such as the William and Flora Hewlett Foundation.

Authors of this opinion paper give the following recommendations:

1. We would like to underline that **investing into creating reliable high-quality OER** should be on the priority list for the Dutch (higher) education systems and funding agencies and for the University of Groningen.

2. We think university **instructors should be encouraged to, but also be rewarded** and receive recognition for, creating OER (e.g., writing open textbooks for courses taught at the faculties). We would like to propose to **allocate time for creating or adopting OER** similar to how that is typically done within universities for other tasks (e.g., time devoted to committees of steering groups is sometimes deducted from staffs' teaching load). Moreover, we also recommend **investing into OER support infrastructure**, for example, incorporating OER in Pure, linking to (inter)national platforms like Edusources.nl.

3. We recommend that **peer review of educational materials should also be recognized** in academic evaluations, potentially through a system like Publons (https://publons.com/about/home/).

4. We suggest that the **University of Groningen should consider its own OER platform**. It will contribute to the visibility of our university in terms of educational innovations and high quality of education and research. Giving it a prominent place on the university webpages will attract potential students and staff.

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[17] https://open.umn.edu/opentextbooks/faq Retrieved 2021-10-24.
[18] LibreTexts https://libretexts.org/ Retrieved 2021-10-24.
[19] https://libretexts.org/advanced.html Retrieved 2021-10-24.
[20] https://libguides.rug.nl/OER/OpenTextbooks Retrieved 2021-10-24.
[21] https://phet.colorado.edu/ Retrieved 2021-10-24.
[22] https://c3d.libretexts.org/CalcPlot3D/index.html Retrieved 2021-10-24.
[23] https://www.geogebra.org/?lang=en Retrieved 2021-10-24.
[24] https://www.geogebra.org/3d?lang=en Retrieved 2021-10-24.
[25] https://www.desmos.com/calculator Retrieved 2022-01-18.
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Images:
Figure 1

a) Mozilla Foundation, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons
b) https://www.python.org/
c) ™/®Blender Foundation, Public domain, via Wikimedia Commons
d) https://www.freepnglogos.com/images/linux-22618.html

In text: logos from
https://openstax.org/
https://open.umn.edu/opentextbooks
https://libretexts.org/

Appendix A: Resources (in a separate file)

Appendix A

Resources

STEM Resources				
Name of OER	*Type of resource(s)*	*How to (potentially) use*	*Terms of use*	*Link to website*
David Tong's lectures and courses (Relativity used by D. Roest for Mechanics and Relativity course for Master students)	PDFs of lessons and problems to work through	Course material for physics courses	Free, but not officially licensed. However, equivalent to CC-BY-NC-ND	*http://www.damtp.cam.ac.uk/user/tong/teaching.html*
Physics of lights and optics textbook	Open Textbook	Reading material for courses	Copyrighted, but free to retain and redistribute with copyright notice	https://optics.byu.edu/docs/opticsBook.pdf
PhET interactive simulations	Interactive physics, biology, chemistry, math, earth science simulations	Hands-on experience of theoretical principles	CC-BY, free to use, only need to give proper attribution	https://phet.colorado.edu/en/simulations/filter?type=html,prototype
CalcPlot3D	Visualization of multivariate, 3d models	Visualization tool	Undeclared license, but parented by Libretexts, which only allows open license materials	https://c3d.libretexts.org/CalcPlot3D/index.html
GeoGebra	Calculator and classroom activities, simulations, exercises, lessons and games for math and science	Graphing tool + ancillary and guiding materials for teaching	CC-BY-NC-SA for website materials GNU General Public License for Source Code	https://www.geogebra.org/

Desmos	Classroom activities + various calculators (Graphic, scientific, matrix)	Various lessons and activities that can be assigned to students + math tools	No specific license, but free for non-commercial, personal use	https://www.desmos.com/calculator
Falstad widgets	Math and physics simulations	Visualization + hands-on experience	No clear license, but attribution is required, and only for non-commercial use. Modification is allowed for non-commercial ends, but unclear if it is allowed for classroom	https://www.falstad.com/
Software Carpentry	Software/computer science lessons	Full lessons on a range of programming topics	CC-BY	https://software-carpentry.org/
WeBWork	Open source homework platform	Home assignments for greater student understand	Requires hosting, so you need a server/institutional approval. Source code is licensed using GNU general public license	https://webwork.maa.org/
Open math notes	Draft works of notes, textbooks and research expositions	Reading for courses	Free, but open dependent on the individual authors	https://www.ams.org/open-math-notes
Active Calculus	Three open textbooks on calculus that include interactive activities	Reading and training for calculus courses	CC-BY-SA	https://activecalculus.org/
American institute of	List of open/free math textbooks	Reading materials for	Different, but at a minimum all	https://aimath.org/textbooks/approved-textbooks/

Mathematics Open Textbook Initiative		different type of math courses	free	
Grasple	Math and statistics exercises	Practice and test materials	Generally CC-By-NC-SA	https://www.grasple.com/nl
QUBES	STEM resources on math, biology, physics, earth sciences etc.	Reading material	All content should be free and open, but specific licensing depends on the resource	https://qubeshub.org/
Freetechbooks	Open textbooks regarding computer science and mathematics	Reading materials	All open licenses or public domain	https://www.freetechbooks.com/
Mathispower4u	Math mini-lessons and videos (Youtube videos)	Ancillary materials for courses	Free, but not open	http://mathispower4u.com/
Biointeractive	biology , biochemistry, earth sciences activities, videos, and interactive media	Ancillary materials for courses	Free, but not open (has to go through their site)	https://www.biointeractive.org/
Biopsychology course by Chris May	(Neuro)biology, psychology	Open pedagogy outcomes, syllabus, and reading materials	CC-BY-NC-SA	Website 1: https://sites.google.com/rug.nl/biopsychologyinterdisciplinary/home Website 2: https://sites.google.com/rug.nl/biopsychologysignatureproject2/home Syllabus: https://edusources.nl/en/materials/9390139a-eb05-43fe-bad1-c21befc9ac0f/

Learning statistics with R	Open textbook	Reading material	CC-BY-SA	https://learningstatisticswithr.com/
Sagemath	Software system/collection of python packages for math work	Self-testing and "doing" mathematics	GNU GPL	https://www.sagemath.org/
CoCalc	Collaborative space for performing calculcations	In-class and research collaborative work	GNU GPL for the software	https://cocalc.com/
General resources				
Name of OER	*Type of resource(s)*	*How to (potentially) use*	*Terms of use*	*Link to website*
Python	Programming language	Training material and analysis tool for students	PSF license (personalised license by Python, similar to GPL)	https://www.python.org/
R(studio)	Programming language aimed at data science	Analysis tool for statistical analyses	GNU GPL	https://www.r-project.org/
Blender	Modeling and animation software	Tool for creative exercises	GNU GPL	https://www.blender.org/
Linux	Operating System	Highly adaptable computer access	GNU GPL	https://www.linux.org/
Firefox	Internet browser	Internet access	Mozilla Public License (personalised license by Mozilla, parent company of Firefox)	https://www.mozilla.org/en-US/firefox/new/
Openstax	Repository of open textbooks	Reading materials for students	CC-BY	https://openstax.org/

Open Textbook Library	Repository of open textbooks	Reading materials for students	CC or GNU GPL, no ND component allowed	https://open.umn.edu/opentextbooks/
LibreText	Search engine/repository for open textbook (some with interactive elements)	Reading materials for students	Only public domain and open licenses (CC, GNU GPL)	https://libretexts.org/
Coursera	MOOCS	Spoken/video course for students opens up room for discussion during class hours	Free, but not open. For certification, you may need to pay	https://www.coursera.org/
EdX	MOOCS	Spoken/video course for students opens up room for discussion during class hours	Free, but not open. For certification, you may need to pay	https://www.edx.org/
Futurelearn	MOOCS (including UG ones)	Spoken/video course for students opens up room for discussion during class hours	Free, but not open. Payment for further access (testing, certificates)	https://www.futurelearn.com/
edusources	Search engine for broad SURFsharekit repository	Varies depending on specific OER	Public domain or CC license	https://edusources.nl/
OER Commons	General OER repository	Varies depending on specific OER	Varies, also has copyrighted but free materials	https://www.oercommons.org/
Merlot	General OER repository	Varies depending on specific OER	Varies, also paid materials	https://www.merlot.org/merlot/
ClassCentral	Search engine for online	Spoken/video course for	Free, but not open, and	https://www.classcentral.com/

	courses	students opens up room for discussion during class hours	sometimes payment needed for certification	
Thiagi	Educational games	Alternative way to engage with educational topics	Free, but not open	http://www.thiagi.com/
Academic Earth	OER search engine for courses/videos	Spoken/video course for students opens up room for discussion during class hours	Varies, free, but not all open	https://academicearth.org/
MIT OpenCourseWare	Course materials from MIT	Full courses to adapt into courses at your own university	CC-BY-NC-SA	https://ocw.mit.edu/
Khan Academy	Courses	Additional training materials and learning materials for students to use	The service is copyright protected but free, but may sometimes make use of other materials that may be open	https://www.khanacademy.org/
FORRT	Resources and infrastructure to teaching open research principles	Useful platform for academic skills training	CC-BY-NC-SA	https://forrt.org/