

# Enhancing the Learning of Computing/IT Students with Open Educational Resources

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**Abstract** — With the advent of the Internet, there is now a vast amount of useful learning resources available. These public resources or Open Educational Resources (OERs) can complement traditional teaching/lectures and student learning. In this paper, we make two contributions to the development of OERs for the global education community. First, we analyze the popular computing/IT-related OERs at MERLOT, one of the major OER repositories in the world. Through the analysis of peer reviews and other data, we present interesting findings and valuable insights for the development of OERs, particularly for the computer science discipline. Second, we present an innovative 3E (Enrich, Extend, Elevate) strategy/pedagogy for the use of OERs with the aim of enhancing student learning from different perspectives. In particular, students can play an important role, to find and even create OERs to enhance their learning to a new dimension.

**Keywords** — OER, e-learning, Internet

## I. INTRODUCTION

According to UNESCO, Open Educational Resources (OERs) are defined as “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] There are other similar definitions, for example, Wikipedia defines OER as “freely accessible, openly licensed text, media, and other digital assets that are useful for teaching, learning, and assessing as well as for research purposes.” ([https://en.wikipedia.org/wiki/Open\\_educational\\_resources](https://en.wikipedia.org/wiki/Open_educational_resources)) In general, an OER has three important elements [2]. First, it should be “Open” (i.e., free to access and reuse as well). Second, the purpose should be for “Education” (i.e., teaching/learning and research purposes). Third, it should provide “Resources” such as online materials. Here we consider a broader perspective by considering online resources in general (i.e., resources that are sharable through the Internet and used/changed freely or with certain rights or restrictions, such as those defined by Creative Commons (CC) licenses (<https://creativecommons.org>).

Access to resources is not sufficient to reach the full potential of openness. OERs allow us to face the major challenges of education that society requires in the future, challenges that have been collected in the UNESCO Incheon

declaration [3]. It establishes how to implement the Sustainable Development Goal (SDG) 4: “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”. The strategy is to promote access to quality education for all, from an early age and throughout life, eliminating any form of inequality. OERs are a key piece supporting the achievement of SDG 4. The Ljubljana Action Plan from the Second World OER Congress [4] states that in order to fulfill this goal, OER must be “used effectively and supported by sound open pedagogical practices”.

According to the different rights provided by CC licenses, open practices can completely or partially change the teaching/learning experience. Wiley [5] establishes different alternatives, from the simple substitution of educational resources to be used by others, to their redefinition, facilitating new forms of learning in which students are partners in the production of content in more realistic situations.

OERs can be used to complement traditional teaching/learning. For example, it is often difficult to maintain student attention in a long lecture of two to three hours. Therefore, it is desirable to introduce various learning activities to complement a lecture and to adopt interactive pedagogies to enhance teaching/learning effectiveness. Online resources can provide an effective way to achieve this. For example, related short videos (e.g., YouTube videos) can be played and students can be asked to answer simple questions or to do simple learning exercises. This strategy can also bring worldwide learning resources into the classroom. In fact, it has been shown in various studies that the use of YouTube videos can greatly facilitate student learning. For example, it was found [6] that the use of YouTube videos can bring significant benefits to students, as indicated by the following survey results: (1) 98.6% of students thought that the videos could facilitate their understanding of the lectures. (2) 77.1% of students thought that the videos were very helpful or extremely helpful, while 20% of students thought that the videos were helpful. (3) 94.3% of students thought that the videos could improve the overall class. (4) 46.4% of students also searched for videos not covered in class.

Another study [7] confirms that the use of YouTube videos can facilitate students’ learning and understanding of complex computing concepts. In general, apart from using YouTube

videos, other online resources such as online animations and demos can also be introduced to complement lectures.

In addition, it is desirable to extend learning beyond the classroom. For example, students can be asked to find related online learning materials and share them through discussion groups within a Learning Management System. This strategy seeks to extend learning after scheduled lectures. In fact, according to the aforementioned study [6], many students are interested in searching for other YouTube videos not covered in class (i.e., probably motivated by the in-class videos). To support this learning activity more effectively, a small participation grade can be introduced. Note that many studies also confirm that online discussion groups can facilitate student learning [8][9].

In recent years, there has also been considerable interest in using various flipped classroom pedagogies to enhance active learning (e.g., see [16] for a comprehensive study/review). In general, flipped learning provides a new way of learning [17], allowing students to play an active role in the learning process. For example, students can be assigned the role of a teacher by preparing online resources for use by other students. In certain subjects, students can be asked to create one online learning resource in an assignment question. Note that this can be a simple animation, video or animated slides to explain or reinforce certain concepts. Again, the learning resources will be shared among students later. To encourage student participation, a competition with prizes can be organized.

Related work in recent years confirms or reiterates the advantages of OER such as enhancing affordability, increasing course completion rate and improving learning [10]. The studies in [11] and [12] draw a similar conclusion, that there is no difference between using textbooks and adopting OERs (i.e., students achieved similar academic results and learning outcomes). However, there are still many obstacles to overcome for the wide adoption of OERs [13]. For example, awareness of OERs among faculty members remains low, although it is increasing. Hence, more work is needed for the promotion and development of OERs [14]. For example, inspired by software engineering, [15] presents an Agile approach for the development of OERs.

To contribute to the development and promotion of OERs, we make two contributions in this paper. First, we analyze a number of popular OERs concerning Information Technology (IT) and Computer Science (CS) from the MERLOT repository (one of the world's major OERs repositories) [18]. In other words, this seeks to address the kinds of popular OERs that are accessed by users. Valuable insights are provided through the analysis. Second, we present an innovative 3E (Enrich, Extend, Elevate) pedagogy for using OERs to enhance student learning. This seeks to answer how OERs can be used effectively and innovatively. The remainder of this paper is outlined as follows: Section II presents the analysis of CS/IT-related OERs in MERLOT; Section III discusses the 3E strategies to enhance student learning with OERs; and Section IV provides a conclusion.

## II. ANALYSIS OF OERs IN MERLOT

This section presents an in-depth analysis of the computing-related OERs in MERLOT ([www.merlot.org](http://www.merlot.org)). Supported by the California State University, MERLOT is one of the world's largest/major OER repositories. In addition to the repository, there are approximately two dozen different discipline community portals – each focusing on OERs and teaching and learning matters specific to that discipline. Two of the portals are the Computer Science (CS) Community Portal and the Information Technology (IT) Community Portal (e.g., see Fig. 1), both of which are endorsed by the IEEE Computer Society and the IEEE Education Society. With the advent of CS/IT, the aim of these portals is to seek a collection of good OERs from global teachers and learners for teaching/learning purposes. One unique feature of MERLOT is that there is an OER review editorial board for each discipline, and selected OERs are reviewed by domain experts on those boards. In addition, there are user ratings and comments posted on the website. The domain expert reviewer comments, also posted on the web, provide additional objective and useful information for MERLOT users.

This section consists of two parts, one quantitative and the other qualitative. In the first, the most recent top 100 CS OERs are analyzed. These are the popular OERs accessed by users through the MERLOT website. In the second part, selected OERs are analyzed based on reviewer (domain expert) comments. Various types of OERs are selected. They provide valuable insights into why and how they are designed and used. Note that to provide meaningful information and analysis, the reviewer comments were only slightly edited for obvious typos/errors. In other words, the original comments were largely retained for the analysis. Indeed, from these comments, valuable insights can be obtained. All of the following reviews, such as the following one, are shared based on the CC BY-NC-ND 4.0 license:

<https://www.merlot.org/merlot/viewCompositeReview.htm?id=1376182>

Please refer to the respective material pages and the following license website for details:

<https://creativecommons.org/licenses/by-nc-nd/4.0/>

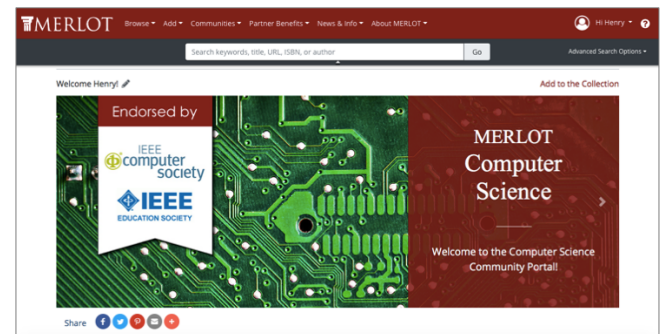


Fig. 1: MERLOT Computer Science (endorsed by IEEE Computer Society and IEEE Education Society)

Fig. 2 shows the percentage of access (the x-axis) for the top 100 CS OERs (the y-axis). In other words, after a keyword

search generates a hitlist, this figure shows how users access the top 100 materials (by clicking the “Go to Material” button for the material). The figure shows a long-tailed distribution. The top 20 OERs account for more than 50%, and many OERs account for less than 1%.

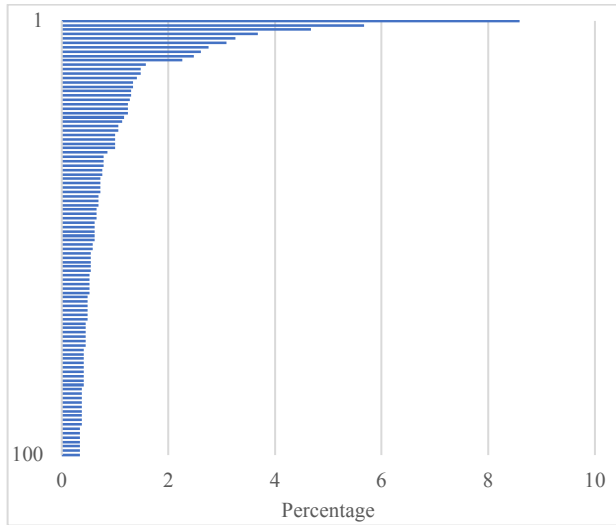


Fig. 2: Percentage of access for the top 100 CS OERs (y-axis showing the ranking: 1-100)

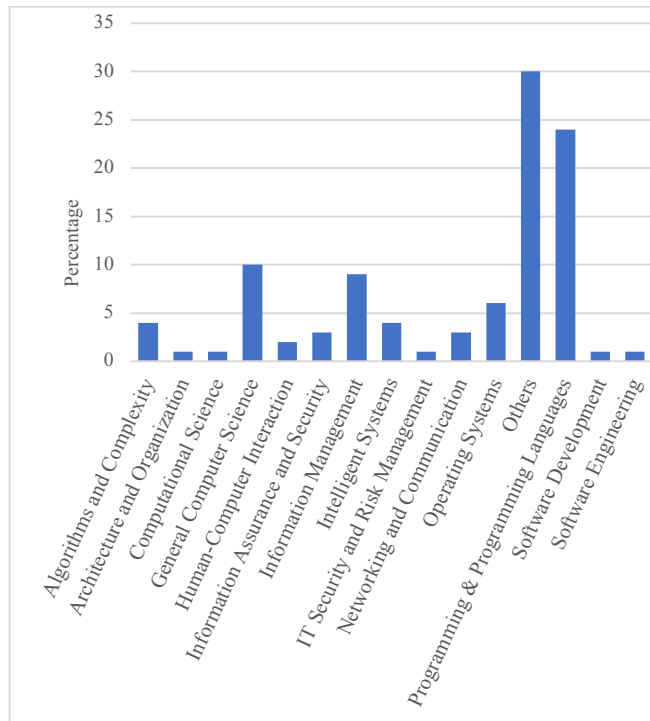


Fig. 3: Distribution of popular CS OERs by different categories

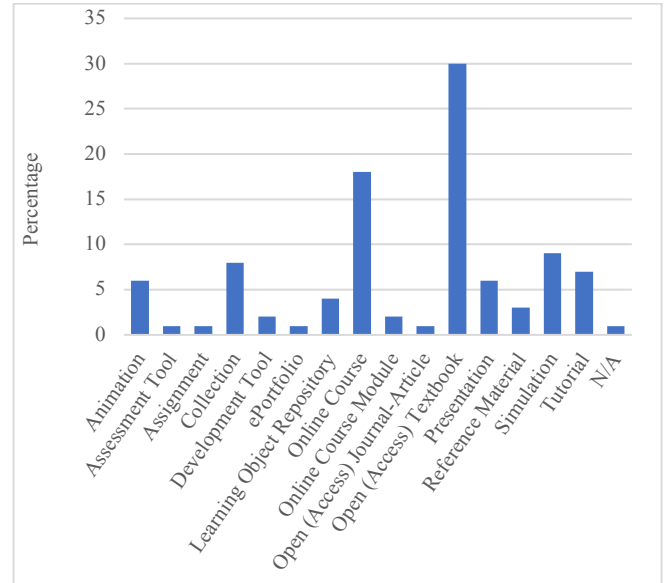


Fig. 4: Distribution of top CS OERs by material type

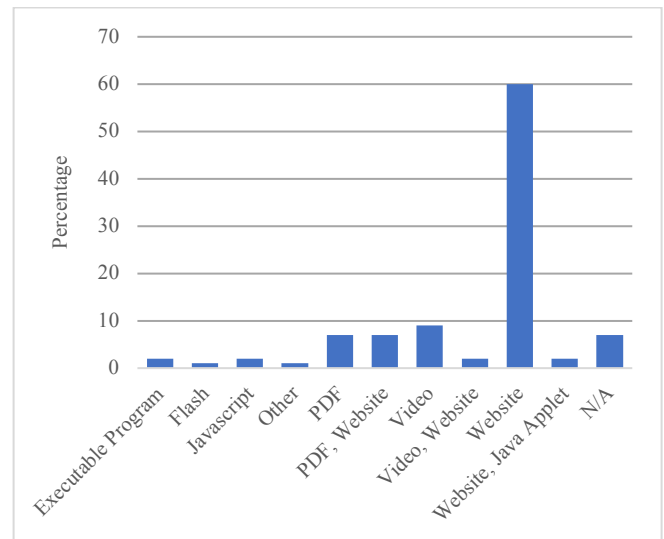


Fig. 5: Distribution of top CS OERs by technical format

Fig. 3 shows the distribution of the top 100 CS OERs by different categories. Note that these OERs are categorized using metadata derived from ACM/IEEE ABET recommended Computer Science Curricular topics. The figure shows that the top 100 CS OERs cover all of the metadata categories. The most popular category is Programming/Programming Languages, followed by General Computer Science and Information Management (except Others (see Fig. 3)). As expected, programming is the core learning topic, and general computer science provides the conceptual foundation. The figure also reflects the importance of information management in the current information-driven society. It is also interesting to note that

others account for 30%, reflecting the diverse nature of learning topics in computer science.

Fig. 4 shows the distribution of the top 100 CS OERs by material type. Again, they cover all available material types. Open (access) Textbook and Online Course account for nearly 50%. As conventional textbooks are often expensive or not affordable for certain students, open text textbooks provide an attractive alternative for students. With the advent of easily accessible online courses such as Massive Open Online Courses (MOOCs), students also find them very good references. Teachers can also use these online courses to complement their own lectures. Note that simulation and animation account for approximately 15% altogether. Indeed, they are useful for illustrating certain computing concepts. As they are typically time-consuming or require considerable effort to produce, teachers can use them effectively in lectures for demonstration purposes.

Fig. 5 shows the distribution of the top 100 CS OERs by technical format. Again, all available technical formats are covered. As expected, websites are the most popular type, accounting for 60%. Note that websites today may provide an integrated platform for various media as well, such as embedding videos. The second most popular technical format is video, followed by PDF. A picture is worth a thousand words and a video is probably worth many thousand words. As PDFs are currently the most commonly used document format for viewing, many learning materials use this format. Note that while Fig. 5 can be used for general reference, the answers may depend on user judgment, as some formats are mixed in nature.

In the second part of the analysis, we have selected a number of popular CS OERs that cover different CS OER types and topics. The aim of the analysis is to study them in three aspects: (1) Content Quality, (2) Effectiveness as a Teaching Tool, and (3) Ease of Use in accordance with reviewers' comments on MERLOT ([www.merlot.org](http://www.merlot.org)). Note that these are the three major criteria used by reviewers for their (eventually posted) peer reviews.

1. Android Developer Fundamentals (Version 2)  
<https://www.merlot.org/merlot/viewMaterial.htm?id=1378815>

The first is an online course (MOOC) for a popular topic (i.e., development of Android apps). As reflected by the following reviewer comments on content quality, it is important to provide comprehensive content with clearly defined lessons. It is also preferable to provide practical exercises.

*"It is very comprehensive course, very contentful, covering the development of Android apps. It is very suitable for Android beginners to learn everything from simple to more sophisticated apps using Android Studio. As also stated in the introduction page, the course is divided into lessons. Each contains some slide deck and concepts chapters, and in most*

*cases, one or more practical sections is also provided. For the topics covered, it describes them in detail. When viewing the videos, I would suggest downloading the codes in the complementary website first; otherwise, they may find the content overwhelming and missing some important points. The materials are very comprehensive for new learners of mobile application development. They consist of topics related to UI development, data storage, background process, etc. The material describes the concepts and the development process in sufficient detail."*

With regard to "Potential Effectiveness as a Teaching Tool," the consolidated reviewer comments are shown below:

*"It starts by presenting the meaning of terms as the background in the development, which is useful for beginners. Beginners will find it easy to follow as the videos teach each step of development, such as the setup of Android Studio, in a very detailed manner. The lectures are presented in YouTube videos. Slides shown are informative and written in point form. It also points out some common challenges in writing Android apps. The learning objectives of the material are clearly stated. The prerequisite knowledge is also mentioned. It contains the program codes and the diagrams to illustrate the development process. It contains a number of tasks to assess students. Learners can also obtain the solutions to check their answers."*

The review indicates the importance of using a step-by-step approach and clearly stating the learning objectives. Furthermore, it is also important to provide tasks and exercises to enhance interaction with learners.

About "Ease of Use," the following reviewer comments reveal the importance to have clear organization and steps to facilitate searching, for example. It is also better to use graphics instead of wordy expressions to enhance usability.

*"The points being presented and power points are relevant. The narrator presents the points clearly, but sometimes it may be a bit wordy; using some graphics may help. The content provided in the video is very rich and every step is clear if the learners follow the sequence of topic; on the other hand, if the learner would like to find a particular topic, it may take some time to find it. The content is very well organized and clear. It can help learners quickly and easily identify the resources. It contains a number of screenshots and diagrams to illustrate the concepts and the development process."*

2. Python Tutor  
<https://www.merlot.org/merlot/viewMaterial.htm?id=1174990>

This is a visual programming tool for learning and testing programs (i.e., learners can test their programs through a web interface). In fact, apart from Python, there are also other programming languages. In terms of "Content Quality," the following reviewer comments reveal the importance of



including a rich and clear set of features to enhance content quality.

*“Support for several of the most relevant programming languages. Good set of features, including the ability to jump to any point of execution. Allows individual use, but also a shared-session mode where users can collaborate or request help from someone. The visualizations the tool shows are clear and helpful for learners to understand, for example, data structures and recursion. No account is required, so it is possible just to access the website and start using it.”*

For “Potential Effectiveness as a Teaching Tool,” the following reviewer comments indicate the effectiveness in three directions: allowing sharing sessions (e.g. for tutors to help students), showing programs in lectures, and tracking program execution.

*“The tool has a good potential for inclusion in lab sessions, as described by the author in several sources. Given that it allows sharing sessions, it makes it possible for tutors to assist students in real time. Students can run their code any number of times, which is highly beneficial as they are learning a new programming language. The tool can also be used in the context of lectures, for example for a lecturer to show the visualization of data structures to students. It is able to visualize logic flow and change in variable content dynamically. It is able to trace programs in both forward and backward directions. It is useful for locating program bugs.”*

The following reviewer comments indicate that ease of use for these kinds of OERs can be enhanced by providing an account-free version (e.g., for basic operation), examples, and shared session functions.

*“No account setup is required, which removes a significant barrier for adoption. The website is simple to use, with most features being appropriately named. Whilst the website is not intended to teach a programming language from scratch, there are several resources that are suggested, including examples. The shared session mechanism is straightforward to use and has significant potential. It is cross-platform and no additional software (such as compiler) requirement.”*

### 3. MIT App Inventor

<https://www.merlot.org/merlot/viewMaterial.htm?id=763912>

App Inventor is a popular and well-known graphical programming tool for creating mobile apps. It works like Lego (i.e., putting programming blocks together). The following reviewer comments indicate the importance of providing a clean website with rich functions and a community.

*“App Inventor provides blocks that allow the user to create both simple and powerful apps. For example, apps can use the phone's GPS system for location or an orientation sensor for games requiring response to screen orientation or the ability to respond to text messages. This can all be done with relative*

*ease. The content is excellent! It's very clean, there are a lot of tutorials, working through building your first app helpful especially with all the step by step guides and community forums. There is a section for educators with additional instructions. It may even be helpful to professionals who are working with the site on their own.”*

With “Potential Effectiveness as a Teaching Tool,” as indicated by the following reviewer comments, it is important to provide supplementary materials and features to motivate students to learn. Furthermore, it is even better to provide a feature (e.g., App of the Month) to showcase student work. In other words, a two-way interaction process is the key to success.

*“The materials are excellent and students will be motivated to create an app. There is a lot of support and a user community. The site is designed in mind with visual learners (in this case, it's a big plus). It's very helpful to have an “App of the Month” section, for example: <http://appinventor.mit.edu/explore/app-month-gallery.html>. There are a lot of troubleshooting and community support options. The creators will recognize that not all beginners will have a Droid phone so it's helpful to have an emulator. The videos and downloadable guides are well done and professional. This is an excellent module for giving the student a successful experience creating a meaningful app. This can serve as a motivating introduction to programming.”*

For “Ease of Use,” the reviewer comments suggest the importance of providing a one-stop approach so that learners can easily find all required resources and materials. In this case, a cloud storage approach is used, to greatly enhance usability (e.g., users can use it anytime, anywhere).

*“Excellent tutorials, user groups, examples, and hands-on portion make this module easy to use. It's helpful to go through the whole site, including additional resources ... The instructions are clear on setting up the inventor: <http://appinventor.mit.edu/explore/ai2/setup.html> Concept cards are very helpful: <http://appinventor.mit.edu/explore/resources/beginner-app-inventor-concept-cards.html>. Everything is stored on the App Inventor server, so there are no concerns about storage.”*

### 4. E-Books Directory

<https://www.merlot.org/merlot/viewMaterial.htm?id=862157>

Apart from subject-specific materials, there are also general useful popular materials, such as an e-book directory like this one. In fact, learners find it useful because it can provide access to free books (OERs) through a single interface. The following reviewer comments clearly indicate the usefulness of this kind of OER. In particular, the content quality can be enhanced by clear organization.

*“The collection offers a broad-based selection of texts in multiple interest areas. All information is freely available, and downloadable features appear to be active. The information,*

*at least in several business marketing sections, appears relevant and timely, with publication dates mostly in the late 2000s. Most publications noted by this reviewer are fairly reasonable page-wise, making these ideal supplements to course content. This website helps users find a wide variety of books. It is well organized."*

The following reviewer comments on "Potential Effectiveness as a Teaching Tool" indicate the value of this kind of OER. It can be used to provide useful references for students in terms of both breadth and depth. As some textbooks may now be expensive, the website provides alternatives (OERs) for both students and teachers.

*"Any website that links users to free books is valuable. This website is one of the better ones that this reviewer has seen, especially when it comes to breadth and depth of topics. Since the material is free, the site lends itself to an affordable alternative for students. Some titles are comprehensive texts, while others delve more into specific areas, affording a number of opportunities to instructors for use. The available categories are numerous, ranging from more broad-based content to more detailed, and due to the easy portability of the material, allows for quick learning."*

In terms of "Ease of Use," this type of OER relies more heavily on good navigation to enhance its usability. The key success factors include good searching, classification and download functions.

*"The website is easy to navigate. The headings, subheadings and search function (via Google custom search) are appropriate and user-friendly. The categories are easily organized in multiple ways, enabling the user to locate interests easily. The speed of download appears to be quick, allowing for instantaneous access to material."*

5. How to Think like a Computer Scientist: Interactive Edition  
<https://www.merlot.org/merlot/viewMaterial.htm?id=1315691>

At MERLOT, there are popular computing OERs for teaching the basic concept of computer science, such as this one. The following reviewer comments point out that it is particularly effective to use a programming language to illustrate computing concepts. The content quality can be enhanced by including videos and program testing functions.

*"Based on a particular programming language, Python, the site gives the user comprehensive and extensive learning materials from the very basic ideas of programming. Videos are also incorporated into the site and are useful for users to follow the steps to start programming. The codelen [sic] is the key feature that allows users to instantly test their code, which is very beneficial for concept reinforcement. The whole set of online materials is very carefully designed and well supported with a systematic framework of key computing/programming concepts, assignment and lab exercises written in Python and embedded with very interesting simulations."*

The following reviewer comments also indicate its effectiveness as a teaching tool. In particular, it is important to provide self-contained materials and quick self-tests to facilitate teaching and learning.

*"The sites are quite self-contained, without the need to get extra or external materials for understanding the steps. They also contains self-test quick quizzes for reinforcing the learning points. These quizzes can also be used as supplementary exercises in other similar courses. The embedded code runner is available in many cases after a specific topic, so the learner can instantly test their understanding with actual implementation. In summary, the material is very easy to easy with high potential to be used as an effective teaching tool."*

In terms of ease of use, guidance and examples are two important success factors, as indicated by the following reviewer comments.

*"Learners are guided to read the material sequentially. Readers are expected to click the "<" or ">" to navigate the pages. However, for first-time users, these arrows are too small to be noticed, in particular on the first page of each chapter. The website can be further enhanced by better responsiveness in the user environment. Further, for better accessibility, it would be better to allow users to change the font size and provide better adaptability on mobile devices. In summary, the material is definitely very easy to use with numerous examples well supported by assignment/lab exercises."*

6. Rijndael (AES) demo  
<https://www.merlot.org/merlot/viewMaterial.htm?id=1315820>

Animations and demos are well suited for explaining some computing concepts. A good example is this AES demo. The reviewer comments clearly indicate the importance of using a step-by-step approach (i.e., with clear actions) to ensure content quality.

*"It used a concrete example to clearly illustrate how the Rijndael operates. The steps are shown in detail and each step is shown with a pace that is easy to follow. The actions shown are clear, but more textual description on each step, e.g. sub-byte, will further enhance understanding. In summary, the animation tool is outstanding. It demonstrates very clearly the different parts of the algorithm."*

As an effective tool for teaching/learning, the following reviewer comments indicate the effectiveness of using examples for demonstration purposes. In fact, it can be used to complement lecture slides.

*"The objective of illustrating the operation of Rijndael is clear. It provides the animation for the user to input an example of a plain text or a cipher text to show the steps of Rijndael cryptography. The steps are shown in detail so the user can easily flow the steps. As most of the cryptography*

*algorithms, the understanding of binary operation, XOR and modular, is needed.”*

To enhance ease of use, the following reviewer comments suggest the need to use appropriate colors and style. Furthermore, it is also better to provide textual descriptions.

*“The interface using the flash allows the user to control the pace of viewing and give input for the operation, which helps the users' learning. It is very suitable to incorporate it into a course on cryptography. The interface quality is high, the content size is appropriate and the colours and style of presentation are appealing. It would be even more explanatory if some more textual description of the steps involved could be added, in particular in the first few scenes.”*

#### 7. A Gentle Introduction to SQL

<https://www.merlot.org/merlot/viewMaterial.htm?id=83289>

As a key programming language for database management, SQL is a popular learning topic. This OER provides a good tutorial for learning SQL. As indicated by the reviewer comments, one key feature of this tutorial is that it is interactive (i.e., with students). Furthermore, in terms of content quality, the OER provides good examples and reference information.

*“The tutorial took four commands with variation and first demonstrated the command then provided opportunities for the student to try it under several database engines. If the statement input was incorrect, a compiler-like error message occurred and the student could see what the resulting incorrect answer would produce. The answer pages are a duplicate of the tutorial page with the commands completed. The student can see the resulting query from the correct answer. The assessment section divided the questions up by difficulty. Some of the databases used in the assessment section were available for download. The diversion section contained other ways to use SQL with examples and the opportunity for the student to view the results. The other section provided links to related topics.”*

The following reviewer comments reiterate the importance of hands-on functions as an effective tool to support teaching/learning.

*“Nothing beats hands-on when learning to program. This site offers plenty of hands-on in the tutorial section and throughout most of the offered sections. Side topics are also available.”*

To enhance ease of use, it is important to provide the most recently updated materials and ensure access speed, as indicated by the following reviewer comments.

*“This site loaded quickly on a LAN connection. The database engines all ran well during the review. Most of the links were current.”*

#### 8. Dash: Learn to code HTML, CSS, and JavaScript

<https://www.merlot.org/merlot/viewMaterial.htm?id=1315444>

With the advent of Internet computing, many OERs are devoted to web programming similar to this integrated tutorial website. The following reviewer comments show that content quality can be enhanced by providing comprehensive information and including examples.

*“The tutorial is comprehensive. It covers most of the essential topics in writing Web pages, which are integrated with CSS and JavaScript. The information is sufficient for learners to learn the basic knowledge and skills in designing a website. Through various example of practical web applications like building a personal website, the process of learning to code in HTML, CSS and JavaScript can be fun!”*

To enhance teaching/learning effectiveness, project-based tutorials with clear learning goals can be used so that they can be used to complement traditional teaching (see the following reviewer comments).

*“The tutorials are like project-based tutorials. Each tutorial aims at creating Webpages containing certain features in HTML, CSS or JavaScript. It is effective and the learning goals of each tutorial are clear. It can be very effective in being used as the case studies for discussions during tutorials or practical exercises for students to gain more hands-on experience during lab sessions.”*

As indicated by the following reviewer comments, the usability of the OER is enhanced by interactive tutorials, visually appealing design and practical step-by-step exercises.

*“The tutorials are interactive. Learners can practice the coding within the platform. So it is very effective. The design is also visually appealing. The usability is high as each set of PowerPoint slides is facilitated by some practical and step-by-step exercises requiring each learner to try out some HTML/CSS/JavaScript statements on the Dash platform running on a Web browser so as to build some practical Web applications.”*

#### 9. Teach Information Literacy and Critical Thinking

<https://www.merlot.org/merlot/viewMaterial.htm?id=739672>

Apart from subject-specific OERs, there are also general OERs like this one (i.e., about information literacy and critical thinking). As indicated by the reviewer comments, there are three important points related to content quality: flexibility, completeness and relevancy.

*“This collection provides instructional librarians and student tools to learn how to use information more effectively in research. It is a complete demonstration of the process of information literacy and critical thinking skills that students need to succeed. It is flexible; individual parts can be used separately. It could easily be adapted for use in other libraries. Content is slightly old, but still relevant.”*

For effectiveness in teaching/learning, the following review comments indicate the importance of specifying learning objectives and including exercises and learning activities.

*“This collection includes a number of exercises and activities for reinforcing concepts. Most of the linked-to content provides information in a succinct, easy-to-understand format. Learner objectives are provided for each content area. Content areas are self-contained and can be done independently. Information presented is relevant.”*

In terms of ease of use, as indicated by the following reviewer comments, clear navigation, up-to-date links and consistent design style are the most important factors.

*“This guide for librarians is easy to use with clear navigational tabs. Examples and built-in assignments are included. Additionally, all links work and are up-to-date. Each content area maintains a consistent design style.”*

In summary, Table 1 shows the selected OERs (i.e., with different types), highlighting their content quality, potential effectiveness as a teaching tool and ease of use. The table also illustrates major design criteria for useful OERs (i.e., why they are preferred by users).

Table 1: Summary of selected OERs

OER / E-learning Resource	Type	Content Quality	Potential Effectiveness as a Teaching Tool	Ease of Use
Android Developer Fundamentals	MOOC	Comprehensive content with clearly defined lessons	Step-by-step approach with clear learning objectives	Clear organization and use of graphics instead of wordy expression
Python Tutor	Visual programming tool	Use of rich and clear set of features	Allow sharing session, showing in lectures and tracking programs	Account-free use and examples
MIT App Inventor	Graphical programming tool for mobile apps	Clean website, rich functions and a community	Motivate students to learn and showcase student projects	One-stop approach and cloud storage
E-Books Directory	Directory for free e-books	Clear organization	Free textbooks and useful student reference	Good searching, classification and downloading functions
How to Think like a Computer Scientist:	Interactive book	Videos and program testing functions	Self-contained materials and quick self-test	Good guidance and examples
Rijndael (AES) demo	Animation	Step-by-step approach	Examples to complement lectures	Appropriate use of colors and style
A Gentle Introduction to SQL	Interactive tutorial	Good examples and reference information	Hands-on functions	Updated materials and access speed
Dash: Learn to code HTML, CSS, and JavaScript	Integrated tutorial website	Comprehensive information and examples	Project-based tutorials with clear learning goals	Visually appealing design and practical step-by-step exercises
Teach Information Literacy and Critical Thinking	Course website	Flexibility, completeness and relevancy	Clear learning objectives and good exercises	Clear navigation, up-to-date links and consistent design style



### III. 3E STRATEGY FOR USING OERS

Fig. 6 shows the proposed 3E (Enrich, Extend and Elevate) strategy/pedagogy. With the aim of enhancing student learning through interactive pedagogies ([19]-[21]), it seeks to enrich conventional lectures with OER or online resources, extend classroom learning by sharing OER through online discussion groups, and elevate student innovative/creative thinking by creating OER (i.e., based on a flipped learning approach). Further explanations are given as follows.

Traditionally, a lecture may last for two to three hours. Using the Enrich strategy, an OER (e.g., YouTube video) can be used to complement the lecture slides. For example, a related short video clip (approximately three minutes) can be shown. In particular, it is useful to show demonstrations or animations to reinforce the concept or introduce a lecture topic (i.e., to stimulate student interest in the topic). After showing the video, short questions about the video can be asked. Furthermore, students can be encouraged to briefly discuss the video or solve a simple problem related to the video. For instance, if the video is about a sorting algorithm, students can be asked to solve a simple question related to the sorting algorithm. In a large class, group responses can be used as well (e.g., testing student understanding using multiple-choice questions). In this case, we can further evaluate the video effectiveness, to ensure student understanding, before proceeding to the next part of the lecture. From another perspective, the Enrich strategy can enhance the internationalization elements of a lecture as worldwide learning resources are introduced into a classroom.

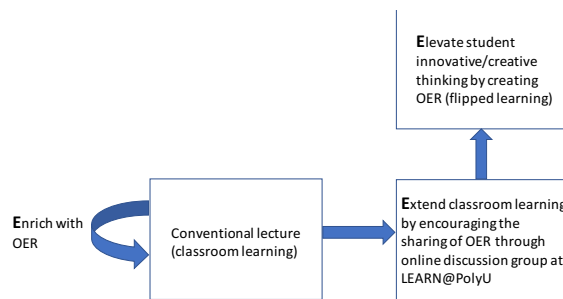


Fig. 6: 3E strategy/pedagogy

To enhance student learning, it is always desirable to extend learning outside the classroom. The Extend strategy can play an important role in this aspect. For example, after a lecture, students can be asked to find related OERs and post/share them to the discussion group of a Learning Management System. Students can also be asked to provide a short reflection (e.g., why the OER is useful). To encourage the posting/sharing of OERs, a small participation grade (e.g., 5%) can be introduced. In other words, students can be rewarded by posting good OERs, both in terms of quantity and quality. We can even ask

students to vote for their favorite OERs. In summary, there are several advantages to the Extend strategy. First, students can be motivated to learn outside the classroom and from one another. Second, posted/shared OERs can reinforce or complement lecture materials. Third, OERs can be selected from a student perspective (i.e., they are chosen by students, not the teacher). For example, students may find certain OERs that are particularly useful to help them get started (i.e., starting their learning engine). Finally, good and relevant OERs found by students can be used in future lectures.

The Elevate strategy seeks to elevate student learning through a flipped learning approach. That means, students are encouraged to create slides, animations or video OERs as if they were teachers intending to teach a certain topic. To motivate students to participate, it would be desirable for them to choose a topic that interests them. For example, after learning a sorting algorithm in a class, a student can create his/her own teaching/learning materials to “teach” others this sorting algorithm in a more effective way (i.e., from the student perspective). Students might use whiteboard animation software to create interesting cartoon-like online resources or perhaps interesting videos. These activities aim to raise student learning to a new level, cultivating their creative thinking. To facilitate the implementation, a student competition (e.g., a semester-based competition) could be organized for students to showcase their OERs and learn from one another. The good OERs can be enhanced for further teaching/learning.

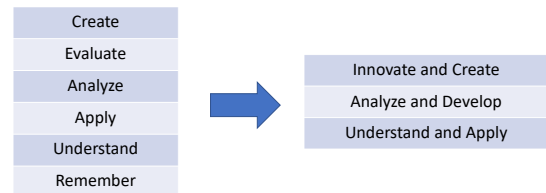


Fig. 7: Bloom's taxonomy/model and three major levels of learning

In summary, the 3E strategy seeks to enhance student learning from a broad perspective (in terms of breadth and depth). In fact, the aforementioned teaching/learning activities are related to the well-known Bloom's model for learning. Broadly speaking, the Bloom model can be generalized into three levels: understand and apply, analyze and develop, and innovate and create (Fig. 7). By viewing a short video and completing a few questions, students can better understand and apply knowledge. By searching for and reviewing online learning materials related to lectures, students can use more critical thinking and conduct more in-depth analyses of course content. By creating online resources (i.e., using a flipped learning approach), students can use their innovative and creative thinking ability (i.e., Bloom's highest level of learning).

#### IV. CONCLUSION

In this paper, we have presented an in-depth analysis of a sampling of the top 100 Computer Science OERs “discovered” by searching the MERLOT repository. A quantitative analysis indicates that the popular OERs basically cover all of the ABET/CSAB metadata categories, with programming/programming languages being the most popular (i.e., learners are most interested in this category). In terms of material type, open textbook and video are the most popular. Furthermore, websites are the most popular technical format – i.e., this is the ‘medium’ by which users prefer to access OERs. The qualitative analysis of the selected OERs (based on the MERLOT discipline reviewer comments) provides valuable insights into the design of OERs, in terms of content quality, effectiveness as a teaching/learning tool and ease of use. Finally, we have presented an innovative 3E (Enrich, Extend and Elevate) strategy/pedagogy for using OERs. In particular, apart from enriching lectures with OERs, students can also play an important role in driving the use of OERs through different learning activities.

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#### REFERENCES

- [1] E. Tovar and N. Piedra, “Guest editorial: open educational resources in engineering education: various perspectives opening the education of engineers”, *IEEE Transactions on Education*, vol. 57, no. 4, pp. 213-219, November, 2014.
- [2] H.C.B. Chan, “Internet of education resources using a chemistry-inspired framework”, *IEEE Computer*, vol. 50, no. 5, pp. 54-60, May 2017.
- [3] UNESCO (2016) - Incheon Declaration and framework for action for the implementation of Sustainable Development Goal 4:  
<http://unesdoc.unesco.org/images/0024/002456/245656E.pdf>
- [4] UNESCO (2017) - Second World OER Congress: Ljubljana OER action:  
[https://en.unesco.org/sites/default/files/ljubljana\\_oer\\_action\\_plan\\_2017.pdf](https://en.unesco.org/sites/default/files/ljubljana_oer_action_plan_2017.pdf)
- [5] D. Wiley (2015) - Open pedagogy: The importance of getting in the air. <http://opencontent.org/blog/archives/3761>
- [6] W. M. Jackman and P. Roberts, “Students’ perspectives on YouTube video usage as an e-resource in the university classroom”, *Journal of Educational Technology Systems*, vol. 42, pp. 273-297, 2013.
- [7] Y. Chtouki, H. Harroud, M. Khalidi and S. Bennani, “The impact of YouTube videos on the student's learning”, *Proc. 2012 International Conference on Information Technology Based Higher Education and Training*, Jun. 2012.
- [8] K.M. Gibson, “Fostering collaboration and learning in asynchronous online environments,” *Journal of Teaching and Learning with Technology*, vol. 2, no. 2, pp. 60-78, Dec. 2013.
- [9] N.K. Subramaniam, “Enhancing learning through the discussion forum,” *Asian Association of Open Universities Journal*, vol. 7, pp. 63-77, Sep. 2012.
- [10] N.B. Colvard, C.E. Watson and H.P. Ewha, “The impact of open educational resources on various student success metrics”, *International Journal of Teaching and Learning in Higher Education*, vol. 30, no. 2, pp. 262-276, 2018.
- [11] J. Hilton, “Open educational resources and college textbook choices: a review of research on efficacy and perceptions”, *Education Technology Research and Development*, vol. 64, pp. 573–590, 2016.
- [12] J.R. Winitzky-Stephens and J. Pickavance, “Open educational resources and student course outcomes: a multilevel analysis”, *International Review of Research in Open and Distributed Learning*, vol. 18, no. 4, pp. 35–49, 2017.
- [13] S. Mishra, “Open educational resources: removing barriers from within”, *Journal of Distance Education*, vol. 38, pp. 369-380, 2017.
- [14] J.E. Seaman and J. Seaman, *Opening the Textbook: Educational Resources in U.S. Higher Education*, Babson Survey Research Group, 2017.  
(<https://files.eric.ed.gov/fulltext/ED582411.pdf>)
- [15] M.M. Arimoto, L. Barroca and E.F. Barbosa, “AM-OER: an Agile method for the development of open educational resources”, *Informatics in Education*, vol. 15, pp. 205–233, 2016.
- [16] J. L. Bishop and M. Verleger, “The flipped classroom: a survey of the research,” *Proc. 120-th ASEE Annual Conference*, Jun. 2013.
- [17] Y. Chen, Y. Kinshuk and N. Chen, “Is FLIP enough? Or should we use the FLIPPED model instead?,” *Computers & Education*, vol. 79, pp. 16-27, Oct. 2014.
- [18] E. Tovar, H.C.B. Chan and S. Reisman, “Promoting MERLOT communities based on OERs in computer science and information systems”, *Proc. IEEE COMPSAC 2018*, July 2017.
- [19] How Students Learn  
(<https://www.teachervision.com/how-students-learn>)
- [20] Principles of Learning  
([https://en.wikipedia.org/wiki/Principles\\_of\\_learning](https://en.wikipedia.org/wiki/Principles_of_learning))
- [21] Catalyst for Learning (<http://c2l.mcnrc.org>)