Open Educational Resources in Computer Science Teaching

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ABSTRACT
Open content and open access to resources are important factors in the innovation of Computer Science education. This paper presents a study aimed at gaining an understanding of the needs of Computer Science educators in terms of Open Educational Resources (OER): what kind of resources they need, when they need them, how they use them, and what are the barriers and the enablers for using OER. The results of the study are compared and analyzed in the context of the popular OER sites. The work contributes to the research on OER utilization and discovery.

Categories and Subject Descriptors
K.3.2 [Computers and Education]: Computer and Information Science Education; H.3.5 [Information Storage and Retrieval]
On-line Information Services

General Terms
Design, Human Factors

Keywords
Open Education, Open Content, Open Educational Resources

1. INTRODUCTION
The vision of open content educational material on the Web, has attracted substantial attention [1]. Open educational resources (OER) include instructional materials, tools, and media used for teaching and learning that are free from copyright restrictions or are publicly licensed for anyone to use, adapt, and redistribute.

One of the challenges facing Open Education is that while the open content grows in popularity and we witness the proliferation of repositories and portals for OER content, it becomes more difficult for potential users to find the content they need.

In this open but competitive environment one obvious question is how OER portals can attract educators and make them use the available content. A derived question is what type of resources the repositories should host and how they should structure and support exploration of their sites. Many aspects, from structuring OER metadata to tuning OER search engines, are factors in ensuring matches between OER and educators who might utilize and benefit from them. Among those, the most problematic is the “finding-getting-using” challenge faced by educators seeking open content. In this relation, one unconventional viewpoint that may become useful is to look at the content itself as a sort of commodity. This brings a market perspective, in a sense of viewing the offered content as a marketplace of competing products. As a result, the value of the repository itself, in particular its capability in helping users find the right content is the proper differentiator and value proposition to the educator [2].

This new viewpoint not only suggests a market perspective but also opens it to the corresponding solutions provided in this area. One idea that we found relevant and promising is the Christensen’s “jobs-to-be-done marketing” theory [3,4]. This theory states that people buy products and services to get jobs done. It holds that products are successful when they connect with a circumstance – with a job that customers find themselves needing to get done. The job-to-be-done model in OER context implies going beyond the conventional practice and trying to see whether there are ‘jobs’ desired by educators that fit to the OER niche. For example, in OER context the model suggests finding the answers of questions, such as: What types of teaching materials are in high demand? Is finding code examples matching subject X, a need experienced by a large population of Computer Science teachers? Is finding content that matches a specific learning goal a frequent task for certain category of instructors?

The “job-to-be-done” approach is motivated and intended for the market economy. It may seem that this view is inconsistent with the open education movement, which aims at an environment freed from the constraints of copyright and monetary exchange. However, “selling more goods” is a viable driving objective in this environment despite the Creative Commons licensing scheme that enables authors to give away their material for use while having the option to retain certain rights. Selling is used here not in its traditional sense, but in the sense of utilization of the offered ‘open’ goods. Open educational sites do take some actions to attract more users: they count the number of visits, the number of downloads, etc. The open and monetary based educational sectors compete for users’ attention. This implies that the “job-to-be-done” point of view is consistent with the open educational environment. It suggests (1) focusing on understanding the jobs that involve use of open educational repositories, and (2) improving repositories’ functional, social, and affective dimensions so that they serve their users better.

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Motivated by these observations, we conducted a study to (1) better understand for what needs/type of jobs Computer Science teachers seek OER, and (2) provide insights about OER design decisions that can address these needs. Only by understanding the Computer Science teaching needs deeply and in their variety can the OER community begin to address these needs.

2. THE STUDY
The purpose of this study was to gather an empirical insight of the potential and the possible impact of OER on Computer Science teaching. In order to understand the instructors’ needs and how the current and future OER meet (should meet) those needs, we conducted a survey. A key motivational factor backing up the survey was the Christensen’s model. Accordingly, the job not the user was in the focus of the survey. We especially tried to avoid questions related to the specifics of user-OER interactions. Our understanding is that the specifics should be derived from understanding and explicating of the “jobs-to-be-done” needs. The central set of questions that emerged as guiding directions for the survey were as follows:

- What kind of OER are most needed?
- When are OER most needed?
- How are OER used?

2.1 The Survey
Data was collected through questionnaire\textsuperscript{1}, distributed to Computer Science instructors via email. The questionnaire was sent to about 3000 teachers via email including SIGCSE, UK OER, and OCW/OER research mailing lists, selected departments, and individual emails. Only 315 instructors (less than 15%) responded. A sizeable number of them - 103, didn’t complete the survey stating that they have never used OER content. In order to diversify the survey results we gathered data from various university categories: research universities (31%) and predominantly teaching universities, including HBCU and Community Colleges (69%). The list of survey participants includes instructors from various geographic regions: North America (168), Europe (71), Africa (45) and South America (31).

The three central questions were translated into 10 survey questions, clarifying and detailing the points of the central set. The top five questions were multiple choice - multiple answer, while the remaining ones were open ended.

2.1.1 Multiple-Choice Section

**Question 1.** Which of the following criteria for selecting material (resources) for your teaching do you consider essential: (a) Completeness of coverage of the topic; (b) Level of complexity (difficulty); (c) Level of detail; (d) The programming language it is based on; (e) The textbook it is related to; (f) Level of illustration by examples; (g) Recency (currency); (h) Popularity; (i) The quality of content; (j) The quality of layout; (k) The institution/author it originates from; (l) Any other criteria you consider important but not listed above?

The purpose of this question was to get an insight about the type of teaching material that an instructor typically needs and thus to provide guidance for a better balance of the hosted OER content. The outcome of the question attests that for Computer Science teachers the need for assignments, code examples, and problems is higher than the need for PowerPoint slides. This fact is also in conflict with the major type of teaching content provided on OER sites. In addition to the listed resource types, the participants proposed: images, animations, cartoons, simulations, audio podcast, journal articles, and blogs as helpful in their practice.

If we name the most frequent and challenging task faced by the teachers in terms of OER utilization as “find my needed content”, then the purpose of the first two questions was to explicate the criteria and the content types characterizing “my needed content”, while the next questions targeted the condition of its use.

**Question 2.** The availability of which of the following resource types do you find most useful in your teaching practice? (a) Lecture notes; (b) PowerPoint slides; (c) Code examples; (d) Assignments/ projects; (e) Tests; (f) Problems; (g) Solutions; (h) Reading lists; (i) Textbooks; (j) Syllabi; (k) Videos; (l) Any other types you consider important but not listed above?

This result is in disagreement with the current trend of OER repositories to focus on structuring the hosted resources based on topicality, with less attention to the other facets of the resources. Besides the listed criteria, some survey participants proposed the granularity, the license, the programming language, and the sequence of topics as additional factors in resource selection.

**Question 3.** When do you (would you) consider using open educational content in your teaching practice: When (a) Designing a new course; (b) Updating course material; (c) There is no adequate textbook or supplemental material available; (d) Covering novel (emerging) topics; (e) Explaining/clarifying a concept; (f) Teaching new concepts skills; (g) Any other cases?
The results of this question point out that teachers turn to OER most frequently when they have to design or update their courses, when clarifying new concepts or when they need to cover novel topics. While the current OER trend is to organize and provide the teaching content in terms of courses, the result implies a need of structures facilitating an access to finer-grain components and accompanying units. For example, teachers should be able to find out whether a specific concept is covered in a particular lecture without going through each slide. In many cases OER repositories don’t provide an appropriate framework for exploring various facets and details of the hosted information.

**Question 4.** How do you (would you) use open educational content: (a) As it is published; (b) By adapting it to fit my context; (c) By incorporating pieces of open content into my own material; (d) By remixing pieces of open content?

The answers to this question signal that users need not only access to the content at different levels of granularity but also in interoperable formats. They need pieces from various lecture notes, along with pieces from PowerPoint slides, assignments and tests. Adapting, incorporating and remixing content requires modularization and compatible formats and grain size.

**Question 5.** Open educational content for which of the following kinds of computer science disciplines (topics) do you consider more needed?: (a) Established; (b) Fast changing; (c) Emerging?

This question targets the category of disciplines ranging from established to emergent, where the need for OER is most evident. The expressed views on this question are mixed. The dominating opinion is that the established topics are most appropriate for OER, followed by the emerging and fast changing topics. According to the answers, educational content in emerging and fast changing disciplines are in proportional demand with established disciplines but in reality the former are almost not existent in the current OER repositories.

### 2.1.2 Open Ended Section

The purpose of the last section containing five open ended questions was to gather qualitative information about the level of awareness and use of OER, the perceived obstacles, potential facilitators and the type of tasks that the teachers would like to accomplish with the help of OER. One way to make OER a viable alternative for the job “find material for my teaching” is to reduce the barriers and foster the enablers for using them. The following two questions are set to capture some emerging patterns regarding the barriers and enablers to OER use.

**Question 6.** What are the most significant barriers to the use of open educational content in teaching?

The responses to this question can be summarized in a keyword style as follows: finding, customizing, availability, awareness, access, quality, and license. Several groups of semantically equivalent answers emerged from the 211 responses to the question. The aggregated meaning of the answers in each group was summarized in a single statement serving as a message carrier for the group responses. The following is a list of such summaries for the groups that contain more than five answers. (Some actual answers are given in italics as supportive illustrations.)

- **Difficulty of finding OER content matching specific context** (87 respondents).
  - Finding suitable material of high quality (often this takes an amount of time comparable to producing one’s own materials)
  - Time to search
  - Finding content appropriate for my audience

- **Difficulty of customizing the content to local conditions and the instructor’s approach** (41 respondents).
  - Teachers may have their own style (regarding structure, preferred sub-topics, level of detail, layout) and thus are afraid of re-using existing content
  - Difference in the style and terminology used

- **Availability and variety of OER content** (23 respondents).
  - Lack of availability for many subjects and lack of variety in what is available
  - Lack of good open content

- **Assurance of quality** (16).
  - Uncertainty about quality of OER
  - Time that should be taken in checking it for accuracy

- **Awareness of the existence of OER content** (14).
  - I didn’t even know open educational content was available
  - Awareness of OER is still limited

- **Incompatible open content licenses** (11).
  - The fear that it might, in error, include some copyrighted sources
  - Restrictive open licences (use of ND clause in Creative Commons licences)

- **Attitude, recognition and publicity** (9 respondents).
  - Attitudes of instructors and administrators
  - Culture of "charity" rather than sharing
  - I think many colleagues are far too protective against their own material
• Worry that “free” means “bad quality” (7 respondents). Most people seem to believe that if it’s really open, it must be (a) unsupported or (b) incomplete or (c) out-of-date I believe the biggest barrier to be attitude – the notion that “free” or ”open” (to many) has the stigma of being not as high in quality or as supported

• Availability of a centralized database containing OER that can be conveniently searched (5 respondents). Find a good repository where you can use and adapt specific content.

The dominating obstacle reported by participants, which amounts to 41% of the responses was the effort needed to find appropriate content. The second major barrier (19% of the responses) was the work needed for adaptation and the third one (11% of the responses) was the availability of appropriate resources. Among the answers not included in the above groups but worth mentioning are: the language barrier for non-English speaking instructors, worry that materials won’t persist, and poor metadata. Previous research on OER utilization has identified finding relevant resources as a significant obstacle [5]. The results of our survey confirmed yet again that it is the most significant barrier for effective use of OER.

Question 7. If there are any enablers that you believe could increase the adoption of open educational content in teaching, please list them below with a brief explanation.

The responses to this question can be summarized by the following terms: finding, central repository, publicity, trust, broader coverage, collaborative tools, clear licenses and accessibility. As before, several groups were identified within the 203 answers to the question. The groups containing more than five answers are summarized below.

• Improved tools for searching and finding relevant content (79 respondents). Less time to find and change content relevant to my subject Really good search capability The only thing that would help would be to make it easier to locate, and have some type of vetting system A rating system that would enable one to find the good stuff quickly Filtering searches by topic, nature of exercise (e.g., lab, homework offline, programming assignment, etc.), environment (operating system, application software)

• Central repository for sharing and reviewing OER materials (76 respondents). Central repository of links to OER material in different institutes A central repository of content, with syllabi for various courses More globally accepted sites to share educational content (there are many yes, but is there really a place that everybody knows?) ACM/SIGCSE sponsored repository for Computer Science material

• Publicity and exposure of successful OER utilization (33 respondents). Help documentation, examples of successful adoption with tips and hints More exposure/advertisement to users

• Quality verification and establishment of public trust (18 respondents). Reviews of open materials in a way that administrators would give credit Include peer evaluation and establishment of public trust

• Broader course and topic coverage (13 respondents). Greater choice of courses and lectures Continued growth of the practice so that more is available

• Tools for collaborative OER content creation (11 respondents). A collaborative resource to produce and distribute educational content, Increasing the use of interactive collaborative tools

• Explicit, unambiguous copyright rules (9 respondents). Clearer use of licenses to establish what one is or is not allowed to do Clear copyright/license/usage rules and standards (type Wikipedia/Media)

• Improved accessibility to OER materials (6 respondents). Better accessibility of the content ...

The top two enablers that were identified are “improved tools for searching and finding” (39%) and “centralized OER repositories” (37%). These enablers are related as the availability of central repositories in general improves resource findability. The next major enabler (16%) is publicity of the OER resources and their usage, followed by tools for collaborative OER creation (9%). Among the enablers shared by several respondents but not listed in the above groups are the metadata and recognition of the value of reusing OER.

The next question was intended to identify the most desirable tasks that can be achieved assuming the existence of relevant resource discoverability tools.

Question 8. Consider tasks such as:

“Find a set of PowerPoint slides matching syllabus X”
“Find PowerPoint slides similar to the material in resource X”
Can you list some other tasks that are not addressed by the current resource discovery services but with possible positive impact on open content use?

As before, the 108 received answers were grouped by meaning:

• Find resource [of type X] on topic Y [of level/competency Z] (48 respondents). Find PowerPoint slides that explain concept C Find code examples for lecture X (junior level) Find an assignment reinforcing concept X

• Browse by category X [refine by category Y] [refined by category Z] (26 respondents) Search the content inside the code examples for examples in java illustrating a given concept Search for a course of a specific level, or from a specific university or from a specific author, based on a specific language

• Find resource [of type X] to be incorporated in resource Y [of topic Z] [of type U] [of level/competency V] (14 respondents). Find a set of pictures illustrating topic X discussed in resource Y ...
Find tests applicable to this course ...
• Find alternative content to the resource X (12 respondents).
  
Find alternative materials for this part of the course
• Find resources [of type X] matching syllabus Y [satisfying course goal Z] (8 respondents).
  
Find textbook type materials matching this syllabus

This open ended question was not expressed in terms of the functionality of the current search tools. Rather it was formulated in a way to provoke participants to respond with a “wish list” of features, which if made available would benefit teachers. The huge multiplicity of the ways users describe “their content” reflects varying needs and also explains the bulk of resource discovery techniques proposed by the participants. On the top of the wish list were tools for finding resources satisfying multiple constrains (44% of the respondents) and browsing by multiple categories/refinements (24% of the respondents).

Question 9. Have you ever used open educational content in your teaching practice?

More than one third of the respondents (123) reported that they have never used OER. This number becomes even more disproportional if we add the 103 individuals who declined to participate in the survey because they have never used OER.

Question 10. How many institutions (sites) offering open educational content do you know of?

The majority of respondents reported that they know one or two sites (typically including MIT OpenCourseWare). At the other end were the 34 participants that knew a dozen or more OER sites.

2.2 What is the Reality?

The low use of OER from Computer Science educators signals that the level of understanding of who the users are and what they need is insufficient. This fact motivated us to carry out two additional studies focused on existing OER sites in order to identify some reasons for this phenomenon.

The goal of the first study was to collect some evidence on the coverage of Computer Science topics by OER sites and how easy it is to find open content on selected topics. We picked a set of introductory and upper-level courses following the latest ACM Curriculum Recommendation (http://www.acm.org/education/curricula/ComputerScience2008.pdf), namely: Analysis of Algorithms, Artificial Intelligence, Computer Architecture, Computer Networks, Database Management, Introduction to Programming, Operating Systems, Programming Languages, and Software Engineering, assuming a lecture level as a granularity criterion for the results. From each of those introductory or core courses we selected topics and searched for resources that can be used as lecture plans or notes (see Table 1). In addition, we included elective type courses and more advanced subjects (see the last seven rows in Table 1) in order to weigh the availability of more specific against more conventional Computer Science OER material. We used Google’s advanced search to narrow down the results to materials licensed under a Creative Commons Attribution. For comparison with the open web search we repeated the search experiment with twelve OER sites providing Computer Science materials, namely: MIT OpenCourseWare, Connexions, CITIDEL, The Open University OpenLearn, OpenCourseWare Consortium, OER Commons, Merlot (general repository with OER content), NSDL, Wikibooks, SOFIA, EDNA, and UCI OpenCourseWare. We used again Google’s advanced search but this time to localize the search within the corresponding domain, which resulted in twelve search sessions triggered by queries such as “operating systems synchronization java site:merlot.org”.

Table 1. Results of Google and OER search on selected topics

<table>
<thead>
<tr>
<th>No</th>
<th>Search Keywords</th>
<th>Found</th>
<th>Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Google</td>
<td>OER</td>
</tr>
<tr>
<td>1</td>
<td>analysis algorithms spanning trees</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>artificial intelligence reasoning systems</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>computer architecture pipelining</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>computer networks congestion control</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>database management normalization</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>data structures binary trees</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>introduction programming java inheritance</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>operating systems synchronization java</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>programming languages data types</td>
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<td>1</td>
</tr>
<tr>
<td>10</td>
<td>software engineering agile development</td>
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<td>4</td>
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<tr>
<td>11</td>
<td>artificial intelligence definite clause grammars</td>
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<td>0</td>
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<tr>
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<td>e-commerce web services</td>
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<td>0</td>
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<tr>
<td>13</td>
<td>hardware media security blue-ray pm</td>
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<td>web programming xml xpath</td>
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</tbody>
</table>

The results showed that the coverage of the selected core and introductory Computer Science courses is quite low - around 2.5 (average) resources per topic. The coverage of elective Computer Science courses and advanced topics is even lower - 0.4 (average) resources per topic. This fact is in contrast with the outcome derived from the survey responses attesting that greater topic coverage is one of the enablers of effective OER use. The latter results also indicate a disturbing imbalance: almost no OER materials were found for emerging disciplines, where instructors need even stronger support since recent advances are typically not covered in textbooks. This study identified additional factors that do not meet the expectations of the survey responders. With a few exceptions, the twelve OER sites are institutional repositories that do not provide support for resubmitting derivative work. The majority of OER repositories do not collect user reviews/comments on the quality of the resources hosted on their sites and do not provide support for social/community recognition (e.g. rating) of resources.

The purpose of the second study was to analyze further the points of disagreement between the survey results and OER sites hosting Computer Science resources. Our first observation was that from the 13,000 courses published by 150 universities [6] only 21 sites provide Computer Science related materials: MIT OpenCourseWare, Connexions, OERCommons, CITIDEL, UCI (OpenCourseWare), Stanford School Engineering Everywhere, Webcast.berkeley, VideoLectures.NET, EDNA, MERLOT, The Open University, OpenLearn, University of Michigan, SOFIA, Intel’s Academic Community, University of Queensland, Notre Dame OpenCourseWare, University of Massachusetts Boston, Utah Valley University, and Weber State
University. Each of the last four sites hosts a single course. The ability to tell at a glance if particular content is a good match for a specific teaching activity is a critical feature for efficient selection of adequate resources. As one respondent reported “I can’t afford to spend even 3 minutes evaluating each resource in a list. If it takes that long, it is often faster to just write my own.”

In general, resource metadata does not meet the expectation outlined in the survey responses. Merlot supports perhaps the richest metadata set that includes material type, date added, date modified, description, author, submitter, peer reviews, audience, language, copyright, source code, accessible information available, cost, creative commons. Most problematic here is the license related metadata. In the majority of the examined cases the provided information was “copyright: yes”, “creative commons: unsure”. This fact along with the cost related metadata is in contradiction with the OER philosophy. With respect to metadata, OER Commons supports the following set: abstract, author, subject, institution name, collection, grade level, course type, languages, material type and media format. However, key criteria related to the quality of content (e.g. indication for peer evaluation) or recency, are missing. MIT Open Courseware supports a comparable although implicit metadata set. The metadata provided by the remaining sites is limited, typically a subset of the following list: author, title, summary/subject, level and year of submission. Some sites support tagging (OpenLearn) or comments (Merlot). The OER resources vary greatly in their depth and target audience. Most of the metadata in the repositories however is about the content itself, and not about its use, which would enable a more efficient selection decision.

In terms of resource type availability, only MIT Open Courseware provides adequate collection of resource types: lecture notes, videos, audio lectures, assignments, exams, solutions, projects, examples, study material, online textbooks, syllabus and interactive demonstrations. It provides also visual means to easily locate the relevant resource types. Unfortunately, those types are distributed unevenly among different resources. For example, we found only one lecture accompanied by an interactive demonstration, one course with a syllabus and another one with an online textbook. Also, program examples if available are not directly accessible. According to the survey assignments, program examples, problems and solutions are the most needed resource types. However, there are only few repositories offering a (limited amount) of those resource types. For example, in Merlot from the 70 resources under category “Programming” only 15 have code examples, and from the 15 resources under the category “User Interfaces” only 1 has code examples. As to the assignments, we were able to locate only four assignments in total. Surprisingly, in Connexions among the 19,034 reusable modules there were no PowerPoint slides, assignments, code examples, problems, solutions or tests for Computer Science topics. Some sites, such as Webcast.Berkeley or VideoLectures.net offer only video materials.

Regarding resource recency only five sites offer fresh content. For example, in Merlot from the 70 resources under category “Programming” only 15 have code examples, and from the 15 resources under the category “User Interfaces” only 1 has code examples. As to the assignments, we were able to locate only four assignments in total. Surprisingly, in Connexions among the 19,034 reusable modules there were no PowerPoint slides, assignments, code examples, problems, solutions or tests for Computer Science topics. Some sites, such as Webcast.Berkeley or VideoLectures.net offer only video materials.

As indicated by the survey, poor support for finding relevant content was seen as a major barrier, while providing adequate tools for finding such content was reported as a major enabler. In this context, there is a significant gap between the desired and actual support. The best example in terms of resource discoverability is probably Connexions, which offers multiple browse and search options. The site allows browsing by subject, title, author, keyword, popularity, language, revision date, institution, all collections, and keyword search that can be narrowed to a specified subject, collection, title, and author. In a similar fashion, OER Commons supports searching by subject area, grade level, resource type, and by tags/keywords. On the other hand, CITIDEL allows users to search by communities and collections, titles, authors, subjects, date and alphabetically. However, the navigation is inflexible and clumsy.

In a nutshell, current OER repositories are falling short of meeting users’ expectations in terms of adequate support for finding needed content. Somewhat unexpected was the fact that desired and not so uncommon search strategies such as “find more like this” are not provided by any of the examined sites.

3. CONCLUSION

Looking for appropriate resources is a frequent job in the teaching practice. OER represent a new “org chart” for dissemination and use of educational resources and the new solutions should not be constrained by old paradigms. The studies we conducted reveal a gap between the views of the potential OER consumers and the solutions offered by the OER providers. A disagreement was identified in several aspects with sometimes unexpected mismatch between the reality and the expectations. Just a great volume of open content is not sufficient. It should come in a variety of depth, details, levels and grain-size. It should support different teaching activities, different selection criteria, and be easy findable and adaptable. Although examples of successful OER utilization are not isolated phenomena, there is a low level of awareness about existing OER. Reducing the gap between the needs of the OER consumers and the solutions offered by the OER providers will bring benefits to Computer Science educators and help them to deal with ever fast changing and emerging subjects.

Our further research agenda includes evaluating the impact of the growing OER content on teaching practice and on learning outcomes, and situating OER within the broader picture of changing models of Computer Science education.

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5. REFERENCES


