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Towards the Establishment of a Capability Model for Open Access Repositories

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Towards the Establishment of a Capability Model for Open Access Repositories

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Em Direção ao Estabelecimento de um Modelo de Capacidade para Repositórios de Acesso Aberto

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Abstract

OLIVEIRA, RAUL. **Towards the Establishment of a Capability Model for Open Access Repositories**. 2023. 107 p. Dissertação (Mestrado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2023.

Education is evolving through the years. Computers, mobile devices and the growing access to the Internet are playing a big role in these changes. Open Educational Resources (OERs) emerge in this context, trying to gather the strengths of the modern and technological society in order to improve the overall quality of global education. OERs are any type of teaching, learning and research materials that can be reached in the public domain or have been published under one of the intellectual property licenses. OERs enable the learning process to be open and flexible, providing suitable opportunities and adapted to individual needs, promoting overall improvement of teaching abilities, reducing the global cultural gap, minimizing the dependence of commercial books and helping students from poor communities. Universities, educational institutions and others non-profit organizations often share their OER content through Open Access (OA) repositories. However, there is some concerns about the quality assurance these OA repositories; most institutions only uses their brand and reputation to persuade their students that their resources have an adequate excellence degree. In a different but related perspective, Maturity and Capability Models emerged as an interesting approach for quality assurance. The main idea is to improve the industry performance through incremental and structured enhancement, increasing the competence of organisations in achieving strategic objectives. Maturity and Capability Models were originally developed for software companies, but nowadays they are often tailored for other fields, specially on the education area. Although there are indeed several educational Maturity and Capability models, none of them are specifically related to OERs. In this context, the main goal of this Master's work is to verify whether a capability model, specifically tailored for OERs sharing initiatives, can improve the academic trust in the related processes of such initiatives. The model should support students searching for OERs, educators that want to share their own resources and maintainers searching for points of improvement in their repositories. Our research indicate which qualities must be considered when characterizing an Open Access Repository. As a result we developed a Capability Model for Open Access Repositories, named CM-OAR, aiming at the enhancement of the trustworthiness of these repositories, by solving, or at least minimizing, the concerns about its quality assurance.

Keywords: Open Educational Resources, Capability Maturity Model, Maturity Model, Sharing Initiatives, Quality Assurance.

Resumo

OLIVEIRA, RAUL. **Em Direção ao Estabelecimento de um Modelo de Capacidade para Repositórios de Acesso Aberto**. 2023. 107 p. Dissertação (Mestrado em Ciências – Ciências de Computação e Matemática Computacional) – Instituto de Ciências Matemáticas e de Computação, Universidade de São Paulo, São Carlos – SP, 2023.

A educação está evoluindo através dos anos. Computadores, dispositivos móveis e o crescente acesso à Internet possuem grande atuação nestas mudanças. Recursos Educacionais Abertos (REAs) surgem neste contexto, tentando agrupar as forças de uma sociedade moderna e tecnológica para melhorar a qualidade geral da educação mundial. REAs são qualquer tipo de materiais de ensino, aprendizagem e pesquisa que podem ser acessados em domínio público ou que foram publicados sobre uma das licenças de propriedade intelectual. REAs possibilitam que o aprendizado seja aberto e flexível, promovendo oportunidades e se adaptando a necessidades individuais, gerando um aumento geral nas habilidades de ensino, reduzindo as fronteiras culturais, minimizando a dependência de livros comerciais e ajudando estudantes de comunidades carentes. Universidades e instituições de ensino frequentemente compartilham seus REAs através de Repositórios Abertos. Entretanto, existem algumas preocupações sobre a qualidade destes repositórios; a maioria das instituições usa apenas sua marca e reputação para persuadir seus estudantes que seus materiais possuem um grau de excelência adequado. Em uma perspectiva diferente, porém relacionada, Modelos de Maturidade e Capacidade surgem como uma abordagem interessante para garantia de qualidade. Seu principal objetivo é aperfeiçoar a performance de processos através de melhorias incrementais, aumentando a competência de organizações em conquistar objetivos estratégicos. Modelos de Maturidade e Capacidade foram originalmente desenvolvidos para companhias de software, mas nos dias de hoje são comumente adequados e adaptados para outros campos, especialmente no educacional. Embora existam vários Modelos de Maturidade e Capacidade educacionais, nenhum deles é especificamente relacionado aos REAs. Neste contexto, o principal objetivo deste trabalho de mestrado é verificar se um modelo de Capacidade, especificamente adaptado para iniciativas de compartilhamento de REAs, pode melhorar a confiança acadêmica nos processos relacionados de tais iniciativas. O modelo deverá apoiar estudantes procurando por REAs, educadores que desejam compartilhar seus próprios recursos e mantenedores buscando por pontos de melhoria em seus repositórios. Nossa pesquisa indica quais qualidades devem ser consideradas ao categorizar Repositórios Abertos. Como resultado foi desenvolvido o nosso Modelo de Capacidade para Repositórios Abertos, chamado CM-OAR, com o objetivo de aumentar a confiabilidade de tais repositórios, resolvendo, ou ao menos minimizando, os problemas associados à garantias de qualidade.

Palavras-chave: Recursos Educacionais Abertos, Modelo de Capacidade e Maturidade, Iniciativas de Compartilhamento, Confiabilidade, Garantia da Qualidade.

List of Figures

List of Tables

Contents

CHAPTER

1

Introduction

1.1 Context and Motivation

Education is evolving through the years. Computers, mobile devices and the growing access to the Internet are playing a big role in these changes. They provide freedom to the student, who can choose when, where and how to learn and consume each one of his/her interests. Schools, colleges, universities and educational institutions in general are in need to adapt and reinvent themselves in order to keep up with this new trending.

The academic community is also aware of this transformation, investigating and researching several open issues in the area, particularly the effects of m-learning in students motivation (JENO *et al.*, 2019), how to evaluate student satisfaction in e-learning applications (VEZZETTI; VIOLANTE, 2019), how to assess the overall quality of Massive Open Online Courses (MOOCs) (FOLEY *et al.*, 2019), among others.

In this context, one of the current and biggest educational challenges has been the development of Open Educational Resources (OERs). In short, the concept OERs tries to gather the strengths of the modern and technological society in order to improve the overall quality of global education. As defined by (HEWLETT; HEWLETT, 2002), OERs are any type of digital courseware that can be reached in the public domain or have been published under one of the intellectual property licenses. According to (WILEY, 2014), these licenses should provide to the student autonomy and freedom to reuse, review, remix, redistribute and retain copies of these educational content.

OERs enable the learning process to be open and flexible, providing suitable opportunities, adapted to individual needs. The shareable and community development aspect of OERs also promotes an overall improvement of teaching abilities, reduces the global cultural gap and quickly corrects misconceptions and mistypings in the educational content. The open aspect can reduce socioeconomic inequality, as it minimizes the dependence of commercial books and

helps students from poor communities (WILEY, 2014)(CASWELL *et al.*, 2008)(D'ANTONI, 2009)(HYLEN, 2006).

Universities, in turn, also play a significant role in the new era of digital learning. Gourley and Lane (GOURLEY; LANE, 2009) claim that every university should make the world of knowledge a lot more democratic and open, bringing education to all that can be benefit by it. Nevertheless, one of the main inhibitors of the OERs growth is the lack of institutional policies and incentives for educators to produce and effectively adopt such resources (YUAN *et al.*, 2008).

Open Access Repositories emerged as a solution to universities, institutions and others non-profit organizations to share and create OER communities. They are online databases where educators can distribute their educational materials to students that want to consume them, all free and without any access restrictions (PINFIELD, 2005) (XIE; MATUSIAK, 2016).

In a previous work (OLIVEIRA; BARBOSA, 2018), we investigated the problems of content and the access difficulty of OERs projects in universities. Specially in Brazil, most of the top universities do not possess such projects. Even universities that effectively produce it, when compared the pioneers of the area like MIT OpenCourseware (OPENCOURSEWARE, 2022), lacks in diversity, quantity and publicity.

In a different but related perspective, Maturity Models (MMs) emerged as an interesting alternative for quality assurance (MUGHRABI; JAEGER, 2018). In short, MMs are approaches that improve the industry performance through incremental and structured enhancement, increasing the competence of organisations in achieving strategic objectives. MMs were originally developed for software companies, but nowadays they are often tailored for other fields as construction, manufacturing, service development and, specially, education (OSWALD; LINGARD, 2019) (SCHUMACHER *et al.*, 2016) (REÇI; BOLLIN, 2017).

The first model proposed with this maturity concept was the Capability Maturity Model (CMM) (Paulk *et al.*, 1993)(PAULK, 2002), aiming at measuring the ability of an organization for continuous improvement in the software development context. The higher the level of the organization, the higher is the chance of improvement through their mistakes. Each level contains a series of activities and processes that are necessary to accomplish a certain standard of maturity, that are extremely related to the quality assurance of their products. Once the organization is assigned to a level, it should be clear which new steps must be taken to reach a higher status.

CMM inspired the vast majority of latter proposed MMs. Capability Maturity Model Integration (CMMI) (TEAM, 2006) is its evolution, fixing most of its criticism and adding useful functionalities from other successful models. The Software Process Improvement and Capability Determination (SPICE) (DORLING, 1993) was also inspired by the CMM, being known for analyzing and evaluating the capability and maturity of each process individually, and also providing a guide for performing the organization assessment.

On the educational area, the e-learning Maturity Model (eMM) is one the most referenced (MARSHALL; MITCHELL, 2004). The authors merged the concepts of CMM and SPICE in order to provide a robust system to serve as a guide to improving course and institutional level adoption of e-learning.

Despite the growing relevance of OERs (TUOMI, 2013) in education, the area still lacks a trustworthy method in order to guarantee the overall quality and maturity of its sharing initiatives. For the purpose of our research, we defined as a sharing initiative any educational institution (universities, schools, profit or non profit teaching organizations) or individual (teachers, courseware designers) that possess an intent or project of sharing OERs.

According to (HYLEN, 2006), some initiatives only uses their brand and reputation to persuade their students that their OERs have adequate quality. On the other hand, MMs are often used as solutions to systematize and improve processes, providing clear guidelines for self assessment and quality assurance marks. Besides that, MMs can also be customized to specific domains, providing results specially in the educational area (MARSHALL, 2009).

So, in order to minimize the problems associated with the difficulty in creating successful open access repositories, educational MM's will be investigated. Considering the lack of MM's designed specially for the sharing of OERs, this Master's project aims to design and evaluate an Capability Model for Open Access Repositories (CM-OAR). The objectives are summarized in the next section.

1.2 Research Objectives

Considering the context previously discussed, this Master's project aims to investigate and propose an open capability maturity model for open access repositories. Such objectives were tailored in order to support the answering of this following research question: *Can a capability maturity model be adapted to assess open access repositories?*. So, the main objectives of this work can be addressed in three lines of investigation:

- Study of OERs and MMs concepts, identifying, understanding and analysing their main requirements, advantages, problems and difficulties. The goal is to characterize the state of the art and the current gaps of these areas, specially on educational MMs.

- Proposition of an open capability model, capable of supporting the assessment and improvement of the overall capability of processes related to Open Access Repositories. From this model, institutions should be able to self evaluate their OA repositories, establishing a clear path of which activities still need to be implemented or improved in order to reach a trustworthy and quality service.

- Validation of the proposed model through feedback from experts and potential users (educators and students). This validation should also guide the development process, drawing attention to points of improvement.

1.3 Outline

In this chapter, we presented the context in which this Master's project is inserted, as well as the motivations for its accomplishment. In addition, the main objectives of the project were outlined.

In Chapter 2, we provide an overview the main areas investigated in this project, related to the research on Open Educational Resources and Maturity Models, respectively.

In Chapter 3, we describe a Systematic Mapping Study with regard to discover educational maturity models, their inspirations, how they were designed and their relation with Open Educational Resources. We conducted this Mapping Study in order to characterize the state of the art and the current gaps of educational MMs.

In Chapter 4, we detail the development of CM-OAR, explaining its design and development process, describing its evolution and metrics.

In Chapter 5, we specify the evaluations performed in our design process. These evaluations were used to gather feedback from experts and potential users of CM-OAR Model, also helping on the improvement and evolution it.

Finally, in Chapter 6 we present the conclusions, contributions and future perspectives of research related to this work.

CHAPTER

2

Background

In this chapter we provide an overview of the two main areas that support our Master's project: Open Educational Resources and Capability Maturity Models. In Section 2.1 we introduce the OERs history, present several OERs definitions, discuss its potential to global education, characterize sharing licenses, present metadata structures and examples of OERs sharing initiatives around the world. In Section 2.2 we introduce the first maturity model, CMM, presenting its main definitions and characteristics. We also provide an overview of CMMI, ISO/IEC 15504, OPM3 and OpenSource MM, models based in CMM, which have being successfully adopted in industry.

2.1 Open Educational Resources

Open Educational Resources (OERs) have contributed to new solutions on the development, use and sharing of knowledge. They allow the learning process to be open and flexible, providing learning opportunities, adapted to individual needs. In general terms, OERs refer to teaching, learning and research materials available digitally or otherwise, being in the public domain or licensed in an open way in order to be reused or adapted by others with little or no restriction (UNESCO, 2002). They can include full courses, learning materials, lecture notes, textbooks, videos, images, software, and any other tools, materials or techniques used to support the construction and access to knowledge.

OERs have potential to enhance education at a global level. As they are usually available in digital formats with no cost, the user only needs Internet access to take advantage of them, regardless of his/her available time or geographical location. From the point of view of the OER philosophy, an "educator, student or any other individual" holds certain rights and freedoms to (re)use, adapt, revise and (re)distribute the educational content in order to benefit others.

Important issues on the adoption of OERs are related to the possibility of sharing and

subsequent (re) creation of related materials. New works can be produced quickly from the derivation of third-part materials. One can also reuse existing materials, adjusting and adapting them to particular contexts or specific needs and educational goals. By virtually allowing anyone to have access to quality education and use and adapt materials previously reserved only for students at elite universities, OERs have the potential to jump start careers and economic development in communities that lag behind (HEWLETT; HEWLETT, 2002), helping to reduce socioeconomic inequality.

Another issue to be highlighted in the OERs context is the possibility of increasing the efficiency and quality of learning materials available on the web. These materials can be reused and constantly reviewed by different users, keeping them up to date. We also point out the reduction on the dependence on proprietary material, such as commercial books. Finally, initiatives to the adoption of OERs are also responsible for providing opportunities for entrepreneurship and innovation in educational institutions, whether public or private.

2.1.1 History of Open Educational Resources

In order to fully comprehend the importance of OERs, there are some events from later years that will be highlighted in this section. Figures 1 and 2 present a timeline of relevant episodes, based on the papers from (BLISS; SMITH, 2017), (WILEY, 2006) and (COURSEHERO, 2014)..

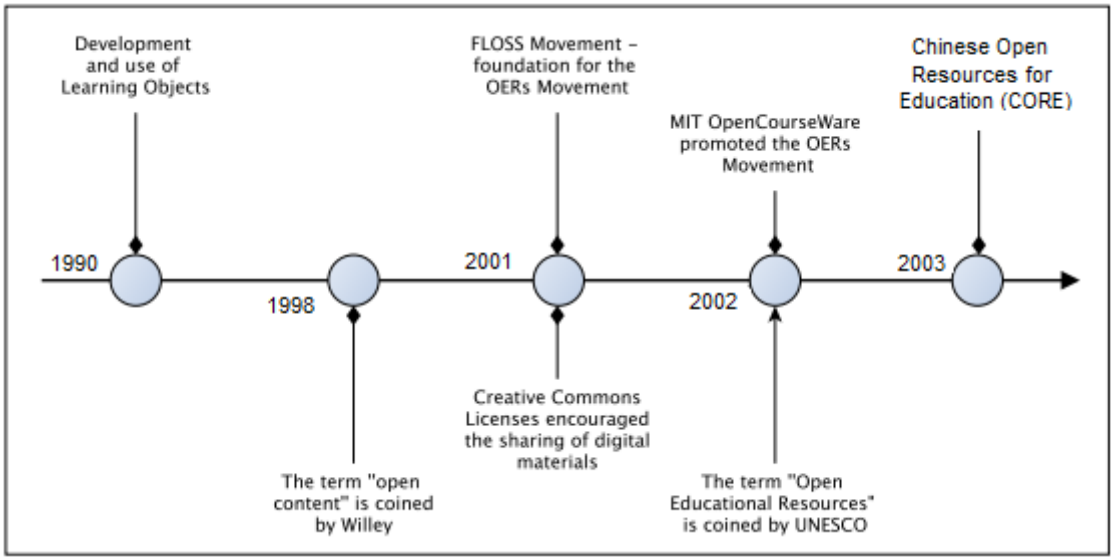


Figure 1 – The history of OERs part 1. Adapted from (ARIMOTO, 2016) (BLISS; SMITH, 2017) (WILEY, 2006)

In 1994 the term “learning object” was coined by Wayne Hodgins, being fastly accepted by the academic community (HODGINS, 2002). Its definition contained one of the main characteristics of OERs, that is digital materials can be designed and produced in such a manner as to be reused easily in a variety of pedagogical situations.

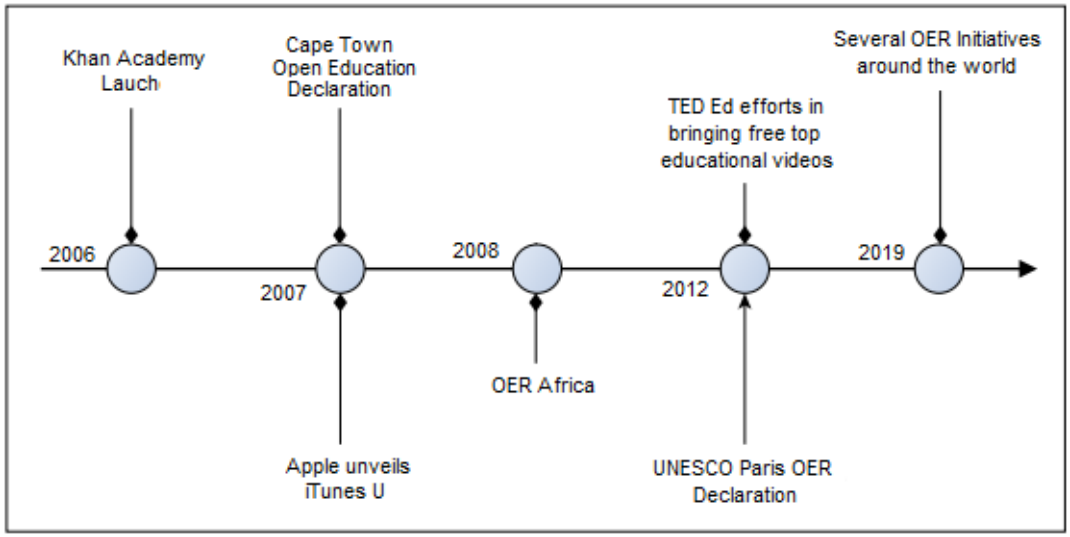


Figure 2 – The history of OERs part 2. Adapted from (ARIMOTO, 2016) (BLISS; SMITH, 2017) (WILEY, 2006)

OERs are also comparable with the principles of the Open Source / Free Software movements. In 1998, David Wiley presented for the very first time the term open content and although he was aiming to gather the attention of the educational researchers, he also got the recognition from open source supporters (GROSSMAN, 1998). This idea that the principles of open source software could be applied to the development of learning materials was starting to get popular.

In 2001, Larry Lessig and others created a set of flexible licenses capable of make OERs available to the community, the Creative Commons (LESSIG, 2003), a set of public copyright licenses that enables free sharing and distribution of copyrighted work, being relevant and heavily used until nowadays.

Still in 2001, the OpenCourseware initiative was announced by MIT, with the goal of publishing nearly every university course for free public access for noncommercial use (ABELSON, 2008). They remain nowadays as one of the main pioneers of the OERs movement, inspiring and encouraging other institutes and universities to also share their knowledge freely to the world.

In 2002, UNESCO gathered a forum of many people compromised to "develop a universal educational resource available for the whole of humanity". In this meeting they coined the term "Open Educational Resource" with the following definition: "Technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes." They are typically made freely available over the Web or the Internet. Their principal use is by teachers and educational institutions support course development, but they can also be used directly by students. Open Educational Resources include learning objects such as lecture material, references and readings, simulations, experiments and demonstrations, as well as syllabi, curricula and teachers' guides (UNESCO, 2002).

In 2003, the Chinese Open Resources for Education (CORE) is founded, a partnership MIT OCW to provide the structure to share open content through hundreds Chinese universities. It was an exchange of knowledge between west universities and the Chinese ones, both translating its contents and sharing it (ATKINS *et al.*, 2007). Their website is down since 2013.

2006 is marked by the launch of Khan Academy (KHAN, 2019), a website developed by a MIT graduate, Salman Khan. It is, up to today, one of the biggest and most successful OER sharing initiative, reaching several different nationalities. The teachers are encouraged to use it as an auxiliary tool to normal classes, as the courses provide lectures, exercises and overview panels (THOMPSON, 2011).

In 2007, Apple releases iTunes U, a service application to manage and share educational audios, videos and PDFs to college students. Although there are content only accessible through payment in the app, it was released with over a hundred free and open courses to more than 120 countries (MARTINS, 2014).

Also in 2007, the Shuttleworth Foundation and the Open Society Institute releases the Cape Town Open Education Declaration, a document trying to gather worldwide attention to open educational resources. The declaration focuses on the barriers of the open movement, and states how different people can work to improve it: educators and learners were encouraged to develop, review, remix and use OERs; the educators were also called to share their existing resources, and at last, institutional organizations, specially the taxpayer-funded, were also emboldened to implement the use and distribution of OERs in their inner educational policies (SHUTTLEWORTH; OPENSOCIETY, 2007).

In 2008, the Hewlett Foundation assisted four African universities to build their own OER sharing initiative, OER Africa. Their mission is to “establish dynamic networks between African OER practitioners, to develop, share, and adapt OER to meet the educational needs of African societies” (AFRICA, 2008). Their web domain is not only used to share their resources, but also to gather other African initiatives and exhibit their research progress on the open movement.

Finally, in 2012, UNESCO releases the Paris Declaration on Open Educational Resources, a document calling governments to promote the establishment of OERs. In the document, there were recommendations that these global institutions should practice in order to improve and evolve international education: to foster awareness and use of OERs, to encourage OER researches, to promote the understanding and use of open licenses in governmental programs, to facilitate the design of policies and tools for the development and sharing of OERs, and to forge international alliances to enhance the spread of the movement worldwide (UNESCO, 2012). According to (PAWLOWSKI; HOEL, 2012), this declaration is viewed as starting point to development of policies, a step towards the establishment of governments collaborations and creation of action plans to improve of education access.

Currently, there are several open and online university courses available. The movement

spread around the world. However, there are still several issues that require investigation in order to effectively evolve the community and support the achievement of more ambitious goals.

2.1.2 Characterizing Open Educational Resources

OERs were defined several times through the years. One of the most classic definitions is the one did by William and Flora Foundation, financier of the OERs movement. It describes OERs as "any type of digital courseware that can be reached in the public domain or have been published under one of the intellectual property licenses, allowing the use and reuse by other" (HEWLETT; HEWLETT, 2002). UNESCO, in turn, describe OERs as "learning materials freely available over the internet or licensed allowing to be used, reused or adapted with little or no restriction" (UNESCO, 2002).

Both definitions, from William and Flora Foundation and UNESCO, have a focus on the free aspect of OERs, but also emphasize on the resources flexibility of use, reuse and adaptation, which can only be allowed through special licenses.

According to the Organisation for Economic Co-operation and Development (OECD), OERs are "digital materials provided freely and openly with the purpose of teaching, learning and researching" (PEÑA-LÓPEZ *et al.*, 2007). The Commonwealth of Learning refers to OERs as any "educational material that is openly available for use by educators and students, without an accompanying need to pay royalties or licenses fees" (BUTCHER, 2015).

Although the Commonwealth and OECD definitions also point the free aspects of OERs, they do not mention the extension of possibilities that users can access with their free materials. In this context, (GESER, 2007) presents a clearer definition, specifying the boundaries of users freedom when in contact with OERs. He suggests three essential attributes when defining OERs:

- The content must be offered free of charge, either by educators, students, educational institutions and others.
- The content must be licensed in way that allows its receivers to use, reuse, modify, combine and remix it freely.
- In order to prioritize the use of open code software, the used system and tools must have their source code available.

Furthermore, (HYLEN, 2006) established a more precise definition of the content aspect, defining which resources could be considered OERs, when proper licensed:

- **Learning Materials:** includes all educational materials used for learning and teaching, such as: presentations, exercises, lecture notes, educational modules, full courses, podcasts, video lessons, images, text books and others.

- **Software:** every software, technique or system that supports the creation or provision of learning materials, such as: learning platforms, repositories, text editors, media format converters and others.
- **Standards:** every standard that assist the design or licensing of learning materials, design principles or the implementation of supporting software.

Finally, one of the most accepted definition of OERs relates it with four principles (4Rs) of openness (WILEY, 2010):

- **R**euse: the right to use the content in its original form.
- **R**eview: the right of modify the content.
- **R**emix: the right of combine the content with another content, in order to create something new.
- **R**edistribute: the right of share the content, in its original, reviewed or remixed forms.

Years later of this definition, the academic community perceived the need of adding a fifth R to the scheme (WILEY, 2014):

- **R**etain: the right to make, own, and control copies of the content.

The 5Rs framework describes in a straightforward way every aspect of OERs. It is an educational content that can be possessed, used, modified, remixed and shared free of monetary costs. For the purpose of our research, this description is used as our main definition for an OER.

2.1.3 The Potential of Open Educational Resources

According to researchers, academy's engagement in the OERs movement can result in plenty of social improvements (WILEY, 2014)(CASWELL *et al.*, 2008)(D'ANTONI, 2009)(HYLEN, 2006)(HEWLETT; HEWLETT, 2002). Among them:

- Overall improvement of the population education. The easier the knowledge access, the better.
- Overall improvement of the teachers ability in teaching. Teachers who spend their time designing and producing OERs will, slightly at least, improve their teaching skills.
- Minimising the dependence of commercial textbooks.
- Increasing of the knowledge delivery to special need students. OERs can be tailored in order to address specific requirements.

- Increasing of the overall quality of educational content. Misconceptions and mistypings can be quickly revised, once everyone are allowed to do so.
- Reducing socioeconomic inequality. OERs allow everyone to access materials previously reserved only for students of elite universities, potentially jump starting careers and economic development in disadvantaged communities.
- Improvement of the relationships between researchers, teachers and students from different nations, reducing language barriers.

As pointed out before, a well established OER sharing project has the power of changing not only the educational facet of global communities, but the economic as well. In a short term OERs facilitate the propagation of knowledge, but in a long term it can reduce socioeconomic inequalities, promote intercultural partnerships and improve scientific advances and researches.

2.1.4 Licenses

In order to preserve copyright and intellectual property, the open / free distribution of a software usually happens through an Open Source / Free Software license. An Open Source license is a document where the owner of a software legal rights authorizes the use of his/her creations. These authorizations allow developers to use and adapt the software to specific needs, or remix it into more complex systems (KON *et al.*, 2011).

Currently, there are several licenses applied to Open Source, among which emerge: BSD License (BSD, 2019), MIT License (MIT, 2019), APACHE License (APACHE, 2019), GNU GPL License (GNU, 2019) and Mozilla License (MOZILLA, 2019).

As already presented in Figure 1, the first initiatives relating education with the Open Source context emerged in 1998, with Wiley's proposition of the term Open Content (GROSSMAN, 1998), referring as every educational content openly available. The Open Content License was proposed following the precepts of Open Source and Free Software movement, although it also contemplates a variety of other types of content, allowing the license to be applied in any domain (LIANG, 2004). The license expresses three fundamental freedoms for the content: the right to make copies, the right to redistribute the content and the right to modify the content. According to Wiley, the idea was to encourage the debate and availability of open educational contents in higher education institutions. Later, Wiley's licenses were replaced by other ones, like Creative Commons.

2.1.4.1 Creative Commons

Creative Commons played a major role in the dissemination of OERs. They are a non-profit organization that supports the sharing of creativity and knowledge through free legal instruments

(COMMONS, 2019). Their licenses provided an easy and legal way to educators share their resources, allowing unprecedented advances on the OERs movement. The licenses are:

- **CC BY:** This is the license recommended when the goal is to maximise the content dissemination. It allows others to share, remix and review the resource, even with commercial intents. This license is one of the most flexible, only requiring to credit the author for the original creation.
- **CC BY-SA:** This license possesses the same attributes from CC BY, allowing free sharing, remix and reviewing, even commercially, but requiring credit to the original author. Its main difference is its "copyleft" nature, requiring that new resources based on it must perpetuate the same license. This is the license used by Wikipedia.
- **CC BY-ND:** This license allows its users to reuse the content, even commercially, but it does not allow its adaptations to be shared, and must provide credit to the original author.
- **CC BY-NC:** This license allows its users to reuse, remix and review the content, but does not allow to be commercially exploited, and its derivations must credit the authors and also not be commercially exploited.
- **CC BY-NC-SA:** Similarly with CC BY-NC, these license allows its users to reuse, remix and review the content, but does not allow to be commercially exploited, and its derivations must credit the authors and must to use this same license.
- **CC BY-NC-ND:** Contents under this license can be downloaded and shared, as long its users credit the original author, but it does not allow they to change or used it commercially in any way. This is the most restrictive of the six main licenses.

In Figure 3 we summarise each of the six licenses presented.

The licenses summarized here provide a series of freedoms that superposes the copyright legislation, so its users do not need to contract lawyers to use these licenses content, since it already establishes a plausible set of copyright rules (LESSIG, 2004).

2.1.5 Patterns and Metadata Structures

With the increasing interest for distance education and OERs proliferation, there are several efforts trying to standardize how these coursewares should be stored in online repositories. In this context, Metadata Structures emerge.

The description of the OERs relevant characteristics through metadata supports their reuse and recover, in addition to allow that such resources to be adopted in different environments and educational systems, composing learning units. Learning Object Metadata (LOM-IEEE) (IEEE, 2002) is one of the most used across repositories, being described next.

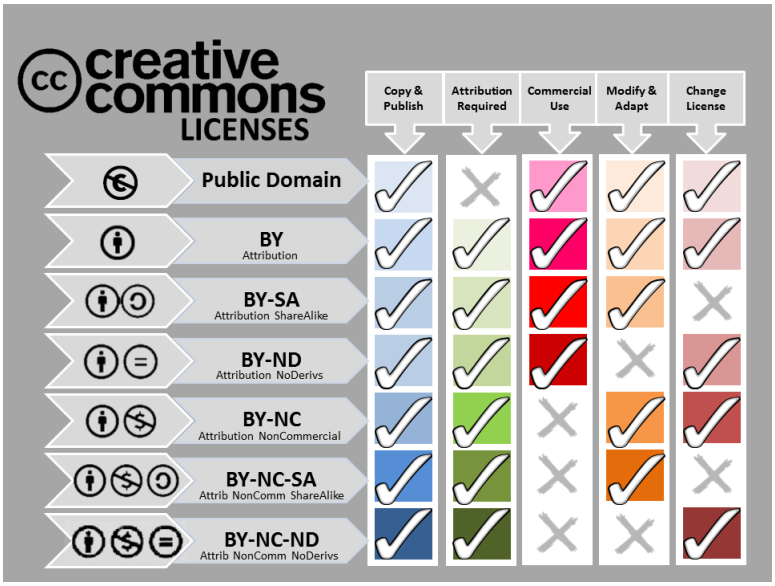


Figure 3 – Creative Commons Licenses. From (ATS, 2013)

2.1.5.1 LOM-IEEE

The standard Learning Object Metadata (LOM) was proposed by the IEEE Learning Technology Standards Committee (IEEE, 2002), aiming to develop rules, guidelines e recommended practices to the educational and computer-supported learning area.

The LOM main objective is to support the search, evolution, acquisition and usage of learning objects by learners and instructors. Besides that, the pattern aims to also support the sharing and exchanges of learning objects, allowing creation of catalogs and inventories. This aspect is important due the cultural and linguistic diversity where these objects and metadata can be applied.

The standard presupposes that there are several specific characteristics (or attributes / elements) that should be used to describe learning objects. Such characteristics are grouped in nine categories (General, Life Cycle, Meta-Metadata, Technical, Educational, Rights, Relation, Annotation, Classification) as shown in Figure 4. As an example, in the General category we can find eight characteristics: identifier, title, description, keyword, coverage, structure and aggregation level. Each category has its own theme and groups attributes to compose that theme.

Although complex, LOM-IEEE also allows the instantiation of its elements, granting an optional aspect to the categories. This aspects allows the community to adapt the model for its context and needs, new elements can be inserted and undesired ones can be excluded or renamed.

2.1.6 Open Access Repositories

The OERs movement is growing through the years. Its worldwide appeal has gathered initiatives from every continent, involving universities, institutions and others non-profit organizations. These initiatives often share their content through Open Access (OA) repositories. OA repos-

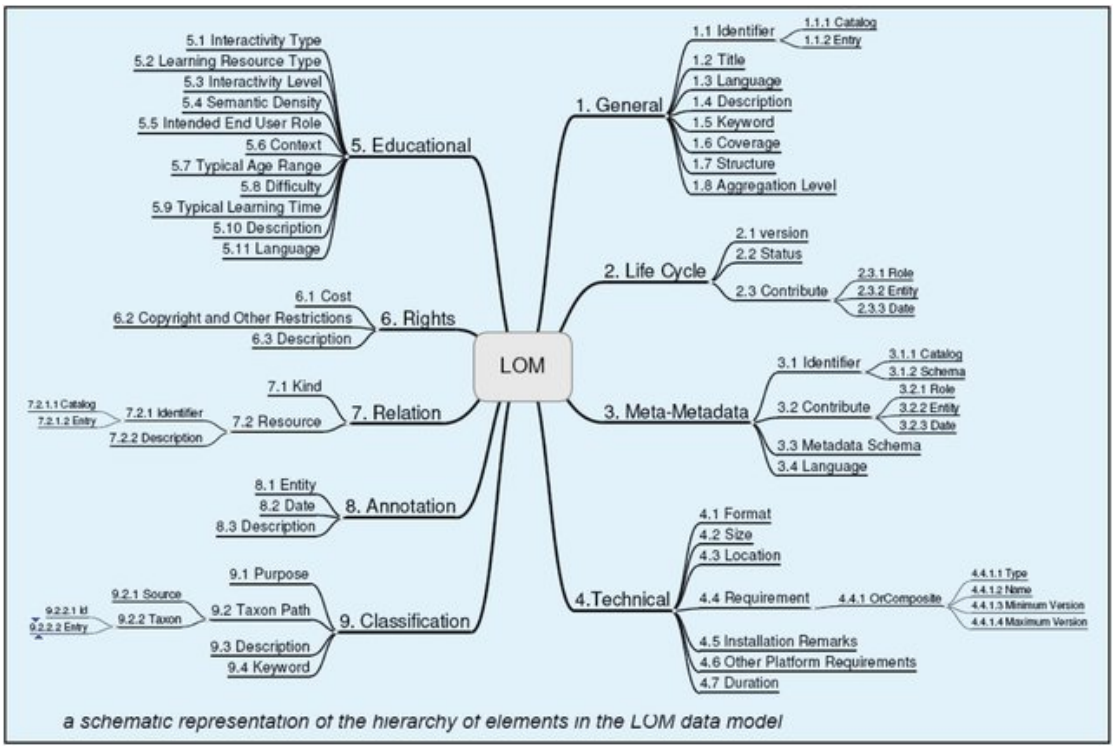


Figure 4 – Learning Object Metadata (LOM-IEEE) (IEEE, 2002)

itories are defined as an online database able to share its content (text, videos, images, slide shares, etc) freely, immediately and without any access restrictions (PINFIELD, 2005) (XIE; MATUSIAK, 2016). OA repositories that are tied to an academic or research institution are named Institutional Repositories. Next we present some of the most OA repositories.

2.1.6.1 MIT Open Courseware

An interesting example of university promoting the open learning initiative is the Massachusetts Institute of Technology (MIT), with the MIT OpenCourseWare (OCW) (OPENCOURSEWARE, 2022). It is a program, launched in 2002 with the support of William and Floret Hewlett foundation and Andrew W. Mellon Foundation, that provides a great number of OERs for undergraduate and graduate students. Such content is originated from the previous year classes, including lectures, exercises, exams, among other learning resources. Everything is free, open and reachable. MIT OCW courses are under BY-NC-SA license.

Figure 5 shows an example of a course page. As can be seen, the open course *Mathematics of Machine Learning* provided plenty of OERs ready to be consumed: syllabus, lecture notes, readings, assignments, every resource can be freely downloaded.

The main challenge in implementing the OCW initiative was not faculty resistance, but rather, the logistical challenges presented by determining ownership and obtaining publication permission for the massive amount of intellectual property items that are embedded in the course materials of MIT faculty, in addition to the time and technical effort required to convert the

educational materials to an online format (OPENCOURSEWARE, 2022).

OCW is one of the most successful OER sharing initiative, being used as example and inspiration to many others around the world. The paper from (D'OLIVEIRA *et al.*, 2010) describes some of the achievements of OCW. It specially focuses on the OERs impact on poor communities, demonstrating in a practical way the potentials cited in Section 2.1.3.

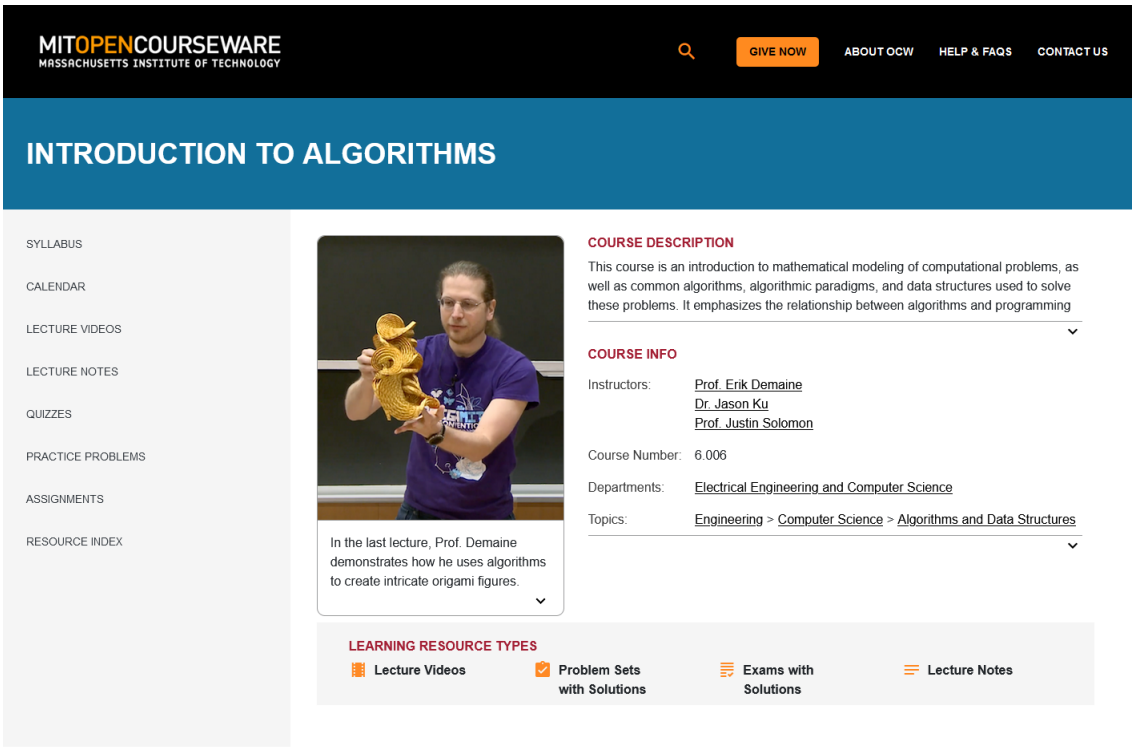


Figure 5 – OCW course page from (OPENCOURSEWARE, 2022)

2.1.6.2 UK OpenLearn

UK OpenLearn (OPENLEARN, 2022) is an UK Open University contribution to the OERs project. The original project was part-funded by the William and Flora Hewlett Foundation. It was one of the precursors of the distance learning modality, aiming at students who do not have access to join presential courses. Their materials are also under BY-NC-SA license.

Figures 6 and 7 present example pages, showing a variety of covered areas in their free courses. As can be seen, UK OpenLearn possesses resources for all the three major knowledge areas (Humanities, Biology, Math Sciences). When presenting a specific course, they provide an expected number of hours and desired level of knowledge for the learner. For example *"Computers and computer systems"* is a 20 hours course at intermediate level.

Even though UK OpenLearn is running and expanding this free courses project, it still has modules that require financial commitment from their students, showing that educational organizations can manage both worlds and still be successful in their objectives.

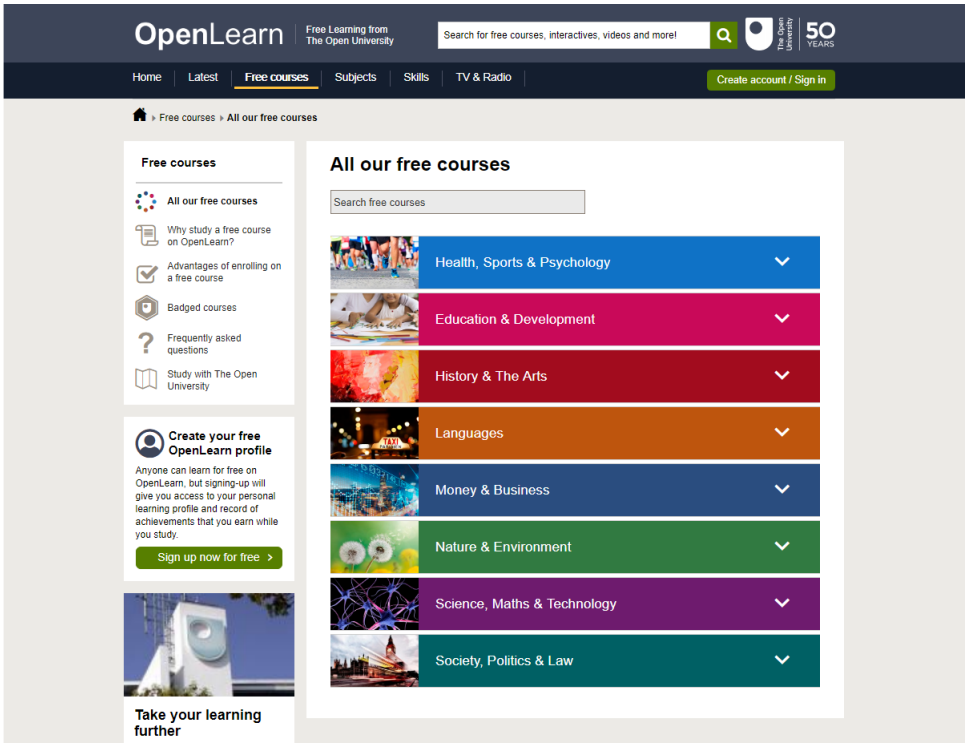
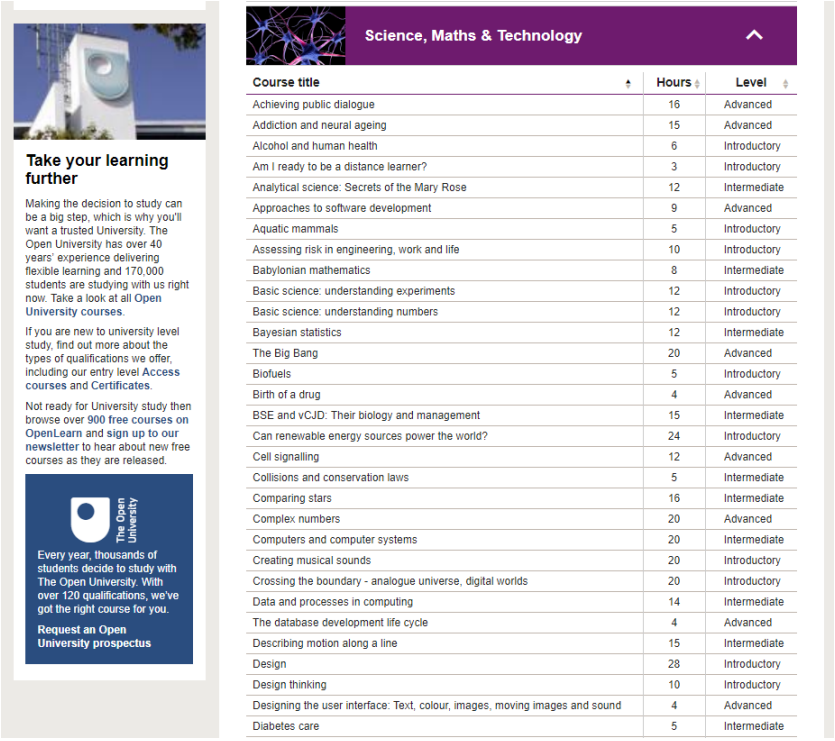


Figure 6 – List of covered knowledge areas from (OPENLEARN, 2022)



Course title	Hours	Level
Achieving public dialogue	16	Advanced
Addiction and neural ageing	15	Advanced
Alcohol and human health	6	Introductory
Am I ready to be a distance learner?	3	Introductory
Analytical science: Secrets of the Mary Rose	12	Intermediate
Approaches to software development	9	Advanced
Aquatic mammals	5	Introductory
Assessing risk in engineering, work and life	10	Introductory
Babylonian mathematics	8	Intermediate
Basic science: understanding experiments	12	Introductory
Basic science: understanding numbers	12	Introductory
Bayesian statistics	12	Intermediate
The Big Bang	20	Advanced
Biofuels	5	Introductory
Birth of a drug	4	Advanced
BSE and vCJD: Their biology and management	15	Intermediate
Can renewable energy sources power the world?	24	Introductory
Cell signalling	12	Advanced
Collisions and conservation laws	5	Intermediate
Comparing stars	16	Intermediate
Complex numbers	20	Advanced
Computers and computer systems	20	Intermediate
Creating musical sounds	20	Introductory
Crossing the boundary - analogue universe, digital worlds	20	Introductory
Data and processes in computing	14	Intermediate
The database development life cycle	4	Advanced
Describing motion along a line	15	Intermediate
Design	28	Introductory
Design thinking	10	Introductory
Designing the user interface: Text, colour, images, moving images and sound	4	Advanced
Diabetes care	5	Intermediate

Figure 7 – List of courses from Science, Math and Technology area, from (OPENLEARN, 2022)

2.1.6.3 Open Learning Initiative

Created by the Carnegie Mellon University in 2002, the Open Learning Initiative (OLI) (OLI, 2022) is a platform of tutoring systems, simulations and virtual labs. OLI have courses from a

lot of different areas, including Computer Science, Math and Business. OLI is supported by the William and Flora Hewlett Foundation, and emerged as one of the big in the OERs movement thanks to their innovative approach and pioneer attitude. OLI resources are under BY-NC-SA license.

OLI main difference from another organizations is the feedback provided to their students. The learners can solve exercises and observe their progress in real time. Figure 8 shows an example. This is a piece of content from a *"Computers, Algorithms, Programs"* course. The resource shows to the student a simple definition of compilers, and right after it proposes a question to help the fixation of the content.

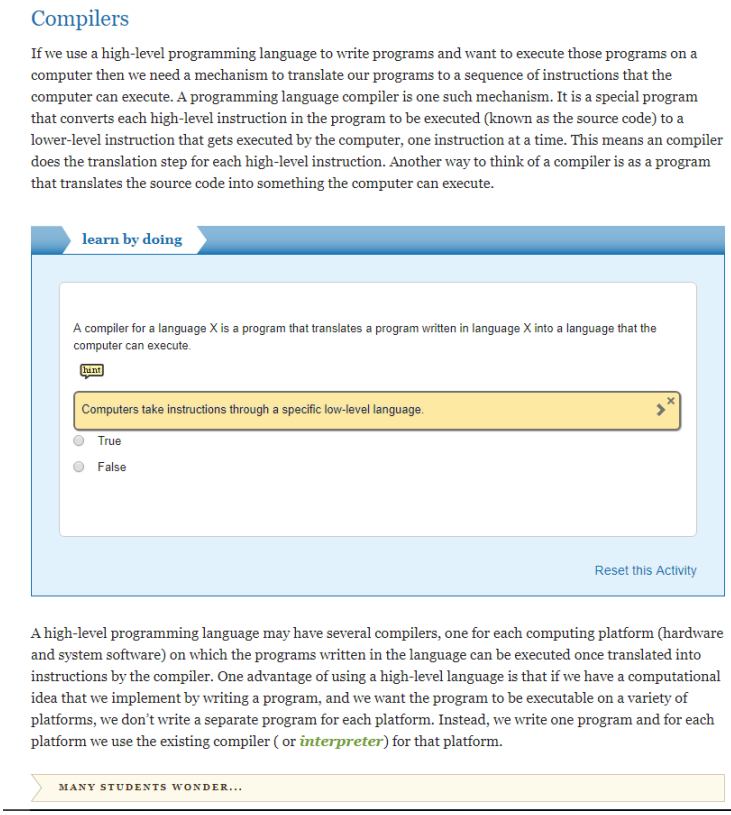


Figure 8 – Exercise from a Computers, Algorithms, Programs course (OLI, 2022)

2.1.6.4 Merlot

MERLOT (MERLOT, 2022) is an open repository of the California State University, created in 1997. MERLOT collection contains over 40,000 materials in 19 different material type categories (including animations, case studies, online courses, quizzes, tutorials and textbooks).

According to the organization: "the MERLOT system provides access to curated online learning and support materials and content creation tools, led by an international community of educators, learners and researchers." (MERLOT, 2022)

The main difference from other initiatives is that anyone can contribute to the library,

adding their own resources for open sharing. One of the most famous contributors is the MIT OpenCourseware and plenty of their courses can be accessed in MERLOT's domain.

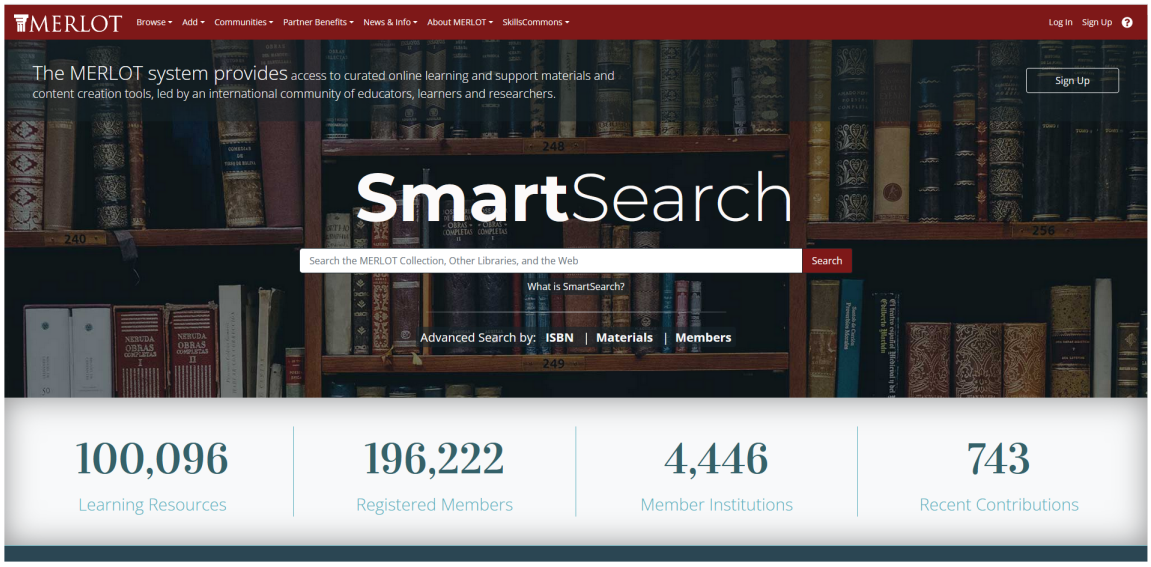


Figure 9 – Homepage of Merlot (MERLOT, 2022)

2.1.6.5 MECRED

MECRED is an online platform created by the Brazilian Ministry of Education, in an association with the Federal University of Paraná (UFPR) and the Federal University of Santa Catarina (UFSC) (MEC, 2022). The goal is to provide an environment where teachers can freely find and share basic learning educational content. The website was developed under the GNU/GAPL license and the source code shared on GitLab.

The repertoire is composed by over 318.000 resources, as they integrate several OERs from other brazilian OA repositories. They also promote campaigns to encourage teachers to collaborate with more materials and coursewares. More than search and download resources, their users can save favorites, group them into bigger collections, follow publishers, share their experiences and rate the content.

2.1.6.6 EDUCAPES Portal

The EDUCAPES Portal is another example of a brazilian institutional repository, managed by the CAPES foundation. The website possesses a collection of thousands of learning objects, encompassing basic education, superior education and postgraduate topics. The resources can be found in texts, didactic books, research papers, thesis, dissertations, videos and images, all of them shared on open licenses or in public domain (CAPES, 2022).

The portal integrates resource inclusions with the DSpace technology (DSPACE, 2022), which uses DUBLIN Core metadata pattern (DUBLIN, 2019). This tech allows automatic inclusion of a file on the collection, if new, whenever it is uploaded in one their partners

Figure 10 – MEC number of resources and features (MEC, 2022)

repositories. Examples of their partners are: São Paulo State University (UNESP), Ouro Preto Federal University (UFOP), Brazilian Open University (UAB), Khan Academy and the National Institute for Space Research (INPE).

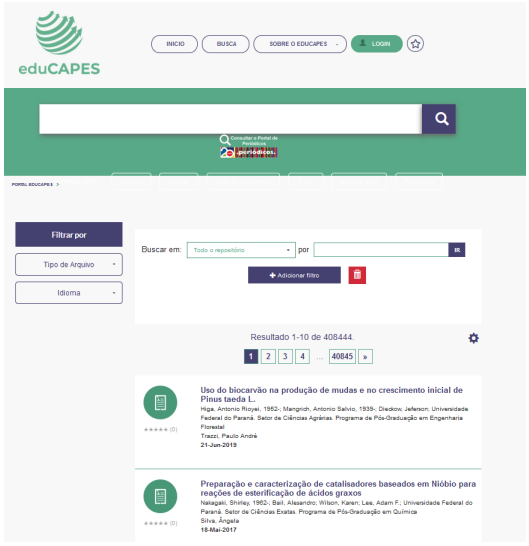


Figure 11 – eduCAPES search page (CAPES, 2022)

Next we discuss Capability Maturity Models as an alternative solution to the gaps presented, investigating the main characteristics and practices of these models, and identifying how them can be adapted to the context of OERs development, improvement and dissemination.

2.2 Capability Maturity Models

Software process improvement is the area that cares about the management, enhancement and support of development process in an organization (AMBLER *et al.*, 2005). Through this area, is

possible to understand existing processes and their changes, in order to improve the software product quality and to reduce development costs and time (SOMMERVILLE, 2011).

According to (DYBÅ, 2002), there are three intervention types related to changes in process: (i) *process assessment*, an assessment or evaluation of the software process, with no modifications; (ii) *process improvement*, continuous or incremental changes on the software process; and (iii) *process innovation*, radical changes on the process, involving partial or total process substitution.

In this context, the Capability Maturity Model (CMM) arises as a solution to support process improvement. CMM objective is to enhance the capability of companies in achieving strategic objectives through structured and incremental improvements in their development processes. This idea of increasing the organisations competence through evolutionary enhancements emerged at the Carnegie Mellon University, by the Software Engineering Institute (SEI) (Paulk *et al.*, 1993) (PAULK, 2002). Through the years, CMM was adapted and modified to suppress some of its flaws, procedure that created a series of other maturity models, like: Capability Maturity Model Integration (CMMI) (TEAM, 2006), Organizational Project Management Maturity Model (OPM3), ISO/IEC 15504 model (DORLING, 1993) and OpenSource Maturity Model (PETRINJA *et al.*, 2009). Maturity models were also created and tailored for other areas such as manufacturing, service development, construction, and e-learning.

2.2.1 CMM Model

On the Software Engineering area, maturity is related on how much an organization can learn and improve from its own mistakes. The more mature an organization is, the more it will optimize its processes in order to achieve a high quality product deliver at its costumer. (Paulk *et al.*, 1993)(PAULK, 2002) (TEAM, 2006) (NAYAB, 2011)(PRESSMAN; MAXIM, 2016).

In an immature organization, there are few or close to none guidelines on how to perform its processes. When problems emerge, they were not predicted and solutions must very often be improvised, causing delay on schedules, exceeding budgets, products with defective functionalities or compromised quality. The success of an immature organization is often related to the individual talents of its employees. Besides that, an immature organization often can not predict the overall quality of its products, since activities related to this matter, such as testing and reviews, are often excluded when hard deadlines are imposed.

On the other hand, a mature organization has a history of succeed projects, knowing the best parallel practices that must be implemented in order to reach a higher product quality. Processes were conducted several times and guidelines were set to replicate the most successful iterations. These iterations also allow precise budget and schedule estimations. Managers know exactly what to expect from each step, and are prepared for the most dangerous and common crises. The quality of the service is always being monitored, with objective and quantitative basis

for judging it. Employees know exactly the responsibilities expected from them.

The Capability Maturity Model (CMM) (Paulk *et al.*, 1993) (PAULK, 2002) is a development model created with the purpose of evaluate the maturity level of software companies, and presenting the necessary steps for their improvement. CMM involves five aspects (Paulk *et al.*, 1993):

- **Maturity Levels:** Five levels that measure the maturity of an organization, with the first level representing companies with erratic and primitive processes, while the fifth level represents an ideal company, with continuous optimization and improvement of their processes.
- **Key Process Areas:** A Key Process Area (KPA) is a set of related activities that needs to be performed in order to achieve a specific goal. Each Maturity Level is composed by required KPAs.
- **Goals:** The goals define the scope and intent of each KPA. They are used to assess and determine the capability of each maturity level, measuring the effectiveness and how complete and optimized the KPAs, from that level, are.
- **Common Features:** Five types of practices are used to implement a KPA in an organization: commitment to perform, ability to perform, activities performed, verifying implementation, and measurement and analysis.
- **Key Practices:** Elements of infrastructure and practices that, when implemented with other related Key Practices, constitutes a KPA.

2.2.1.1 Maturity Levels

Continuous process improvement is based on many small, evolutionary steps (Paulk *et al.*, 1993)(PAULK, 2002). The staged structure of CMM is based on principles of product quality and a trustworthy process. CMM provides a framework for organizing these evolutionary steps into five maturity levels, that lay successive foundations for continuous process improvement. The levels define an ordinal scale for measuring process maturity and evaluating process capability.

The levels also help an organization prioritize its improvement efforts. Each maturity level is constituted by a set of process goals that, when satisfied, stabilize an important component of a process (Paulk *et al.*, 1993)(PAULK, 2002). Achieving each level of maturity establishes a different component in process, resulting in an increase in the process capability of a organization. The five maturity levels of CMM are summarized next:

- **Level 1 - Initial:** At this level, companies are chaotic, uncontrolled, unstable and reactive. Its processes are typically undocumented and constant changing, and its development

cycle often ad hoc. There are no related KPAs, and its success is often due to the individual qualities and efforts from its employees.

- **Level 2 - Repeatable:** Companies at this maturity level are starting to repeat some of its most consistent processes. During times of stress or crises, some rigorous plans may be followed. The companies are starting to gain interests into improve their process management.

- **Level 3 - Defined:** In this level, the companies are establishing and documenting standards processes. This is most often an experimentation and these standards are subject of improvement over time.

- **Level 4 - Managed (Capable):** The main characteristic of this level is the concern of the management team in evaluating each iteration of the standard processes. Using determined metrics and effective assessment, the management team starts to analyze how impactful minimums changes are, on the standard process, into the overall quality of the final product. This practice allows processes to be tailored and adapted to particular projects, without a considerable loss of quality, increasing of budget or delay on the schedule.

- **Level 5 - Optimizing (Efficient):** Finally, at this level the focus is the continuous improvement of the processes performances through the use of statistics and technology innovation.

2.2.1.2 Key Process Areas

Key process areas indicate where an organization should focus to improve its software process. They identify the issues that must be addressed to achieve a maturity level, as illustrated in Figure 12. In order to establish a KPA, a company must: implement each activity and meet all objectives related to this KPA. These activities and goals are the characteristics that defines a KPA, and the methods used to implement and achieve them will differ from project to project.

Each maturity level has a set of required KPAs and a company only reaches a certain level when it implements every KPA related to that level. But CMM does not describe in detail how each one of these activities must be achieved, it only provides a series of parameters that should be used to determine if it is implemented or not. The organization using the CMM is the responsible to solve how to implement the requirements for each level.

2.2.2 CMMI Model

The Capability Maturity Model Integration (CMMI) was developed by SEI and is defined as metamodel process based in a software engineering capacities set that should be present in mature software development companies (PRESSMAN; MAXIM, 2016). CMMI was created to solve several of CMMs deficiencies, and merged the best functionalities from CMM, SECM (System

Maturity Levels	Key Process Areas
5 – Optimizing (focus on continuous improvement)	• Process Change Management • Technology Innovation • Defect Prevention
4 – Managed (focus on product & process quality)	• Quality Management • Process Measurement & Analysis
3 – Defined (focus on engineering process)	• Peer Reviews • Intergroup Coordination • Software Product Engineering • Integrated Software Management • Training Program • Organization Process Definition • Organization Process Focus
2 – Repeatable (focus on project management)	• Software Configuration Management • Software Quality Assurance • Software Sub-contract Management • Software Project Tracking & Oversight • Software Project Planning • Software Requirements Management
1 – Initial (focus on individual)	• None

Figure 12 – Key Process Areas. From (Paulk *et al.*, 1993)

Engineering Capability Model) (SEI, 2019) and IPD-CMM (Integrated Product Development Capability Maturity Model) (SEI, 2019).

CMMI can be classified as a Descriptive Model, since essential attributes (or keys) are described to characterize an organization in a particular maturity level. It can also be classified as a Normative Model, since the detailed practices characterizes the normal types of behavior expected from an organization that develops large scale projects (TEAM, 2006). Finally, CMMI can also be classified as abstract, considering it does not determine how these practices should be implemented by these organizations (TEAM, 2006).

CMMI characteristics can be implemented in two ways (SEI, 2019):

- **Staged:** in this representation the model provides a predetermined sequence of improvements based in stages. Each stage serves as a basis to the next one, being characterized as Maturity Levels. In this representation, maturity is measured by a set of processes. Thus, in order of an organization to reach a maturity level, it needs to implement every process assigned to that level.
- **Continuous:** enables the company of adopting the best improvement order that attends to its interests, being characterize as Capability Levels. In this representation, capability is measured separated by process, so different process can be classified in different capability levels, varying according to the needs of the company.

The CMMI Maturity Levels for the Stage representation are (SEI, 2019): **Level 1 (Ini-**

tial) – does not have process areas; **Level 2 (Managed)** – projects are planned, performed, measured and controlled; **Level 3 (Defined)** – organization-wide standards provide guidance across projects and programs; **Level 4 (Quantitatively Managed)** – the organization is data driven with quantitative performance improvement objectives that are predictable and align to meet the needs of internal and external stakeholders; and **Level 5 (Optimizing)** – organization is focused continuous improvement and is built to pivot and respond to opportunity and change. The organization stability provides a platform for agility and innovation.

For the CMMI Continuous representation, the Capability Levels are (SEI, 2019): **Level 0 (Incomplete)** – the process is not being performed by the organization; **Level 1 (Performed)** – the process is performed in order to complete its objective; **Level 2 (Managed)** – the process is planned and the result is compared with its expectation; **Level 3 (Defined)** – the process is constructed under existing process guidelines and its description is maintained for further needs.

The five maturity levels scheme appears in both CMM and CMMI. Both also uses KPAs to track the organizations progress in these levels, but CMMI have some additional activities to overcome the inefficiency of CMM in some management flaws (NAYAB, 2011):

- **Level 1 (Initial):** In both CMM and CMMI, the first level is used to describe a chaotic company, with undefined process, ad hoc development, lack of control and reactive attitude.
- **Level 2 (Repeat):** In CMM Level 2 the organization starts to repeat some of its processes, but in CMMI there is a requirement for new KPAs, whose goals are the planning, performing, measuring and controlling of processes.
- **Level 3 (Defined):** To attain Level 3 of CMM, the organization need to document and standardize process in order to achieve consistency in their business process. In CMMI, the Level 3 is a sequel of CMMI Level 2, but requiring a more rigid controlling of process, usually setting procedures, standards, methods and tools.
- **Level 4 (Manage):** The Level 4 of CMM is composed by the use quantitative statistical techniques, aiming to gain further control over the organization processes. CMMI works in a similar way, but also adds some additional KPAs to improve the overall process efficiency.
- **Level 5 (Optimized):** Finnaly, at CMM Level 5, the organization need to use objectives and quantitative tools to guide the process improvement. But in CMMI Level 5, the improvements are continuous and come from innovative technological improvements.

In CMM, an organization maturity level is assessed by inquiring which KPAs are being performed, but not how they were implemented. CMM also does not pay specific attention to overall management of the company. On the other hand, CMMI takes a result-oriented approach, and when evaluating a company the method used to achieve each of KPAs goals is also considered.

CMMI also presents a series of industry best practices in organizations management, trying to solve some of the risks that are present in companies early stages. In short, CMM has focused attention on processes, while CMMI focuses attention on result-oriented processes (NAYAB, 2011).

2.2.3 ISO/IEC 15504

The ISO/IEC 15504 reference model (Figure 13) is a set of technical standards documents aimed to assist companies into improving their software development and business management process.

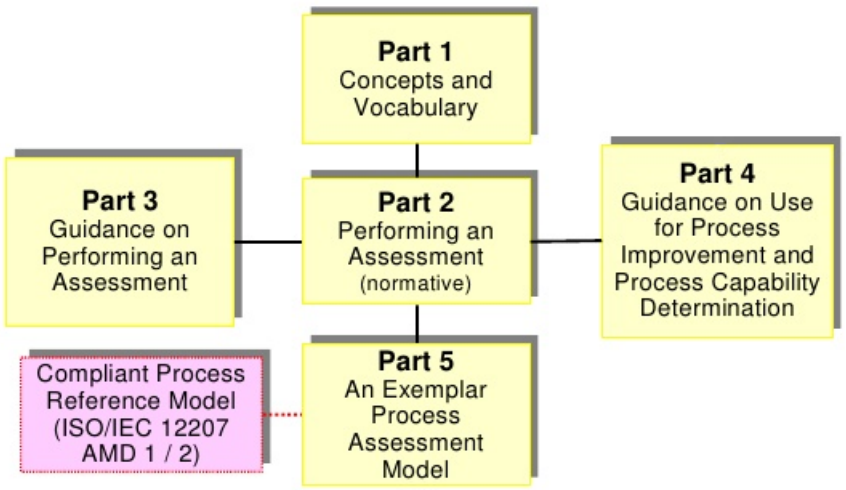


Figure 13 – Five parts of the ISO/IEC 15504 reference model. From (ISO, 2019)

Part 1 (Concepts and Vocabulary) is the entry point of the model. It describes the terms and definitions that are presented in the other parts. Additionally, it also describes how the other parts integrate themselves and provide orientation to select and use them (ISO, 2019).

Part 2 (Performing and Assessment) specifies the requirements for the assessment of the processes, raising the chances of objective, impartial, consistent, repeatable and representative results. Also, this part defines the framework of process capability assessment measures. This framework is composed by nine process attributes, divided in six capability levels, from 0 to 5. Each capability level sets the adherence degree of the an evaluated process (ISO, 2019):

- **Incomplete:** There is little to no evidence of a systematic achievement of the process.
- **Performed:** The implemented process can achieve the expected results.
- **Managed:** The process is implemented in a managed way, and its inputs and results are properly established, controlled and maintained.
- **Established:** The process is implemented using a previously defined process, capable of achieving its results.

- **Predictable:** The process operates inside predefined limits for its results.
- **Optimizing:** The process is dynamically adapted to effectively reach relevant business objectives.

In order to define the capability of a process, there is a need of evidence collection in a reliable and repeatable way. Each process is assessed on a four-point (N-P-L-F) rating scale: **N**ot achieved (15%), **P**artially achieved (50%), **L**argely achieved (85%), **F**ully achieved (100%).The rating is based upon evidence collected against the practice indicators, which demonstrate fulfillment of the process attribute. A process reaches a capability level when every process attributes from the previous levels are fully achieved and the process attributes of the current level are fully achieved or largely achieved.

Part 3 (Guidance on Performing an Assessment) provides the orientation on the minimum requirements fulfillment in order to perform an assessment, previously defined in Part 2. An overall view of the assessment is provided, in addition to a guidance. This orientation is related to supporting tools, competence of the involved team and the factors that contribute to the success of the process (commitment, motivation, confidentiality are some examples (ISO, 2019)).

Part 4 (Guidance on Use for Process Improvement and Process Capability Determination) guides how to use the process assessment in an improvement program or how to choose to which capability level a process belongs. This part supports the understanding of the achieved results, directing the responsible on the next steps for further improvements (ISO, 2019).

Finally, **Part 5 (An Exemplar Process Assessment Model)** defines a model for process assessment, compatible with Part 2. The model uses in the process dimension the reference model ISO/IEC 12207 AMD 1 and AMD 2, and in the capability dimension the framework assessment model, defined in Part 2 (ISO, 2019).

ISO/IEC 15504 was well received in the industry, being supported by the international community, used in major sectors as automotive, space and medical systems, and with more than 4000 assessments performed (ISO, 2019). On the other hand, was not as successful as CMM, majorly due to not being available as free download, and most of its differential characteristics being lately incorporated in CMMI.

2.2.4 OMM Model

The Open Source Maturity Model (OMM) (PETRINJA *et al.*, 2009) is a methodology, released under the Creative Commons license, for assessing Free/Libre Open Source Software (FLOSS) and more specifically the FLOSS development process.

OMM can be referred as a model and methodology. It contains a set of rules and guidelines describing how to conduct the assessment process, but also, as a model, contains all the descriptions and relations of all assessed elements. The OMM objectives are:

- To be simple and ease of use. It is intended to be used by teams spread into multiple locations around the globe, hence it needs to be practical and less rigid than the others maturity models.
- To provide a basis of how to evaluate projects developed by FLOSS development teams.
- To provide a basis on how FLOSS must be developed, aiming to improve the trustworthiness of its products to potential costumers. This can be useful for companies as well, which can use its described activities to improve the quality on their mainstream products.

OMM establishes three maturity levels, as described next:

- **Basic Level:** the initial level can be reached by implementing few necessary practices essential to the releases of high quality products, some examples:
  - **Product Documentation (PDOC):** to properly document each functionality and code aspects of the product.
  - **Licenses (LCS):** proper use of the required open software intellectual property licenses.
  - **Number of Commits and Bug Reports (DFCT):** to register and manage the amount of commits and bug reports on the developed product.
  - **Configuration Management (CM):** to manage every version of the product, explaining and registering its changes over the development.
  - **Requirements Management (REQM):** all the activities related to the management of the product requirements, from inquiring the essential functionalities with the costumer, to surveilling if they are being respected by the development team.
- **Intermediate level:** OMM second level can be achieved by implementing all activities from the basic level and the elements relate to reputation, roadmaps, stakeholders commitment and assessment made by third parties, such as:
  - **Relationship between Stakeholders (STK):** to perform a systematic way of communicating with the product Stakeholders, aiming improve the understanding of their needs and to diminish the drawbacks that a later implementation of a missing functionality will cause.
  - **Project Monitoring and Control (PMC):** use of the inputs from previous activities to monitor the progress of the project, comparing to its schedule and planning.

  - **Product Quality Assurance (PPQA):** to implement a series of related activities to assure an overall high quality on the product. This implies, for example, software testing and feedback gathering from stakeholders.

- **Advanced Level:** the highest maturity level that FLOSS projects can achieve, the team must fulfill every activity from Basic and Intermediate level, and the ones related more complex management tasks, such as:

  - **Risk Management (RSKM):** to gather the necessary information, from previous projects, to proper estimate the probability and impacts of possible risks to the development project. The team must also present solutions to diminish the chances or attenuate its impacts.
  - **Results of third party assessment (RASM):** to open its processes to third party assessments and use its feedback for further improvements.
  - **Product Integration (PI):** building of mechanics that facilitates the updates, changes and modifications on the code of the product by external contributors.

2.3 Final Remarks

In this chapter we presented an overview on the essential topics of OERs and maturity models. We brought a brief introduction of OERs importance, followed by a timeline that exhibited important events through its history. Next, we stated definitions and characterized the most known sharing licenses. Later, we presented some metadata structures for the educational resources and provided some examples of OERs sharing initiatives around the world. Although the potentials and improvements of the area, there are some concerns surrounding OERs researchers, specially when dealing with quality assurance and trustworthiness of OERs sharing services. In order to bridge some of these gaps we investigated maturity models as a possible solution. So, we brought an overview on the essential topics of maturity models for our research project, with a brief introduction of its importance, followed by the description of the most important ones: CMM, CMMI, ISO/IEC 15504 and OMM.

Similarly to the software industry, maturity models have been developed in the field of education, focusing on the capability of an institution to deliver successful programs and to assure the student learning within the course offered. In the next chapter we focus on this matter, performing a Systematic Mapping Study, in order to identify and characterize such educational maturity models.

CHAPTER

3

Educational Maturity Models: a Systematic Mapping Study

Open access repositories are an important mechanism to share OERs. According to Wani (WANI *et al.*, 2014), open access repositories have set new standards for information sharing and management. They are growing in quantity and diversity, being a significant research trend in OERs. Universities, in turn, also play a significant role in the new era of digital learning. Gourley and Lane (GOURLEY; LANE, 2009) claim that should be a goal to every university to made the world of knowledge a lot more democratic and open, bringing education to all that can be benefit by it.

Despite the existence of several repositories related to the delivery of OERs worldwide, there are still some known concerns about the expansion and sustainability of the movement. One of the main issues is the lack of quality assurance provided by the practicing institutions, both in terms of resources quality and in the effective adoption of such resources by educators in their pedagogical plan. Some institutions only uses their brand and reputation to persuade students that their OERs have adequate quality (HYLEN, 2006).

Similarly to software development, the production and application of OERs require the use of appropriate mechanisms to ensure the productivity of the development process and the quality of the resulting materials (ARIMOTO; BARBOSA, 2013).

In a different but related perspective, maturity models (MM) (Paulk *et al.*, 1993) (PAULK, 2002) (TEAM, 2006) (DORLING, 1993) (PMI, 2003) (PETRINJA *et al.*, 2009), have emerged as an interesting alternative for quality assurance in education (MUGHRABI; JAEGER, 2018).

Motivated by this scenario, in this chapter we describe the planning and conduction of a systematic mapping study (SMS) in order to provide the state of art of MMs being used in the educational context. We also investigated which models from other areas were used as inspiration and which specific methods the authors used to design them. Additionally, we aim to discover

which of these studies are related to Open Educational Resources (OERs). This study follows an evidence-based approach, through a systematic mapping. In this chapter we focus on the main aspects of the SMS conducted. More details can be found at (OLIVEIRA; BARBOSA, 2019).

This chapter is organized as follows. In Section 3.1 we discuss the planning and performing of the SMS conducted. In Section 3.2 we analyze the data and results obtained from the SMS. In Section 3.3 we discuss the threats to validity related of the study. In Section 3.4 we summarize the main findings and concluding remarks.

3.1 Planning and performing the SMS

A mapping study provides a systematic and objective procedure for identifying the nature and extend of the empirical study data that is available to answer a particular research question (BUDGEN *et al.*, 2008). The aim is to map the study within a research area instead of providing detailed information about a research question or interest phenomenon (PETERSEN *et al.*, 2015) (KITCHENHAM; CHARTERS, 2007). Performing a systematic mapping study on educational maturity models is fundamental to identify and gather their main characteristics, inspirations and design methods, which is the main goal of our work.

So, the main goal of our SMS is to characterize the maturity models proposed and used to support the quality of educational processes in general. We are interested in their main aspects, their inspirations and which methods or strategies were used to design them. There is also a concern of how many of the retrieved maturity models are particularly related to OERs.

To address the main objectives of the study we defined three Research Questions (RQ):

1. RQ1. What maturity models have been proposed and used in educational processes?
2. RQ2. What maturity models from other areas have inspired these educational maturity models?
3. RQ3. What methods or strategies have been used in designing of these educational maturity models?
4. RQ4. Which of these models are specifically related to open educational resources?

We selected the following data sources in order to perform our systematic mapping: ACM [1], IEEE Xplore Digital Library [2], Scopus [3], Web of Knowledge (Web of Science) [4] and Compendex [5].

[1] dl.acm.org
[2] ieeexplore.ieee.org/xplore
[3] scopus.com
[4] isiknowledge.com
[5] engineeringvillage.com

We defined a set of common terms and synonyms related to the topic under investigation, dividing them into two categories:

1. **Maturity Model**: including maturity model and CMM;
2. **Educational context**: including education, teaching, learning and student.

In Table 1 we present a general search string for our MS. When necessary, the search string was refined and modified to suit the needs of each data source.

Table 1 – General search string.

(("education" OR "teaching" OR "learning" OR "student") AND ("cmm" OR "maturity model"))

All searches were limited per year, ranging from January 2001 until December 2018. The restriction from 2000 was due to the fact that educational maturity models started appearing in such period. In certain data sources, such as Scopus and Web of Knowledge, searches were also limited by area, i.e., Computer Science, Engineering, Education and Educational Research.

To obtain coherent and consistent results for the research, we defined some inclusion and exclusion criteria for the retrieved studies.

Inclusion Criteria (IC) included:

- IC1. Studies describing the application of maturity models in educational processes
- IC2. Studies focusing in the design of maturity models in educational processes.

Exclusion Criteria (EC) included:

- EC1. Studies not focusing on educational maturity models.
- EC2. Studies describing maturity models applied in non educational areas.
- EC3. Studies not fully available for download and reading.
- EC4. Studies not published in English.

3.1.1 Performing the SMS

The studies selection was performed in two phases. Firstly, the studies retrieved by the data sources were filtered through a preliminary selection based on reading their title, keywords and abstracts. Duplicate studies were excluded. Then, the potentially relevant studies were fully read by two reviewers. Disagreement in relation to the inclusion or exclusion of a particular study

was discussed face-to-face between reviewers. When conflicting opinions persisted, the study was submitted to another reviewer. As the studies were selected, relevant information about them was gathered and documented for further analysis.

A total of 2057 studies were retrieved. In Table 2 we summarize the number of studies selected in each data source, both in the first and in the final selection phases. In the first selection, we identified 77 potentially relevant studies. After a complete reading of the "pre-selected" studies, we identified 25 primary studies relevant to the research objectives. In this phase, we found a significant number of duplicate studies; in general, this occurs due to the fact that some data sources, such as Compendex and Scopus, index other data sources, including IEEE Xplore Digital Library and ACM Digital Library. All duplicate studies were excluded from the results.

Table 2 – Summary of the included and excluded primary studies of each data source.

Data Sources	**Results**	**First Selection**		**Final Selection**	
		Included	Excluded	Included	Excluded
Scopus	697	39	658	14	25
Compendex	602	13	589	5	8
IEEE Xplore Digital Library	386	5	381	1	4
Web of Knowledge (Web of Science)	308	19	289	4	15
ACM Digital Library	64	1	63	1	0
Total	2057	77	1980	25	52

The selected primary studies are summarized in Table 3.

3.2 Data Analysis and Results

In Figure 14 we show the distribution of the primary studies according to the year of publication, from 2002 to 2018, synthesizing the community's interest in this research area through the years. As can be observed, the first studies on the area appeared on 2002 and 2004, lead by the papers from (DUGGINS, 2002), (PETRIE, 2004), (MARSHALL; MITCHELL, 2004) and (NEUHAUSER, 2004). After a lack of studies between 2005 and 2008, the community rekindled their efforts from 2009, with a peak of four studies in 2013.

Next we map and summarize our main findings in order to answer the research questions of this systematic mapping.

3.2.1 What maturity models have been proposed and used in educational processes?

This research question aimed at investigating and providing a general overview of the maturity models being proposed and applied with the purpose of improving and managing processes related to the educational context. Table 4 presents each one of the retrieved models, and their respective acronyms and references. The most interesting ones will be discussed next.

Table 3 – Final List of Approved Studies

ID	Title	Reference
S01	A maturity model for assessing the use of ICT in school education	(SOLAR *et al.*, 2013)
S02	A maturity model for computing education	(LUTTEROTH *et al.*, 2007)
S03	A maturity model: Does it provide a path for online course design?	(NEUHAUSER, 2004)
S04	A preliminary study about the analytic maturity of educational organizations	(Guitart *et al.*, 2016)
S05	A quantitative approach to eMM	(Zhou; Zhang, 2008)
S06	Applying CMM towards an m-learning context	(Alrasheedi; Capretz, 2013)
S07	Applying SPICE to e-Learning: An e-Learning Maturity Model?	(MARSHALL; MITCHELL, 2004)
S08	Applying capability maturity model to curriculum design: A case study at private institution of higher learning in Malaysia	(THONG *et al.*, 2012)
S09	Business Intelligence Maturity in Educational Institutions - Sultan Qaboos University: A Case Study	(RASHDI; NAIR, 2017)
S10	CMMI for educational institutions	(Ramanamurthy *et al.*, 2012)
S11	Crossing the ditch: Applying the e-learning maturity model to australian institutions	(MARSHALL, 2009)
S12	Development of strategic framework for supporting higher education graduates' early careers	(ANIČIĆ; DIVJAK, 2015)
S13	Enterprise SPICE based education capability maturity model	(MITASIUNAS; NOVICKIS, 2011)
S14	Intellectual Capital Management in European Universities in times of changes: an IC Maturity Model	(SECUNDO *et al.*, 2015)
S15	Managing the quality of teaching in computer science education	(REÇI; BOLLIN, 2017)
S16	Maturity model for process of academic management	(SILVA; CABRAL, 2010)
S17	Online course quality maturity model based on evening university and correspondence education(OCQMM)	(GU *et al.*, 2011)
S18	Process teaching and learning in engineering education	(DUGGINS, 2002)
S19	Project Management Maturity Model (PMMM) in educational organizations	(DEMIR; KOCABAŞ, 2010)
S20	Teaching quality in higher education: An introductory review on a process-oriented teaching-quality model	(CHEN *et al.*, 2014)
S21	Towards an engineering education capability Maturity Model	(PETRIE, 2004)
S22	UNEK plus , an academic entrepreneurship Maturity Model for higher education institutions	(MARKUERKIAGA, 2017)
S23	Using a Capability Maturity Model to build on the generational approach to student engagement practices	(NELSON *et al.*, 2015)
S24	Using the e-learning maturity model to identify good practice in E-learning	(MARSHALL, 2013)
S25	Utilising a capability maturity model to optimise project based learning- case study	(MUGHRABI; JAEGER, 2018)

The e-learning Maturity Model (eMM) is the one with most appearances in accepted studies (S05, S07, S11, S24), and hence, with the most citations (Zhou; Zhang, 2008), (MARSHALL; MITCHELL, 2004), (MARSHALL, 2009), (MARSHALL, 2013). It was developed by a collaboration from S. Marshall and G. Mitchell, merging the concepts of CMM (Paulk *et al.*, 1993) and SPICE (DORLING, 1993), in order to provide a robust system for improving development process in online delivery of teaching. In its first version, the model had more than 40 processes, divided in five categories (*learning, development, co-ordination, evaluation and organization*). Each process was evaluated through six capability levels (not performed, initial,

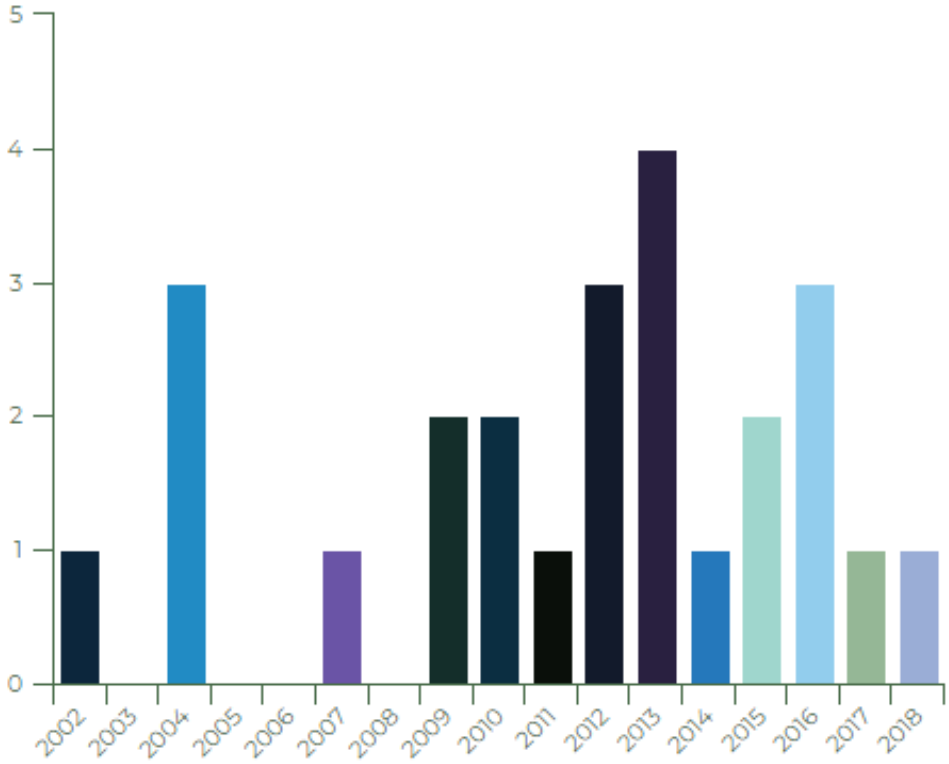


Figure 14 – Distribution of the primary studies by year of publication

planned, defined, managed and optimising). The maturity level of the organization was defined based on the results of this assessment. The model also evolved through the years, being used in several applications, including an analysis of Australian institutions and a series of workshop evaluations.

ICTE-MM (Information and Communication Technology in school Education - Maturity Model) (S01) is a model developed by Solar et al. (SOLAR *et al.*, 2013), which aims to measure the use of ICT standards in schools. It used as inspirations CMMI (TEAM, 2006), National Educational Technology Standards (NETS)(ISTE, 2007), and ICT Competency Standards for Teachers (CST) (UNESCO, 2011). It possess 25 Key Processes Areas (KPAs), divided in five leverage domains. Each one of these leverage domains has its own maturity levels. A formula is used to set the maturity level of the whole organization. The authors define it as not just a diagnostic tool but as also a guide for the principals to move towards best practices in management and ICT investment.

EduSpice (S13), presented by Mitasiunas and Novickis (MITASIUNAS; NOVICKIS, 2011), is an example of a SPICE-based model. The authors goal was to develop a ISO/IEC 15504 conformant education process capability maturity model, introducing a participative approach to education capability assessment and improvement. It has 10 primary processes (*Reflective Research, Course Development, Production, Distribution, Course Delivery, Academic Student Support, Assessment, Education Support System, Registration, and Learning*), each one of them

Table 4 – Educational Maturity Models Retrieved

Studies	Acronym	Name	Reference
S01	ICTE-MM	ICT in school Education - Maturity Model	(SOLAR *et al.*, 2013)
S02	CEMM	Computing Education Maturity Model	(LUTTEROTH *et al.*, 2007)
S03	OCDMM	Online Course Design Maturity Model	(NEUHAUSER, 2004)
S04	—	The Delta Maturity Model	(Guitart *et al.*, 2016)
S05, S07, S11, S24	eMM	e-learning Maturity Model	(Zhou; Zhang, 2008), (MARSHALL; MITCHELL, 2004), (MARSHALL, 2009), (MARSHALL, 2013)
S06	—	m-Learning Maturity Model	(Alrasheedi; Capretz, 2013)
S08	CDMM	Curriculum Design Maturity Model	(THONG *et al.*, 2012)
S09	TDWIMM	The Data Warehouse Institute Maturity Model (adapted)	(RASHDI; NAIR, 2017)
S10	—	CMMI for educational institutions	(Ramanamurthy *et al.*, 2012)
S12	—	Maturity Model for supporting higher education graduates' early careers	(ANIČIĆ; DIVJAK, 2015)
S13	EduSpice	SPICE based education capability maturity model	(MITASIUNAS; NOVICKIS, 2011)
S14	ICMM	Intellectual Capital Maturity Model	(SECUNDO *et al.*, 2015)
S15	TeaM	Teaching Maturity Model	(REÇI; BOLLIN, 2017)
S16	ACMM	Academic Management Maturity Model	(SILVA; CABRAL, 2010)
S17	OCQMM	Online course quality maturity model	(GU *et al.*, 2011)
S18	—	Maturity Process Teaching Model	(DUGGINS, 2002)
S19	PMMM	Project Management Maturity Model	(DEMIR; KOCABAŞ, 2010)
S20	T-CMM	Teaching Capability Maturity Model	(CHEN *et al.*, 2014)
S21	—	Engineering Education Capability Maturity Model	(PETRIE, 2004)
S22	UNEK	Academic Entrepreneurship Maturity Model for Technological Faculties	(MARKUERKIAGA, 2017)
S23	SESR-MM	Student Engagement, Success and Retention - Maturity Model	(NELSON *et al.*, 2015)
S25	PBLCMM	Project Based Learning Capability Maturity Model	(MUGHRABI; JAEGER, 2018)

being composed by several sub-processes, its own goals and purposes. However, the model validation was not included in the study.

The study conducted by Ramanamurthy et al. (S10) (Ramanamurthy *et al.*, 2012) is a sample of a CMMI based educational maturity model. They proposed a framework that would assist, in a general way, any educational institution to know how to improve itself. Their work characterize every institution in one of five levels: *Struggling, Surviving, Reputed, Recognized and Leading*. They also stated a series of key activities that would be necessary to be implemented in order to advance to higher levels. At last, the paper presents a Process Improvement Matrix, an assessment tool used to track these key activities. A software containing this framework was mentioned as future work.

Another example of CMMI-based model is the study performed by Mughrabi and Jaeger, the Project Based Learning Capability Maturity Model (PBLCMM) (S25) (MUGHRABI;

JAEGER, 2018). The model is presented in three KPAs: *quality of PBL project, quality of PBL facilitation and quality of PBL assessment*. They designed its activities by interviewing area experts and validated by applying them in two case studies. They concluded that the model could be improved by introducing adequate control of authenticity of students' work, as well as considering students' effort throughout the span of the project, and, in order to institutionalise the PBL model, it will be necessary an introduction of general goals and practices.

Finally, as a case of CMM-based educational maturity model, there is the research developed by Alrasheedi and Capretz (S06)(Alrasheedi; Capretz, 2013), the m-Learning Maturity Model. The model aims to assist any educational institution that intends to improve their m-learning usage. They describe the aspects of what an institution in that level would be close of, and what steps they should take to improve their maturity.

Next we discuss the inspirations of the presented models in order to achieve a better understanding of how they work.

3.2.2 What maturity models and standards from other areas have inspired the retrieved educational maturity models?

This research question aims to discover what maturity models and standards were the most influential on the retrieved studies. Knowing beforehand which of these models are the most popular in the educational context can aid the development of future ones. We summarize the results of this question in Figure 15. As can be seen, CMM (Paulk *et al.*, 1993) (PAULK, 2002) presents the major influence with 53.3% of appearance in accepted papers, followed equally represented by SPICE (DORLING, 1993) and CMMI (TEAM, 2006), both with 20%. At last, TDWIMM (The Data Warehouse Institute Maturity Model) (INSTITUTE, 2015) and OCDMM (Online Course Design Maturity Model) (NEUHAUSER, 2004), both with 3.3% of the total amount.

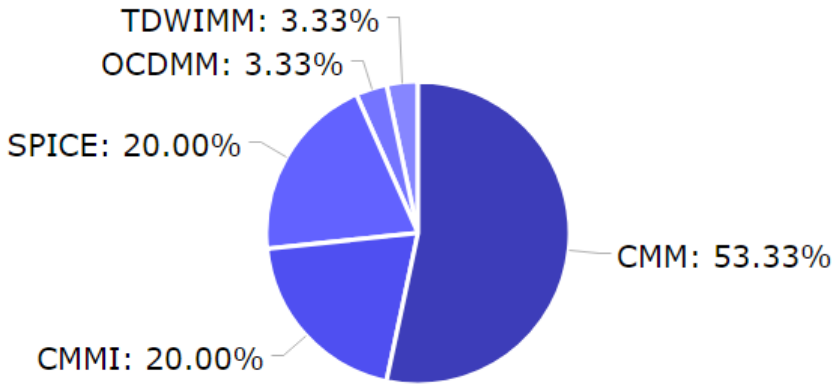


Figure 15 – Maturity Models used as inspirations by the primary studies.

Figure 16 illustrates which model/standard inspired each one of the retrieved educational maturity models. Some models had more than one inspiration (eMM, m-learning MM). Also, CDMM was the only model that was directly based on another educational maturity model.

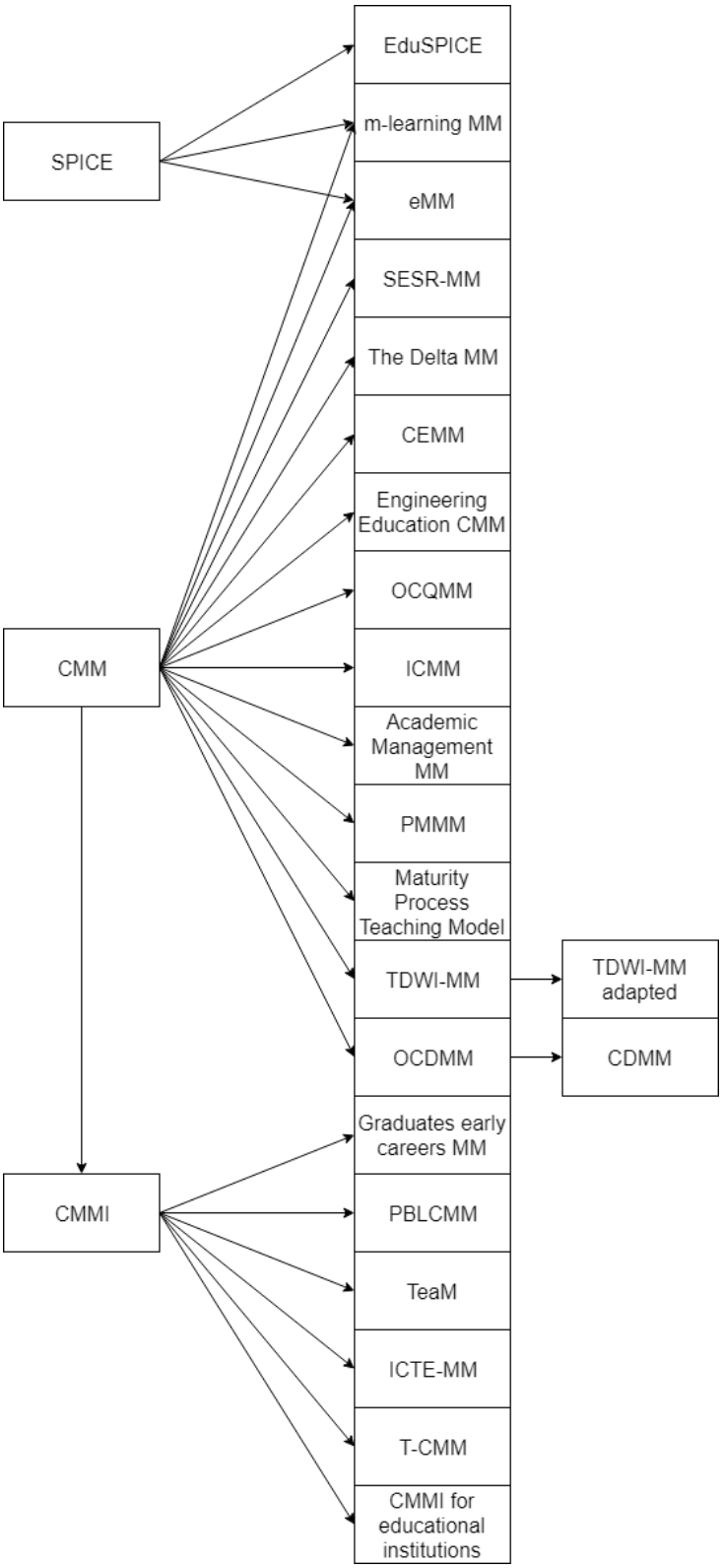


Figure 16 – Tree representing the influence of models and standards on the educational maturity models.

From the SMS performed, we observed that the retrieved models characteristics were mostly inherited from their predecessors, specially CMM and CMMI.

3.2.3 What methods or strategies were used in designing of these educational maturity models?

This research question aims to discover what methods or strategies the authors from retrieved studies used to design their educational maturity models. The results are presented in Figure 17.

Unfortunately, there is a high number of studies that failed to answer this question: a total of 10 studies did not provide sufficient information in this topic. Following that, 6 studies designed their models only studying older models. With the third most appearance, with 4 studies, there were ones that also based their models in previous studies, but additionally performed a test using pilot versions, improving it after feedback. Aiming at a higher and more qualified volume of criticism, there were studies that designed their models using suggestions from experts through workshops and surveys, with 2 appearances each. At last, there was a study using Mettler MM Design Method (METTLER, 2010), which will be explained next.

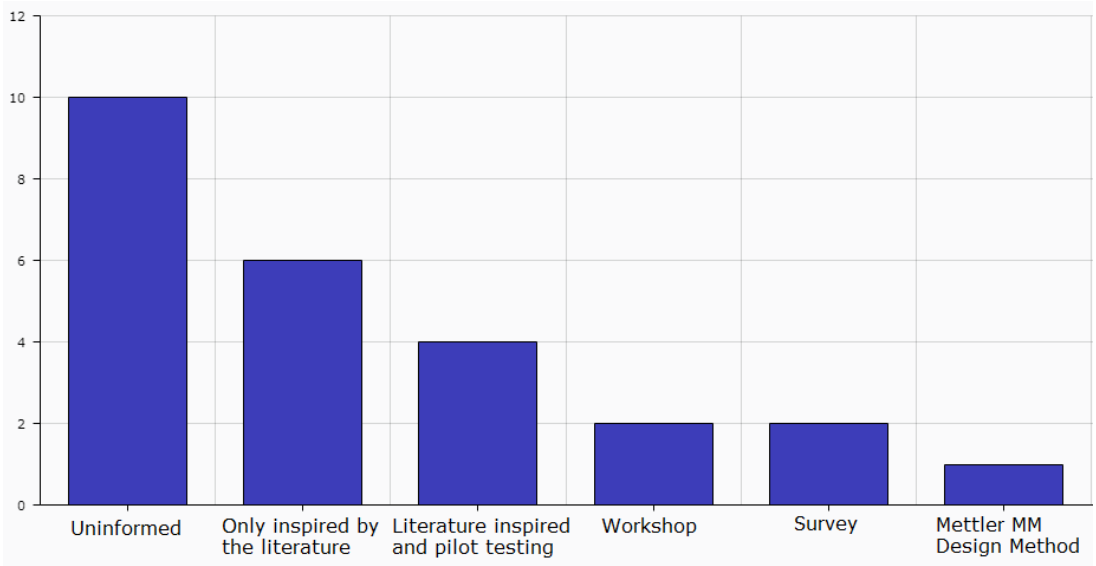


Figure 17 – Design methods retrieved from accepted papers.

Thong et al. (THONG *et al.*, 2012) developed the Curriculum Design Maturity Model (CDMM) after a literature study. They used the model developed by Neuhauser (NEUHAUSER, 2004) (OCDMM - Online Course Design Maturity Model) as a guide to design the pilot version of their work. In order to refine their framework, they tested the pilot on bachelor degree level program and concluded that improvement is needed to ensure that the model helps the curriculum designers to develop a better program of study. But, even in its first iteration, they were capable of affirm that the model could provide a roadmap to improve curriculum redesign processes.

Secundo et al. (SECUNDO *et al.*, 2015) attended to three workshops through the process of building the Intellectual Capital Maturity Model (ICMM). Before the first one, the authors did a series of studies that gathered information about the main concerns and issues of intellectual capital management at universities across Europe. Then, they met with area experts at the first and second workshops in order to brainstorm solutions to these issues. To develop a maturity model to assist the area was one of their conclusions. In the last workshop they returned with sketches and model proposals, the participants analyzed each one of them, and the result is their final model.

Instead of gathering in workshops, Reçi and Bollin (REÇI; BOLLIN, 2017) developed the Teaching Maturity Model (TeaM) collecting experts opinions through online surveys. They executed the first one with the purpose of defining their KPAs. It was asked which educational processes were the most important to the context of their model. They processed the data and created the pilot version with the results. The model was redesigned after analyzed by a maturity model expert. With a stable version, a survey was executed once again, but at this time asking for criticism. The final version was created assembling this final input.

Anicic and Divjak (ANIČIĆ; DIVJAK, 2015) used Mettler MM Design Method (METTLER, 2010) (Figure 18) to create their maturity model for supporting higher education graduates' early careers. Mettler built his method by examining existing design methodologies and, based on their similarities and differences, proposed the 5-step design methodology: (1) Identify need or new opportunity, (2) Define scope, (3) Design model, (4) Evaluate design, and (5) Reflect evolution. Anicic and Divjak's model was submitted at the second step (define scope), and their conclusions present how they will execute the next ones.

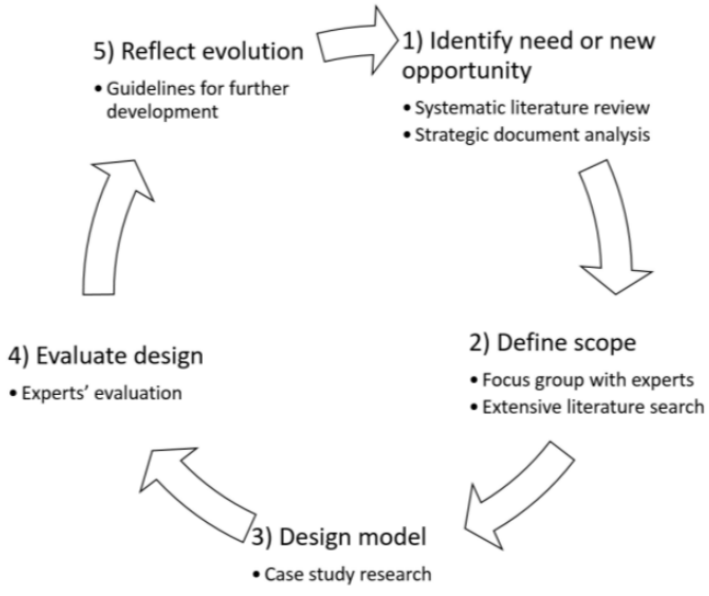


Figure 18 – Five step design methodology by (METTLER, 2010)

Finally, in Figure 19 we mapped how each retrieved model was designed (axis x) with their inspirations (axis y). The combination of CMM inspiration and unspecified designed methods had the most appearances (9). The second and third combinations with the most hits were CMM/Literature inspired (4) and SPICE/Unknown (3), respectively. CMMI was the only inspiration that was paired with Surveys and the Mettler Design Method.

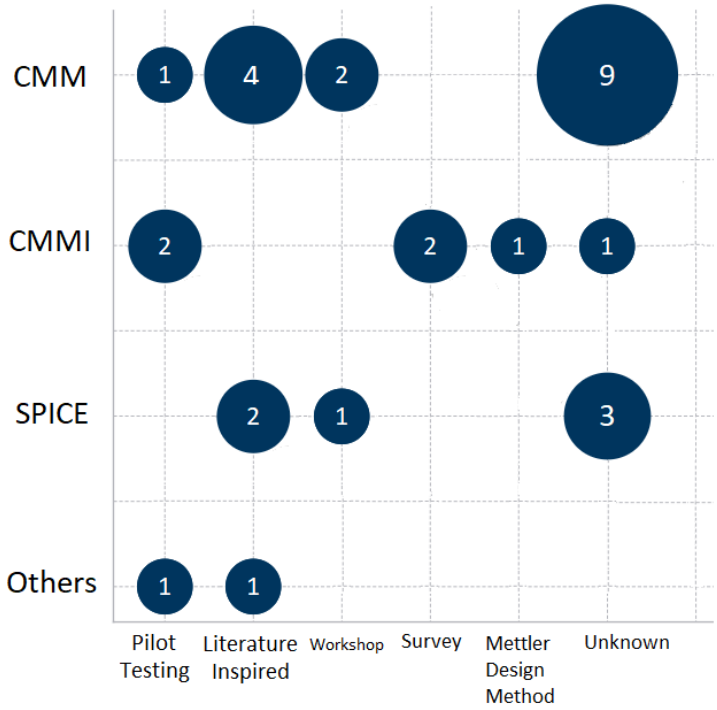


Figure 19 – Relation between how each study was designed and what was its inspiration

3.2.4 Which of these models are specifically related to open educational resources?

As mentioned before, every retrieved paper was subjected to a thorough reading in order to answer all research questions. And none was related to, or even mentioned, open educational resources. There was also said that OERs have potential to enhance the education at a global level, jump starting careers and economic development in communities that lag behind, helping to reduce socioeconomic inequality (HEWLETT; HEWLETT, 2002). It is a major educational topic of this decade, a quick search at Scopus database shows more than 1200 studies retrieved using the keyword "open educational resources".

The lack of this topic among the retrieved studies highlights a gap in the area, demonstrated by the concern that some authors posses over the overall quality among OERs sharing services (HYLEN, 2006), (ARIMOTO; BARBOSA, 2013).

Table 5 summarizes how each retrieved study answered every research question.

Table 5 – How each study answered the RQs

Study	RQ1	RQ2	RQ3	RQ4
S01	ICTE-MM	CMMI	Literature inspired and pilot testing	Non related
S02	CEMM	CMM	Unknown	Non related
S03	OCDMM	CMM	Unknown	Non related
S04	Delta MM	CMM	Unknown	Non related
S05	eMM	CMM/SPICE	Unknown	Non related
S06	m-Learning MM	CMM/SPICE	Unknown	Non related
S07	eMM	CMM/SPICE	Literature inspired	Non related
S08	CDMM	OCDMM	Literature inspired and pilot testing	Non related
S09	TDWIMM	TDWIMM (adapted)	Literature inspired	Non related
S10	CMMI for educational institutions	CMMI	Unknown	Non related
S11	eMM	CMM/SPICE	Unknown	Non related
S12	Graduates' early careers MM	CMMI	Mettler MM Design Method	Non related
S13	EduSpice	SPICE	Literature inspired	Non related
S14	ICMM	CMM	Workshop	Non related
S15	TeaM	CMMI	Survey	Non related
S16	ACMM	CMM	Unknown	Non related
S17	OCQMM	CMM	Literature inspired	Non related
S18	Maturity Process Teaching Model	CMM	Unknown	Non related
S19	PMMM	CMM	Unknown	Non related
S20	T-CMM	CMMI	Literature inspired and pilot testing	Non related
S21	Engineering CMM	CMM	Literature inspired	Non related
S22	UNEK	CMM	Literature inspired	Non related
S23	SESR-MM	CMM	Literature inspired and pilot testing	Non related
S24	eMM	CMM/SPICE	Workshop	Non related
S25	PBLCMM	CMMI	Survey	Non related

3.3 Threats to Validity

The main threats to validity related to our SMS are summarized as follows:

- **Search strategies**: when using automated searches, potentially relevant studies cannot be retrieved by the data sources. Recent studies cannot be indexed by search engines as well. We tried to use significant terms and keywords associated to the subject under investigation. The general search string was tested and refined several times before executing the systematic mapping. We also used manual searches including reference searches, journals and conference proceedings of the research area. We conducted a rigorous and through search within the selected data sources to obtain the maximum potentially relevant studies.

- **Sample representativeness**: the quantity of selected primary studies is still small and may not be representative of the population. However, we tried to conduct a comprehensive and exhaustive search for primary studies in order to obtain the maximum relevant studies and achieve consistent and coherent results for the research.

- **Studies Selection**: when searching for potentially relevant studies, hundreds of results can be retrieved by the data sources. Then, the first selection filter for the studies retrieved takes place through skimming and scanning their title, keywords and abstracts. Some studies can be excluded if they have a poor abstract but a rich content. We tried to minimize this risk by using peer-review, and considering the whole content. Sometimes divergent opinions on a specific study may reject it even though the study is relevant to the research. In this case, we consider the opinion of a third reviewer in order to solve any doubt or divergent opinion on rejecting or accepting a given study.

3.4 Final Remarks

In this chapter we discussed the planning and execution of a SMS aiming at providing a big picture (a map) about the educational maturity models. From this mapping, we were able to identify 22 educational maturity models, divided among 25 studies.

In short, we identified the inspirations, previous models and standards that influenced the design of such models – CMM, CMMI and SPICE were the most common ones. We also investigated which methods the authors used to design their models. Unfortunately, a high number of studies failed to answer this question; even though, literature study, pilot testing, workshop and surveys were common answers as well. Finally, we noticed that no study was related to open educational resources, highlighting the importance and innovation of this this Master's work on the area.

The SMS described in this chapter served as a guide to help the development of our Capability Model. The designed methods, evaluations, gaps and structures of these retrieved educational MMs are used as literature inspiration, in order to justify our decisions when conceiving our Capability Model for Open Access Repositories.

Based on the main findings and conclusions from this SMS, in the next chapter we propose a model that aims to improve the service of OA repositories towards the sharing of OERs.

CHAPTER

4

Developing the Model

In this chapter we describe the the development process of the CM-OAR Model. We used an interactive design method, evolving the model through a repetition of four steps: (i) gathering of research input, (ii) input analysis, (iii) determination of changes and (iv) designing of the model. The model was based on the premises of the Capability Model present on CMM, aiming to evaluate how capable a OA repository is in sharing their OERs. Educators can use the model to evaluate which repositories have better processes and structure to manage the resources that they intend to upload. Students can also use it to know which repositories are more capable of satisfying their educational needs. Finally, the owners of such repositories can also use it to learn in which aspects their platforms can be improved.

This chapter is organized as follows. Section 4.1 summarizes the research paradigm used for the model development - Design Science Research. Section 4.2 describes the development process of the CM-OAR Model through three iterations. Finally, in Section 4.3 we present the the CM-OAR Model in its current iteration, which concludes the research. The validation and experiments performed for this research are described in Chapter 5.

4.1 Design Science Research

Design Science Research (DSR) is a research paradigm that aims to solve real-world problems through the creation and iteration of an innovative artifact (models, methodologies, frameworks, etc) (WINTER, 2008). Differently to research methodologies that have pre-defined processes, DSR has a more adaptive nature, requiring different validations for each applied context, thus being more aligned as a research paradigm (IIVARI, 2007). By focusing on real-world problems, DSR enables the resolution of societal challenges and contributions of significant societal value (WATSON *et al.*, 2010) (BECKER *et al.*, 2015).

In DSR the researcher typically follows a loop of building and evaluation. On each

iteration the researcher gets a better grasp of the problem and improve the developed artifact (MARKUS *et al.*, 2002). Once there is no more iterations needed, the final artifact is produced. CMMs are qualified as artifacts and DSR is often used to design them (STEENBERGEN *et al.*, 2010) (LAHRMANN *et al.*, 2011) (KESHAVARZ; NOROUZI, 2021). For instance, Mettler MM Design Method (METTLER, 2010) was designed using DSR principles.

As stated on previous chapters, OERs have answers for educational problems and OA repositories are one of the better ways of sharing OERs with others interested. In our work, we intend to provide an artifact capable of evaluating the quality of such repositories. It was developed using a DSR, investigating which of the CMMs characteristics can be used to achieve that goal. The model should be able to assess which repositories are more capable at managing and sharing their resources.

Although DSR is defined as a paradigm, methods based on its premises are encouraged and can be used for research purposes (BASKERVILLE, 2008). In our work, we adapted a method from the DSR paradigm, as can be seen in Figure 20. The method has a loop of four steps that are described below:

1. **Gather Research Input:** Every effort that involves knowledge acquisition on the research scope. It involves the bibliographical research of Chapter 2, the SMS from Chapter 3 and the validations from Chapter 5.

2. **Input Analysis:** After the input is gathered, an analysis of its content is proceeded, aimed to find possible changes and its impacts. This analysis needs to be adapted to match the nature of each input.

3. **Determine Changes:** Once the analysis is done and its conclusions are exposed, this step establishes what corrections need to be made at the model.

4. **Design the Model:** The fourth step concludes the iteration cycle. With the changes settled, a new and improved model is designed, ready to be evaluated again.

In the next section we describe the use of this method in the refinement of the CM-OAR Model and how it evolved from each iteration.

4.2 Development and Iterations of the Model

In this section we present the iterations of the CM-OAR. On each topic it is exhibited an executed loop of our inspired DSR method (Figure 20). The full description of the Capability Model for Open Access Repositories is presented on Section 4.3.

Figure 21 summarizes the iterations presented in this section. The first iteration was developed using the bibliographical research (Chapter 2) and the SMS (Chapter 3) as research

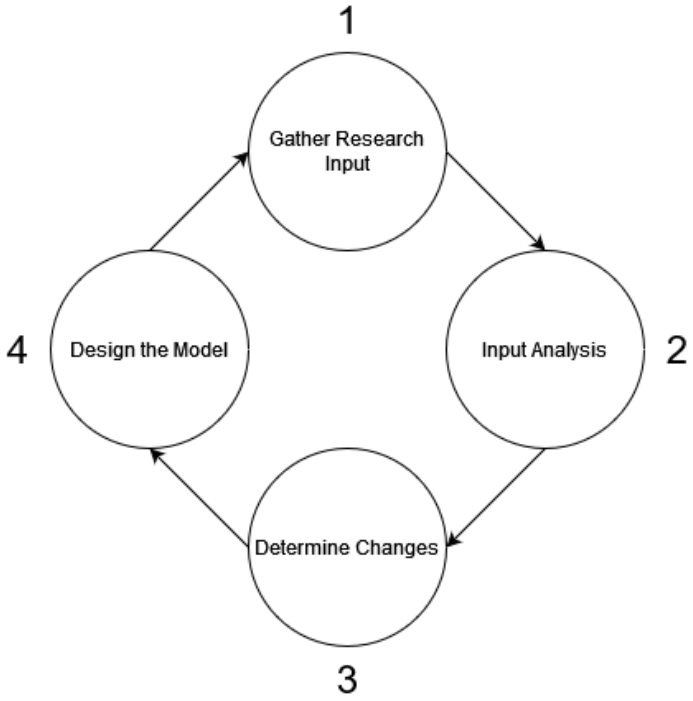


Figure 20 – Method adopted in our work, inspired by (WINTER, 2008) (METTLER, 2010)

input. The second iteration was designed using the feedback from Survey 1 (Section 5.1). Finally, the current iteration of the Capability Model for Open Access Repositories was designed using the input from surveys 2 and 3 (sections 5.2 and 5.3).

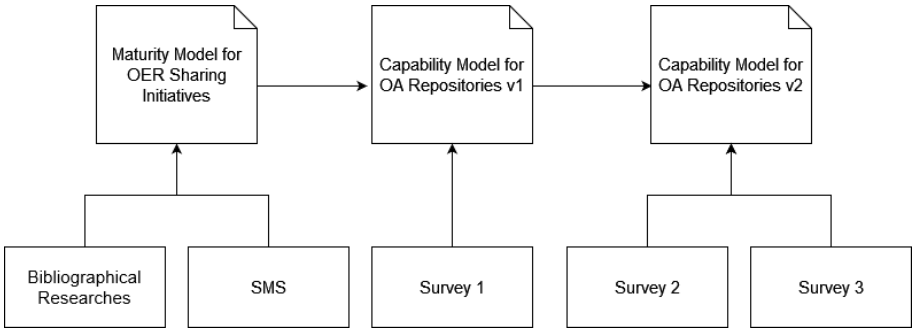


Figure 21 – Iterations of the Capability Model for Open Access Repositories

4.2.1 First Iteration

This iteration was the first design, it is a prototype aiming to grasp the core topics involving this project: Capability Maturity Models and Open Educational Resources. Built using bibliographical researches, the goal of this iteration was to learn more about the problems around sharing OERs, how maturity models work and how they were used to solve related problems on educational contexts. The objective of this iteration is to provide a way of assessing Sharing Initiatives, so future users (educators and students) can better chose which repositories they want to share and look for OERs. The loop was conducted as follows:

1. **Gather Research Input:** The inputs were gathered through bibliographical researches. Chapter 2 covered the studies among the two axis of this project, Open Educational Resources and Capability Maturity Models. It was an investigation into the main researchers, history and definitions of both topics. Additionally, a SMS (Chapter 3) was conducted to study the intersection of both study areas, inspecting how CMMs were used and designed in the past to solve educational context problems.

2. **Input Analysis:** The studies concluded that OERs researches have concerns on quality assurance and trustworthiness on their sharing services. It was also concluded that MMs could be used as a solution to those matters. The SMS provided answers on how MMs were being developed for educational problems and how educational MMs were adapted from the original one.

3. **Determine Changes:** Being the first iteration of the model, there was no changes from previous versions.

4. **Design the Model:** The model was built using the core premises of Maturity Models. It was aimed at OER Sharing Initiatives, which at the time was defined as any educational institution (universities, schools, profit or non profit teaching organizations) or individual (teachers, courseware designers) that possess an intent or project of sharing OERs. It had five maturity levels: Initial, In Development, Structured, Expansion and Optimization, adapting the five levels from CMMI (TEAM, 2006). The KPAs were: Functionalities, Metadata Structure, System Quality, Repertoire, Marketing and OER Quality (an initial draft for the main observable characteristics of a successful sharing initiative). As is common in MMs, the initiative could only reach a specific maturity level once it reached the requirements on each one of the KPAs of that level.

In the first iteration, the initiative could only reach a maturity level once possessed every characteristic of that level. The maturity levels were designed as follows:

1. **Initial:** This level defines the minimum processes and structures that are needed for the work of a sharing initiative. The initiative has a platform to share its resources. The platform does not have its metadata structured visible to the user. The only possible interaction for the users is to download or visualize the resources. It is not possible to upload new resources, contact the owners, revise the OERs or to make comments. The platform has periods of instability and presents a low quality control. The platform has a simple OERs collection, normally only storing a single format for this data (only text files or only video files). Also, it is common to have only one sharing license for all of its resources. The shared resources have the same target audience. There is not much effort into promoting the initiative.

2. **In Development:** At this level, the initiative raises the awareness towards improving the quality of its processes and structures. Although instability issues can still occur, now the initiative has a dedicated team to search and solve them. The platform allows its users to send their own resources. The platform still possesses a simple collection, but now it has resources of different themes and file formats. The majority of its content is expositive. Despite the fact that more target audiences are being addressed and the resources can be made available through different sharing licenses, the common user can have difficulties in differentiating them due to the lack of a well defined metadata structured. There is a minimum effort into promoting the initiative.

3. **Structured:** At this level, the initiative aims to consolidate its structures and establishing a consistency through its processes. There are periodic and pre-determined routines to correct undesired system behaviours and to investigate possible new functionalities. The system is stable and online 24/7. The metadata structured is well defined and observable for the users, addressing at least the OER name, author, main theme and sharing license. The users can comment or rate the shared resources. The initiative begins to care about the quality of the uploaded resources. The collection has a higher diversity of resources, approaching different themes, languages, interactivity types and target audiences. Processes aiming to publicize the platform begin to appear, resulting in alliances with larger educational portals and promotion of the URL.

4. **Expansion:** At this level, the development team starts to quantitatively to evaluate the implementations in order to most efficiently establish new functionalities. The platform allows its users to form communities, send messages and form groups of study. There is a specific team to assess the quality of new resources. Defamatory content, injuries and "fake news" are filtered from the incoming materials. The initiative can visualize which themes, languages, interactivity types and target audiences are most common among their collection, neglected ones can be included in incentive campaigns promoted to authors. There is also a team to focus on promotion and expansion of the platform, among their actions there are partnership with universities, schools and other community groups, raising the initiative reach to people.

5. **Optimization:** The initiative has reached international reference in sharing OERs, assisting other initiatives in developing their platforms. There is a continuous enhancement of its process based on quantitative feedback, idea testing and innovating technologies. The innovations are product of scientific research promoted by the initiative. The initiative has partnerships with universities and the industry, supporting the development of technical knowledge among new professionals. Their collection is diverse, contemplating many themes, languages and target audiences. The quality control is acknowledged among its peers.

The KPAs processes were divided among the maturity levels, but their scope is described as follows:

- **Functionalities:** This KPA characterizes which functionalities were developed and established in the platform. Download, upload and commenting resources are examples.
- **Metadata Structure:** This KPA characterizes how well structured are the metadata of their resources, if it has the minimum fields to allow sharing licenses to function and facilitate the searching for specific topics to its users.
- **System Quality:** This KPA characterizes the overall quality of the software behind the platform. How often major bugs interfere on the user experience, how quickly they are fixed or if the platform is stable for usage are examples.
- **Repertoire:** This KPA characterizes how diverse their OER collection is on themes, target audience, languages, interactivity types and file formats.
- **Marketing:** This KPA characterizes the efforts of the initiative on promoting their platform, including partnerships with universities, educational websites and the industry.
- **OER Quality:** This KPA characterizes the efforts of the initiative on quality control of submitted resources, avoiding defamatory content and "fake news".

The second iteration is presented next. It aimed to validate the design with educators.

4.2.2 Second Iteration

The goal of this iteration was to validate the definitions of our previous design, exposing the characteristics of the maturity model to educators. We performed an exploratory survey on the subject, gathering feedback in order to perform improvements for the next design. It was expected that respondents had previous knowledge on OERs. The steps are described as follows:

1. **Gather Research Input:** In the second iteration, the input was gathered through an exploratory survey. The goal was to quantify how much previous knowledge an average educator has with Capability Maturity Models and how they would relate several Sharing Initiatives characteristics with Maturity Levels. The conducting and detailed results of this survey are described on Chapter 5 (Section 5.1).
2. **Input Analysis:** The survey showed that the participating educators had little experience with Maturity Models. Most of them never had any contact with the subject and only a fifth of them had professional or academic knowledge. Even after exposed to its premises and definitions, the respondents had difficulty to relate essential aspects of Sharing Initiatives

to the minimum maturity level. The survey highlighted the dilemma of how to translate the concept of Maturity Models to an OER setting.

3. **Determine Changes:** The decision for the second design was to simplify the model. We lowered the scope from Sharing Initiatives to Open Access Repositories. Our object of evaluation should be concrete and with a broadly accepted definition. We also changed from a Maturity Model to an adapted Capability Model. Since maturity is more complex and bureaucratic to evaluate, the change aimed to allow a more straightforward understanding for educators, students and repository maintainers firstly exposed to its premises. Capability started being evaluated in levels on the CMMI continuous representation (TEAM, 2006), defining goals and breakpoints in order to evaluate structural processes. This representation allows the organization to focus in which key areas they find most important, creating individual paths to progression and providing clear ways to compare with other repositories. We also took the opportunity to reevaluate the main observable characteristics of OAs Repositories. In order to better suit their descriptions, Repertoire key area as changed to OER Collection, System Quality was changed to Platform Stability, Platform Functionalities was changed to 5Rs Management and Marketing was changed to Repository Promotion.

4. **Design the Model:** The new model now had Capability Levels that were based on NPLF rating, adapted from ISO/IEC 15504: Not Achieved, Partially Achieved, Largely Achieved and Fully Achieved (GALIN, 2004). The characteristics of the OA repositories chosen to be evaluated were based on the premise that the better they were presented, the greater the chances of a shared OER reaching its target audience. Each characteristic is grouped in a key area, which is evaluated individually by observing its specific metrics and implementation of processes. The characteristics were divided in six key areas: 5Rs Management, Metadata Structure, Platform Stability, Repository Promotion, OER Collection and OER Quality. Marketing was excluded in this new assessment.

4.2.3 Third Iteration

The goal of the third iteration was to validate the changes made in the previous one, assessing if repositories better evaluated in the key areas are also the most preferred ones among educators. The inputs of this iteration are evaluations of Brazilian OA repositories, the respondents being educators and post graduated students in Computing Applied to Education. The steps are described next:

1. **Gather Research Input:** In the third iteration, the input was gathered in two surveys. The first one (Chapter 5, Section 5.2) aimed to evaluate three Brazilian OA repositories (EDUCAPES (CAPES, 2022), MECRED (MEC, 2022) and Escolas na Rede (SEEC, 2022)). Respondents needed to explore the repositories, upload an OER of their own

creation, and rate each repository on a series of characteristics that reflected the key areas defined in the previous iteration. We also evaluated the usability of the repositories, suspecting that although the area would required more attention to be properly assessed in the future, it would be beneficial for the objectives of our model at the time. The results of the survey indicated that a deeper investigation on the usability as an area would be beneficial, thus the need of applying a second survey (Section 5.3). In the second one, the same respondents needed to answer a SUS questionnaire (System Usability Scale, a survey used to evaluate the usability of products and services (BANGOR *et al.*, 2008)) for the explored repositories, aiming to find which one of them had a better usability score. At the end, they also needed to rank the importance of the six key areas of evaluation together with usability, with the purpose of comparing the importance of usability with the other settled six key areas.

2. **Input Analysis:** The surveys reinforced the idea that, the higher the results of a repository on the assessed areas, the higher the chances for the repository to satisfy their target audience. They also reinforced the importance of usability when users are choosing which repository invest their time and resources on. When comparing the importance of each key area for the respondents, usability was the highest one, closely followed by the others. For now, establishing an weight system for balancing the scores of the areas is not being considered.

3. **Determine Changes:** The biggest change from the previous version of the model was the inclusion of Usability as an area of evaluation. We noticed that usability was essential for achieving the needs of the users needs to be left out. Besides that, some key areas had their metrics and processes calibrated and rearranged on the NPLF scale. The key area Repository Promotion (previously Marketing) was redesigned to User Traffic - at first the key area had the objective to quantify the effort that the repository had in promoting their platform, but this proven to be difficult to evaluate inside our purpose of a simpler model. So, instead we will evaluate the monthly number of access of the platform, that indirectly should encompass the repository ability of promoting their service. It was also necessary to settle details on the evaluation processes other key areas.

4. **Design the Model:** The new model now has Usability as an area of assessment. SUS grade rankings were used to determine the breakpoints in the NPLF scale. Every area now has a defined method of evaluation. Most of them demands exploration of the platform, observing if the desired characteristics and methods are present. User Traffic and System Stability need aid from external tools to assess their benchmarks. Usability requires the application of a SUS questionnaire.

After three iterations, we reached the final version of our CM-OAR, which is described next.

4.3 CM-OAR - A Capability Model for Open Access Repositories

In this section we present the final version of the Capability Model for OA Repositories. Although the model has reached a final iteration, it is worth mentioning that the DSR paradigm allows and motivates the continuous improvements, thus enabling more iterations and modifications in the future, as part of the evolution process of its proposed solutions.

4.3.1 Objectives

The initial research question of this work was: *"Can a maturity model be adapted to assess open access repositories?"*. As part of the development process of our research, a slightly different research question was established: *"Can a capability model be adapted to assess open access repositories?"*

In order to answering it, the CM-OAR model should should reflect the following objectives:

1. To be able to assess the capability of an OA repository of sharing OERs. This includes the educators ability of uploading their resources; students, in turn, need to be able to find and access the resources of their desired subjects. Once repositories are evaluated, their potential users should be able to decide which one is the most capable of solving their needs.

2. To be able to provide points of improvements for the maintainers of the assessed repositories: the metrics and processes that the repository should achieve to reach higher scores need to be visible.

4.3.2 Capability Levels

Each area can be individually rated into 4 capability levels, each level using a rating adapted from NPLF (ISO/IEC 15504 (GALIN, 2004)) described next:

0. **Not Achieved:** This level indicates an unsatisfying level of achievement, the area is incipient or not implemented yet.

1. **Partially Achieved:** This level indicates a partially satisfying achievement, having a minimum performance to guarantee a functioning repository.

2. **Largely Achieved:** This level indicates an area with processes and metrics largely achieved. Although there is still room for improvement, its execution already provides a quality service to users.

3. **Fully Achieved:** The area fulfills all possible expectations, fully reaching its potential. It is an example for other repositories.

4.3.3 Key Areas

Next, we present the CM-OAR key areas of evaluation. These areas were chosen in order to represent core characteristics of OA repositories. The higher the score of the repository in a given area, the more capable is the repository in sharing OERs. We also present the processes and metrics that the key areas have to achieve to be evaluated at each capability level.

4.3.3.1 KA1: System Usability

This area refers to how difficult is to use the repository. It is assumed that, the higher the system usability, the better is the experience of educators in sharing their resources and students in finding materials of interest. This area can be assessed using a SUS questionnaire. SUS is an instrument of usability evaluation, built from 10 questions, easy to use and providing a single reference score for its respondents (BANGOR *et al.*, 2008).

- **Not Achieved:** The repository scored a "Worst Imaginable" or "Poor" on SUS grade rankings.
- **Partially Achieved:** The repository scored a "OK" on SUS grade rankings.
- **Largely Achieved:** The repository scored a "Good" on SUS grade rankings.
- **Fully Achieved:** The repository scored a "Excellent" or "Best Imaginable" on SUS grade rankings.

4.3.3.2 KA2: System Stability

This area refers to how often the system becomes unavailable or offline. It is assumed that if the service is unstable, both educators and students will have problems attending their needs. It is measured through exploration of the website and tools that monitor if the website goes offline. For this research we used UptimeRobot (UPTIMEROBOT, 2022).

- **Not Achieved:** The repository is not available for use.
- **Partially Achieved:** The repository is functioning, but it is unstable, being offline many times during the week. Users can easily find bugs while navigating.
- **Largely Achieved:** The repository is stable, and the occurrence of bugs is minimal.
- **Fully Achieved:** The repository is stable and always available (24/7). Pages do not take long to load.

4.3.3.3 KA3: OER Diversity

This area refers to how diverse the OER collection is. It is assumed that a repository with a higher diversity in its collection will have a higher chance of having a resource capable of attending the needs of its users. This area can be measured through exploration of the website repertoire.

- **Not Achieved:** The repository does not have enough OERs to be operational.
- **Partially Achieved:** The repository has a simple repertoire of OERs, both in topics covered and in a variety of file formats (usually just text or just video files). Only a single sharing license is applied to all files. The OERs have the same target audience.
- **Largely Achieved:** There may be OERs for different target audiences or using different sharing licenses. The repository's repertoire has a greater diversity of OERs, covering languages, themes, types of interactivity, different target audiences. It is already possible to find OERs of different formats.
- **Fully Achieved:** It is possible to analyze the collection of OERs and determine which are the most common and the least common types. The repository is able to display the themes, languages, types of interactivity, target audiences most approached, and proposes incentives for categories neglected by its content producers.

4.3.3.4 KA4: OER Quality

This area refers to how much attention the repository pays to the quality of its available OERs. It is assumed that a repository with OERs of higher quality will have better chances of attending the needs of its users. This area can be measured through exploration of the website repertoire.

- **Not Achieved:** There is no concern about the quality of the OERs uploaded.
- **Partially Achieved:** The quality of uploaded OERs starts to be a concern.
- **Largely Achieved:** The repository has a highlighted section for OERs considered to be of high quality, facilitating the access for new users.
- **Fully Achieved:** There is a specific team to check the quality of new entries. Filters are imposed to avoid defamatory, slanderous content or any content that can be classified as "fake news".

4.3.3.5 KA5: Metadata Structure

This area refers to how the metadata is structured. It is assumed that repositories with better structures will facilitate target audiences reaching their OERs. This area can be measured through exploration of the website repertoire. The metrics were based on the essential attributes by (FERLIN *et al.*, 2010).

- **Not Achieved:** The repository has no metadata structure.
- **Partially Achieved:** The repository has a metadata structure, but it does not follow a validated pattern and is not visible to the users.
- **Largely Achieved:** The metadata structure needs to at least address the OER name, author name, central theme and which sharing license is being used.
- **Fully Achieved:** The metadata structure is well defined and observable by users. All future insertions are guided by it. In addition to having the author's name, central theme and which sharing license is being used, it contains other more specific attributes (language, interactivity type, target audience, dependencies are examples).

4.3.3.6 KA6: User Traffic

This area refers to how many users visit the repository per day/month. It is assumed that repositories with higher user traffic will have higher chances of spreading an OER to a larger amount of students, which is desirable to educators. User Traffic is measured through tools that analyse website traffic. For this research we used Similarweb (SIMILARWEB, 2022). The threshold numbers were based on average accesses of recognized repositories as (OPENCOURSEWARE, 2022) and (MERLOT, 2022) as examples.

- **Not Achieved:** The repository is not available for use.
- **Partially Achieved:** The repository has less than 10.000 accesses per month.
- **Largely Achieved:** The repository has less than 100.000 accesses per month.
- **Fully Achieved:** The repository has more than 100.000 accesses per month.

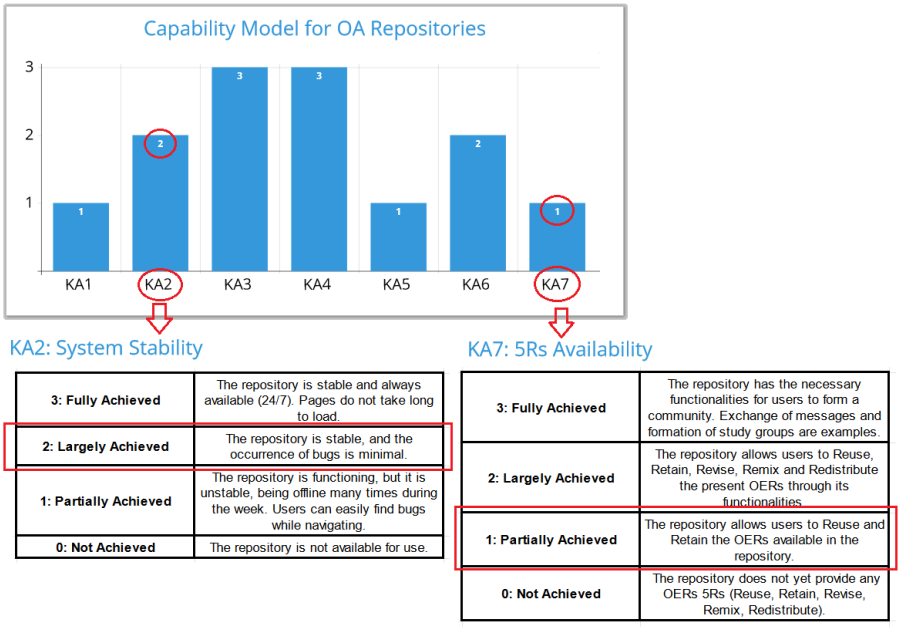
4.3.3.7 KA7: 5Rs Availability

This area refers to how many of the OER 5Rs are covered by the functionalities of the repository. The capability of a repository in sharing OERs is directly related to its 5Rs covering. This area is measured through exploration of the website functionalities. We chose this order of achievements based on the scale of CC licenses coverage (COMMONS, 2019). Reuse and Retain are present in even the most basic open licenses, followed then by Revise, Remix and Redistribute.

- **Not Achieved:** The repository does not yet provide any OERs 5Rs (Reuse, Retain, Revise, Remix, Redistribute).
- **Partially Achieved:** The repository allows users to Reuse and Retain the OERs available.
- **Largely Achieved:** The repository allows users to Reuse, Retain, Revise, Remix and Redistribute the OERs through its functionalities.

- **Fully Achieved:** The repository has the necessary functionalities for users to establish a community. Exchange of messages and formation of study groups are examples. The repository not only allows all 5Rs but also encourages and facilitates their usage inside their own domain.

Figure 22 shows an example of assessment using the Capability Model for OA repositories. In this example the repository reached a "Largely Achieved" capability level for the **KA2: System Stability**, meaning that its repository is stable with minimal bug occurrences. For the **KA7: 5Rs Availability** the repository reached a "Partially Achieved" capability level, meaning that the repository only allows users to Reuse and Retain the OERs available in the collection, but not providing tools or licenses for revising, remixing or redistributing.



3: Fully Achieved	The repository is stable and always available (24/7). Pages do not take long to load.
2: Largely Achieved	The repository is stable, and the occurrence of bugs is minimal.
1: Partially Achieved	The repository is functioning, but it is unstable, being offline many times during the week. Users can easily find bugs while navigating.
0: Not Achieved	The repository is not available for use.

3: Fully Achieved	The repository has the necessary functionalities for users to form a community. Exchange of messages and formation of study groups are examples.
2: Largely Achieved	The repository allows users to Reuse, Retain, Revise, Remix and Redistribute the present OERs through its functionalities.
1: Partially Achieved	The repository allows users to Reuse and Retain the OERs available in the repository.
0: Not Achieved	The repository does not yet provide any OERs 5Rs (Reuse, Retain, Revise, Remix, Redistribute).

Figure 22 – Example of an rated repository in the Capability Model for OA Repositories

On Figure 23 we can see another example of CM-OAR application. These are the results for the MECRED repository:

- **KA1 - System Usability:** The repository scored a "Good" on SUS grade rankings.
- **KA2 - System Stability:** The repository is stable and always available (24/7). Pages do not take long to load.
- **KA3 - OER Diversity:** There may be OERs for different target audiences or using different sharing licenses. The repository's repertoire has a greater diversity of OERs, covering languages, themes, types of interactivity, different target audiences. It is already possible to find OERs of different formats.

- **KA4 - OER Quality:** The repository has a highlighted section for OERs considered to be of high quality, facilitating the access for new users.
- **KA5 - Metadata Structure:** The metadata structure is well defined and observable by users. All future insertions are guided by it. In addition to having the author's name, central theme and which sharing license is being used, it contains other more specific attributes (language, interactivity type, target audience, dependencies are examples).
- **KA6 - User Traffic:** The repository has less than 10.000 accesses per month.
- **KA7 - 5Rs Availability:** The repository has the necessary functionalities for users to establish a community. Exchange of messages and formation of study groups are examples. The repository not only allows all 5Rs but also encourages and facilitates their usage inside. their own domain.

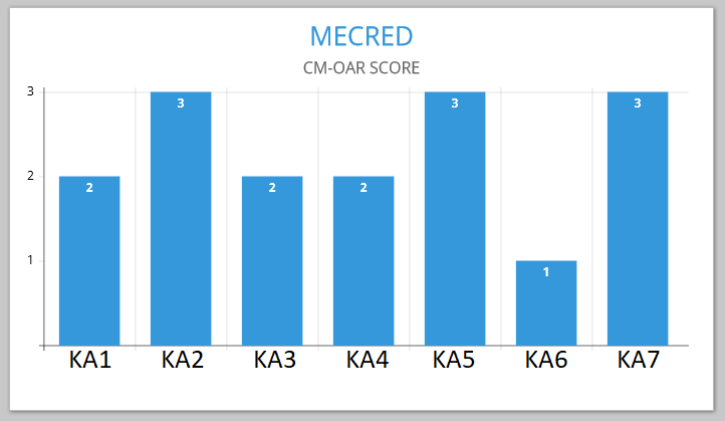


Figure 23 – MECRED Capability Levels on the CM-OAR Model

4.4 Final Remarks

In this chapter we described the development process of the CM-OAR model, detailing how it evolved through three iterations and presenting its final version. In Chapter 5, we discuss the three surveys performed through the development process of CM-OAR.

CHAPTER

5

CM-OAR Model: Application and Evaluation

In this chapter we present the surveys used as input to design the CM-OAR Model. A survey can be described as data or information acquisition about the characteristics, actions or opinions of group of people representing a target population. Its often related to an explanatory, exploratory or descriptive purpose (FREITAS *et al.*, 2000). The surveys were done in different stages of the development process, and their impact was described in Chapter 4. Each survey supported the improvements from the model previous iterations, used as "Research Input" on the process prescribed by DSR (Figure 20, Chapter 4). At the end, the CM-OAR Model was applied in three Brazilian repositories.

This chapter is organized as follows. In Section 5.1 we present an exploratory research, aimed to educators, with the objective of relating maturity levels and common characteristics of OA Repositories. In Section 5.2 we present an overall evaluation of three OA Repositories made by postgraduate students (EDUCAPES, MECRED and Escolas na Rede). In Section 5.3 we present an usability evaluation of the same three repositories, using a System Usability Scale (SUS) questionnaire (BANGOR *et al.*, 2008). In Section 5.4 we present the conclusions and discuss the application of CM-OAR Model on the same three repositories.

5.1 Survey 1

5.1.1 Context and Objectives

This survey was applied at the first phases of the model development. At that time, the project was focused into Maturity Models and OER Sharing Initiatives. For the purpose of the research, we defined as a "sharing initiative" any educational institution (universities, schools, profit or non profit educational organizations) or individual (teachers, courseware designers) that had an intent or project of sharing OERs.

The first version of the CM-OAR Model was developed based on the literature research

described in Chapter 2, and on the maturity models retrieved on the SMS described in Chapter 3.

The targeted audience were educators and teachers with previous knowledge on OERs. The objectives of this survey were:

1. Quantify how much prior knowledge an average educator had with respect to Capability Maturity Models.
2. Identify how the educators would relate various characteristics of Sharing Initiatives to Maturity Levels.

5.1.2 Results

Next, we summarize the most important issues and results of the survey. A total of 15 educators participated answered the survey. Questions are available at <shorturl.at/rsvF6>; they were presented in Portuguese, to reduce research bias into their transcription.

5.1.2.1 Respondent Characterization

Figure 24 present the previous knowledge of the respondents on OER (A), Sharing Initiatives (B) and Maturity Models (C). On each question there was a brief description of the topic, following by the inquire of how the respondents would describe their knowledge on that topic. There were four possible answers:

1. I have no knowledge on the subject.
2. Minimum Knowledge: I have some knowledge on the subject, but never have put into practice.
3. Academic Knowledge: I have knowledge on the subject and applied its concepts at scientific researches.
4. Professional Knowledge: I have knowledge on the subject and applied its concepts at professional level.

OER was the topic were the respondents were most acquainted. As can be seen in Figure 24, 46.7% had Minimum Knowledge, 33.3% had Academic Knowledge and 20% had Professional Knowledge on the topic. The respondents knowledge into Sharing Initiatives was also summarized: 60% had Minimum Knowledge and 40% had Academic Knowledge.

On the other hand, the Maturity Model topic was the most unfamiliar to the respondents. As can be observed, more than a half of the educators (53.3%) had no previous knowledge on the topic, 26.7% had Minimum Knowledge, 13.3% had Academic Knowledge and only 6.7% had Professional Knowledge.

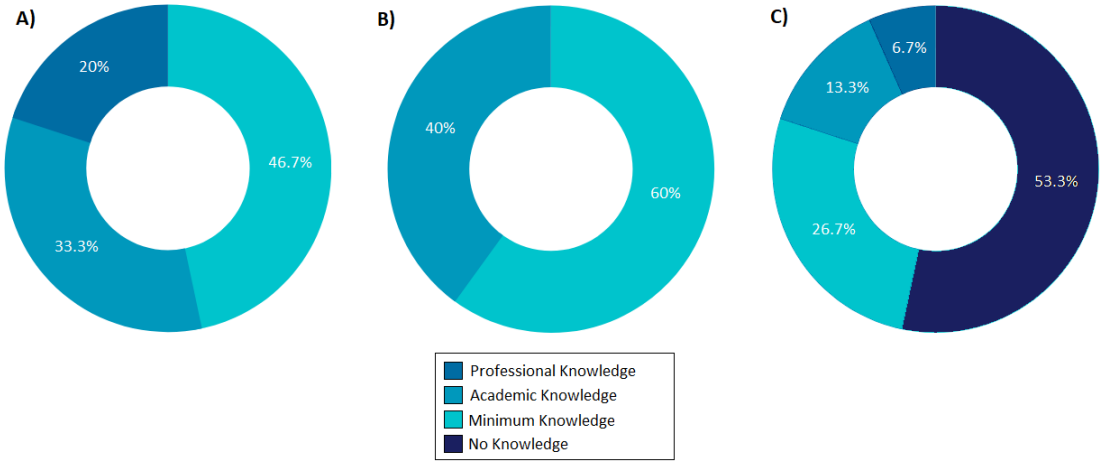


Figure 24 – Respondents previous knowledge on OERs (A), Sharing Initiatives (B) and Maturity Models (C)

5.1.2.2 Maturity Levels and Sharing Initiatives Characteristics

For the purpose of the first survey, we defined four Maturity Levels for Sharing Initiatives. In each question the respondent had to choose which level should better represent a Sharing Initiative characteristic. The levels were defined as follows:

- **Level 1 - Minimum:** the Sharing Initiative presents the minimum characteristics to keep operating.
- **Level 2 - In Development:** the Sharing Initiative has as objective to expand its operation.
- **Level 3 - Consistent:** the Sharing Initiative aims to achieve consistency in its operation.
- **Level 4 - Optimization:** the Sharing Initiative aims to optimize their processes in order to assure better performance in its operation.

The characteristics were defined adopting the concepts of CMMs and OERs described in Chapter 2, and Educational CMMs retrieved on the SMS in Chapter 3. We grouped them into six topics as follows:

- **Platform Functionalities:** every characteristic related to the set of functionalities that the platform of the Sharing Initiative offers to its users.
- **Platform Quality:** every characteristic related to the improvements and maintenance of the platform technical qualities.
- **Metadata Structure:** every characteristic related to the implementation and use of metadata structures to identify OERs in the platform.

- **OER Collection:** every characteristic related to the diversity of the platform collection.
- **OER Quality:** every characteristic related to the maintenance and observation of the OER quality in the platform collection.
- **Platform Advertisement:** every characteristic related to the advertisement of the Sharing Initiative.

Next we discuss the results retrieved on the characteristics in each of these topics.

5.1.3 Characteristics Evaluation

Platform Functionalities

In this topic we defined the following characteristics (CA):

- **CA1:** The platform of the Sharing Initiative allows its users to visualize and download the available OERs.
- **CA2:** The platform of the Sharing Initiative allows its users to upload their own OERs.
- **CA3:** The platform of the Sharing Initiative allows its users to rate and comment on the available OERs.
- **CA4:** The platform of the Sharing Initiative allows its users to form communities. Message exchanging and group studies are examples of such functionalities.

Figure 25 shows the results for Platform Functionalities. CA1 had divergent results among the respondents, as five of them had related with the lowest of the maturity levels (1) and six related with the highest (4). On CA2, two respondents selected maturity level 1, four selected maturity level 2, four selected maturity level 3, and five selected maturity level 4. The majority of the respondents considered that CA3 appropriate level was 3. Finally, in CA4 no respondent related it in level 1, three related to level 2, five related to level 3, and seven related to level 4. Table 6 presents the average maturity level for each CA.

Table 6 – Platform Functionalities CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	2.5
CA2	2.8
CA3	3
CA4	3.2

Platform Quality

In this topic we defined the following characteristics (CA):

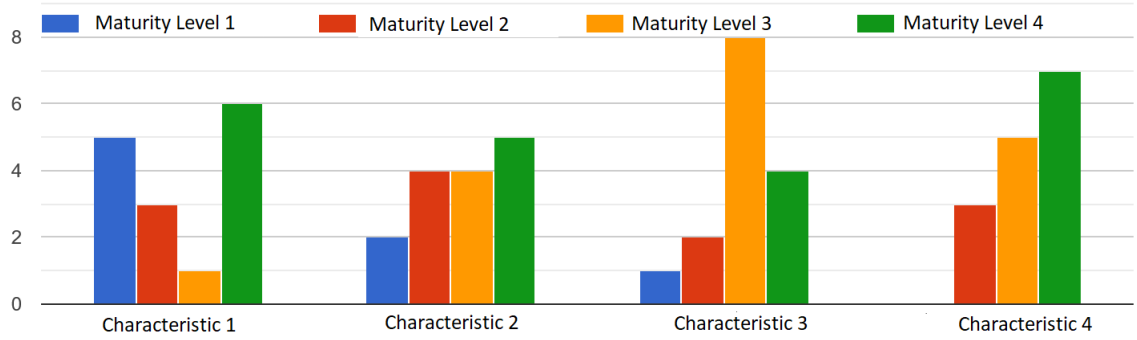


Figure 25 – Platform Functionalities characteristics and their related Maturity Levels according to respondents

- **CA1:** There is a concern about the platform quality. Procedures have been developed to assess and correct possible execution errors. There is still instability cases.
- **CA2:** The platform is unstable, with low quality control.
- **CA3:** The platform quality monitoring process is well defined, with a specific team responsible for it.
- **CA4:** The platform is stable and always available (24/7).
- **CA5:** There are periodic routines to correct undesirable behaviors of the system and to assess the quality of new functionalities.
- **CA6:** The platform development team starts to evaluate its implementations, aiming to find the most efficient method to introduce new functionalities.
- **CA7:** There are continuous process improvements due to feedback, testing ideas and innovative technologies. Innovations rise through research incentive.

In Figure 26 and Table 7 we can see the full results for this topic. CA1 and CA4 had spread answers across all levels. In particular, CA4 had the smallest difference between the number of respondents choosing level 1 and level 4, with three and six occurrences respectively. The lowest average was CA2, with the majority of the respondents relating it to Maturity Level 1. CA3, CA5, CA6 and CA7 were the ones with highest averages, being mostly related to maturity levels 3 and 4.

Metadata Structure

In this topic we defined the following characteristics (CA):

- **CA1:** The platform has a metadata structure, but it is not visible to the user.

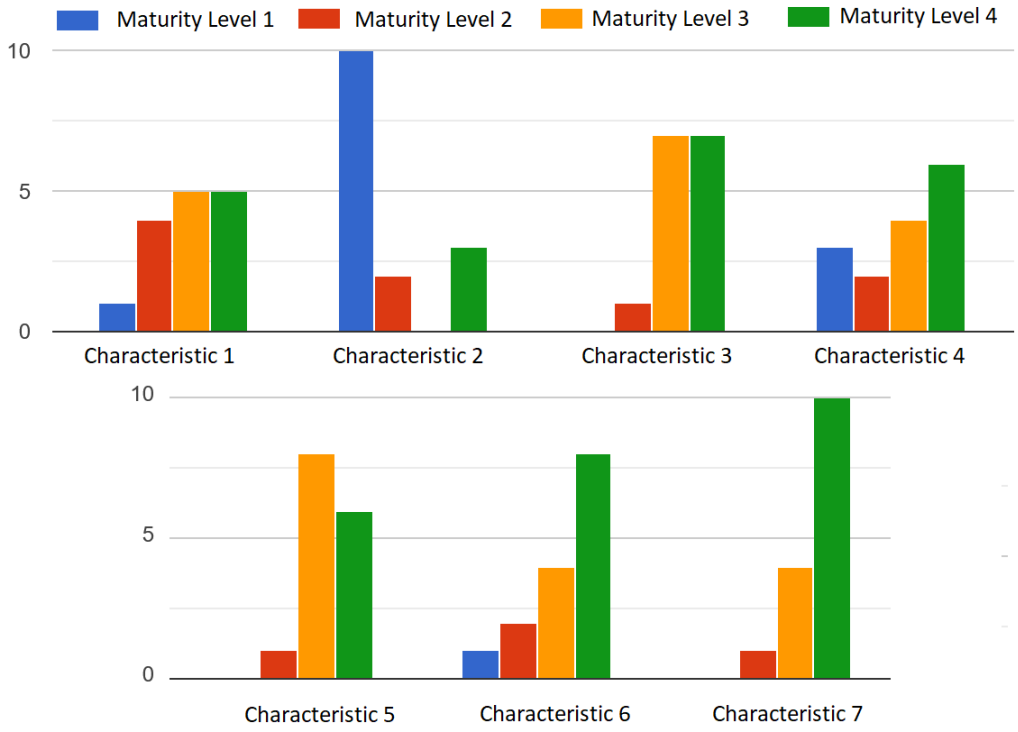


Figure 26 – Platform Quality characteristics and their related Maturity Levels according to respondents

Table 7 – Platform Quality CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	2.9
CA2	1.7
CA3	3.4
CA4	3
CA5	3.3
CA6	3.2
CA7	3.6

- **CA2:** The metadata structure is well defined and observable to the users. Every new insertion is guided through it.

- **CA3:** The metadata structure needs have fields to address the OERs name, authors name, main theme and which sharing license is being used.

According to Figure 27, CA1 had the majority of the respondents relating it to Maturity Level 1, with 9 answers. According to Table 8, CA2 had the highest average with a 2,9 score. Finally, in CA3 the most predominant option was Maturity Level 2, with 7 occurrences.

OER Collection

In this topic we defined the following characteristics (CA):

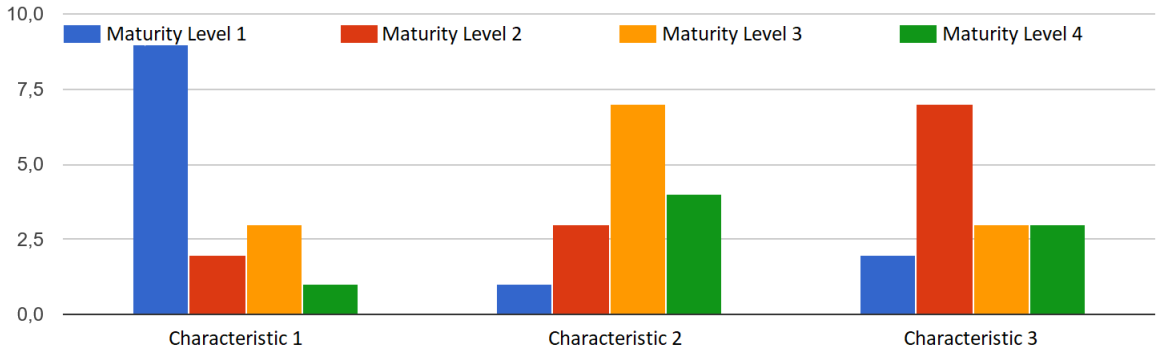


Figure 27 – Metadata Structures characteristics and their related Maturity Levels according to respondents

Table 8 – Metadata Structures CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	1.7
CA2	2.9
CA3	2.4

- **CA1:** The platform has a simple collection, both in topics covered and in the diversity of file formats (normally only text files or video files).
- **CA2:** Only one sharing license is applied to every submission.
- **CA3:** The OERs share the same target audience.
- **CA4:** The platform has a simple collection, but it already covers different themes inside the same area.
- **CA5:** It is possible to find OER from different format files, but the approach is majorly expository.
- **CA6:** There are OERs for different target audiences or using different sharing licenses.
- **CA7:** The platform collection possesses larger OER diversity, covering different languages, topics, interactivity types and target audiences.
- **CA8:** The initiative has means to know which topics, languages, interactivity types and target audiences are approached the most, and encourages its users to share OERs from the most neglected categories.

In this topic, CA2 and CA3 were the ones with lowest averages, having the highest number of responses in Maturity Level 1, with nine and six occurrences respectively. CA4 and CA5 were the ones with the highest number of occurrences in Maturity Level 2, with eleven and eight responses respectively. CA6, CA7 and CA8 were the ones with highest averages. CA8 was the one with most answers in one level, eleven in Maturity Level 4. CA1 was the most

controversial one, with three levels possessing the same amount of answers, level 1, 2 and 3 with five respondents each. These results can be seen in Figure 28 and Table 9.

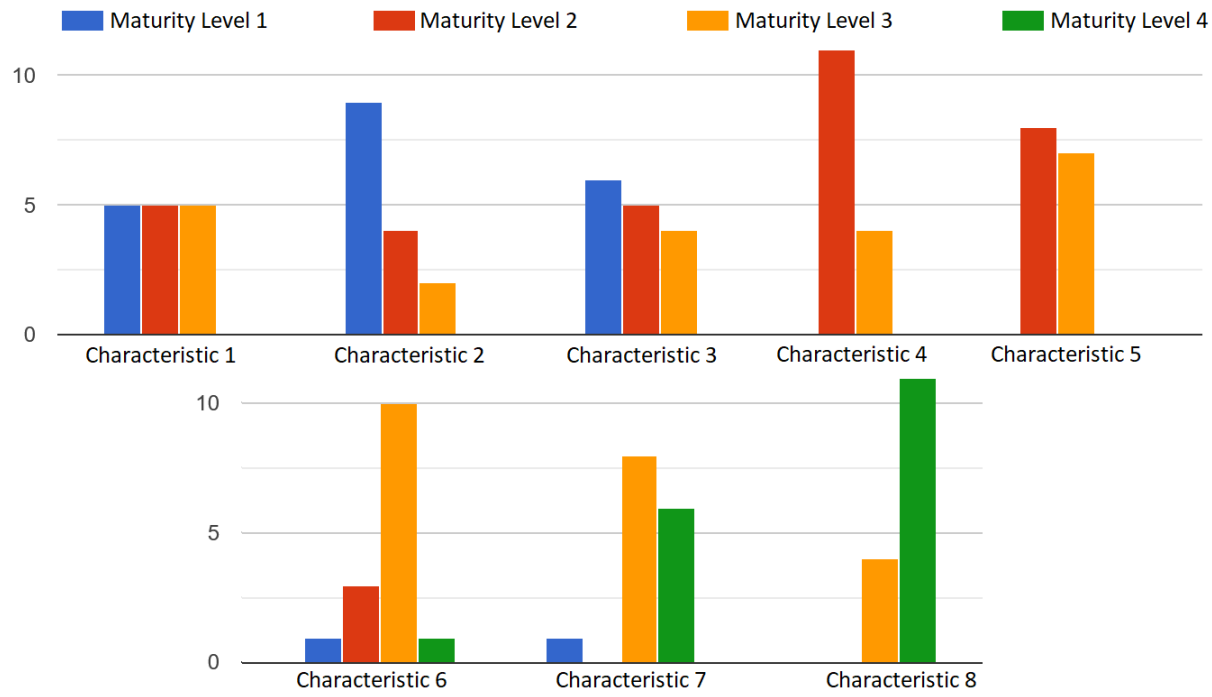


Figure 28 – OER Collection characteristics and their related Maturity Levels according to respondents

Table 9 – OER Collection CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	2
CA2	1.5
CA3	1.8
CA4	2.2
CA5	2.4
CA6	2.7
CA7	3.2
CA8	3.7

OER Quality

In this topic we defined the following characteristics (CA):

- **CA1:** There is no concern regarding the quality of uploaded OERs.
- **CA2:** There is a small concern regarding the quality of uploaded OERs.
- **CA3:** There is a specific team assessing the quality of new insertions. Filters are imposed to avoid defamatory content or fake news.
- **CA4:** The initiative is recognized for its effort into assessing the quality of its OERs.

Figure 29 and Table 10 summarize the results for this topic. Maturity Level 1 was the option with most respondents in CA1, with eleven occurrences. CA2 had the majority of its respondents in Maturity Level 2, with ten occurrences. Both CA3 and CA4 had the majority of its respondents between levels 3 and 4, being the highest averages of the topic.

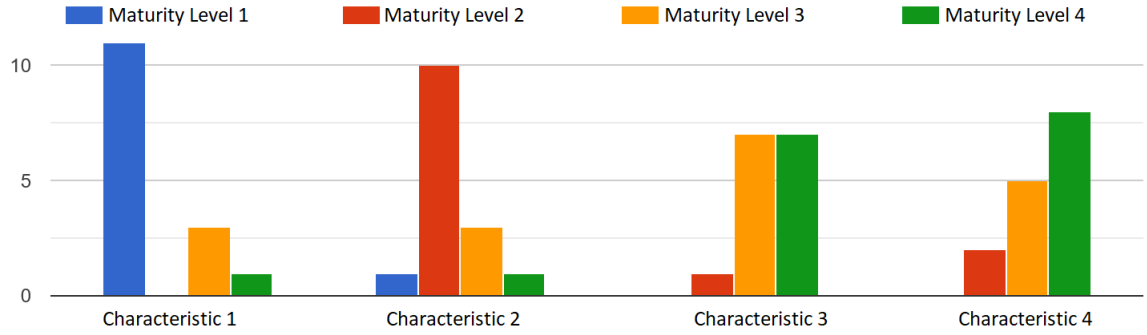


Figure 29 – OER Quality characteristics and their related Maturity Levels according to respondents

Table 10 – OER Quality CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	1.6
CA2	2.2
CA3	3.4
CA4	3.4

Platform Advertisement

In this topic we defined the following characteristics (CA):

- **CA1:** There is no effort into the advertisement of the initiative.
- **CA2:** There is a minimum effort into the advertisement of initiative, but nothing that can constitute a campaign.
- **CA3:** Processes aiming at the advertisement of the initiative start to appear, often resulting into alliances with bigger educational portals, promoting URL access links.
- **CA4:** There is a specific team responsible for the advertisement and expansion of the initiative. The objective is to improve the reach of the initiative and open education as a whole.
- **CA5:** The initiative has partnerships with universities, the industry and other types of institutions, encouraging the development and use of its materials to improve technical and professional capacities.

In this topic, CA1 was the one with lowest average, with the majority of its respondents in Maturity Level 1, eleven answers. CA2 predominant option was Maturity Level 2, with also 11 respondents. CA3 had most of its respondents between levels 2 and 3, with an average of 2,7. CA4 and CA5 were the ones with highest averages, the first one having nine respondents in Maturity Level 3, and the second one with 12 respondents in Maturity Level 4. These results are shown in Figure 30 and Table 11.

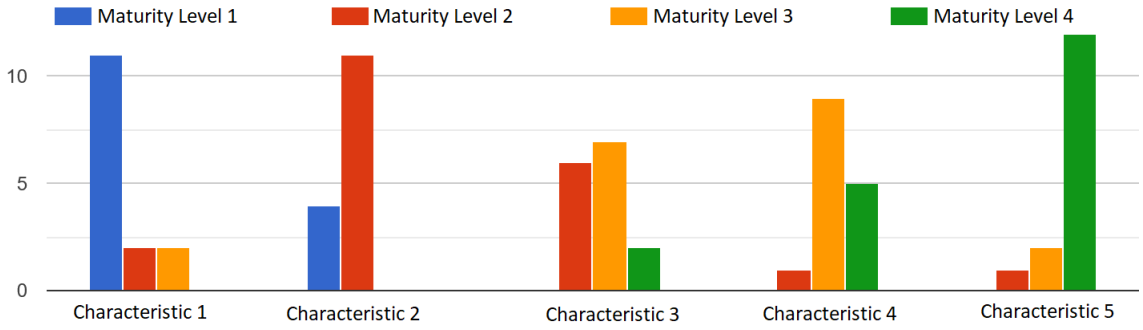


Figure 30 – Platform Advertisement characteristics and their related Maturity Levels according to respondents

Table 11 – Platform Advertisement CAs average maturity, according to respondents.

Characteristic	Average Maturity Level
CA1	1.4
CA2	1.7
CA3	2.7
CA4	3.2
CA5	3.7

5.1.4 Conclusions

The first observation of Survey 1 lies on the profile of the respondents. As noticed, most of them had never been exposed to CMMs and only a fifth of them had professional or academic knowledge. The second observation is a consequence of the first one. Many characteristics had conflicting results where respondents had difficulty to relate essential aspects of Sharing Initiatives to the minimum maturity level (1).

CA1 from Platform Functionalities is an example of this behavior. The characteristic stands for “The platform allows its users to visualize and download the available OER”, one of the fundamental premises of any OERs sharing initiative, appearing in every OA repository definition. However, for most of the respondents, this CA does not belong to the Maturity Level 1 (Minimum).

The same behavior can be seen in CA1 from OER Collection. The characteristic is “The platform have a simple collection, both in topics covered and in the diversity of file formats (generally only text files or video files)”. Six respondents considered that the CA should related

to maturity level 2 or higher, implying that an OA repository could work on a minimum standard without a "simple collection".

Actually, this highlights a difficulty of the theme: how to better translate the whole concept of MMs to an OER setting. As could be seen in Survey 1, at first glance the definition of MMs can be difficult and complex, so we opted for a more straightforward approach to reach these educators. The next survey present a new version of the CM-OAR Model, but with a decrease in scope: the OA Repositories Capability Model.

5.2 Survey 2

5.2.1 Context and Objectives

The second survey was applied after changing the scope of the project: instead of a Maturity Model for Sharing Initiatives we are now dealing with a Capability Model for Open Access Repositories. The respondents were students of a *Computer Technology Applied to Education* graduate course, and they had to evaluate three OA Repositories: MECRED, EDUCAPES and Escolas na Rede.

Each respondent executed the following steps:

1. Create an original OER of his/her area of interest.
2. Explore the three target repositories and publish that OER in each of them.
3. After acceptance of the publication, search for that OER on that same repositories.
4. Rate his/her experience in each repository with respect to the following qualities:: ease of usage, OER diversity, OER quality, metadata structure and amount of functionalities.
5. Finally, answer if in the future he/she would like to use the repositories again.

The purpose of these steps was to simulate the common usage of an OA repository and the qualities being rated reflects the assessed categories of the new CM for OA repositories. Finally, the objective was to discover if the repositories that had better evaluated qualities were the same ones where the respondents would like to use again. The results are discussed on the next section.

5.2.2 Results

A number of 212 respondents rated the qualities of each repository. The qualities could be rated from 1 to 5, with 1 being the less desirable score and 5 being the better one. Due to

time constraints and students dropouts from the discipline, 191 respondents chose their favorite repository and answered the final two questions.

Figure 31 shows the results for *Ease of Usage* for the analyzed repositories. EDUCAPES had the highest results with 115 respondents categorizing it as score 5 and 60 respondents as score 4. MECRED had the majority of the answers on scores 5, 4 and 3, with 71, 64 and 44 respondents respectively. Finally, Escolas na Rede had the overall lowest scores, with 71 rating their Ease of Usage as 1 and only 16 rating it as a 5.

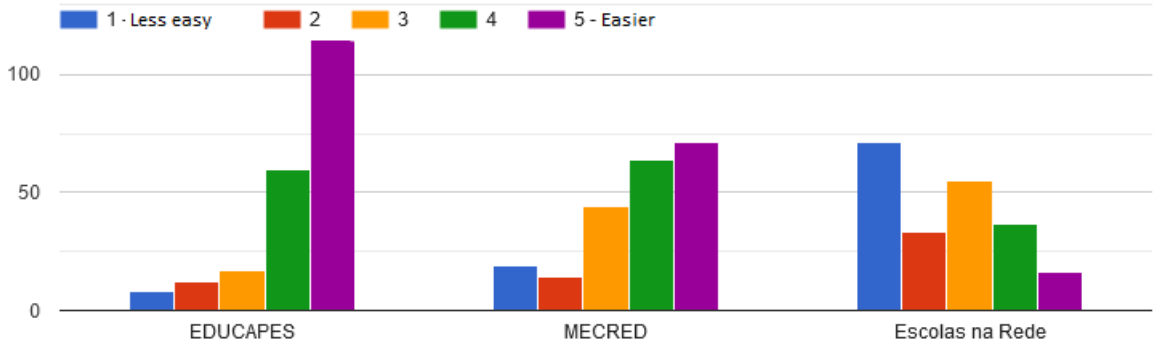


Figure 31 – Respondents on the ease of usage of the analyzed repositories.

In figures 32 and 33 we can observe the answers for the characteristics *OER Diversity* and *OER Quality*. EDUCAPES had similar results in both OER Diversity and OER Quality, where the majority of the respondents classified it with a score 5 in these topics. Although slightly above on OER Quality, MECRED also scored similar results in both topics, with the majority of the respondents divided between 5, 4 and 3 scores. Ultimately, Escolas na Rede had the lowest scores among the three repositories, but holding a higher average on quality than on diversity.

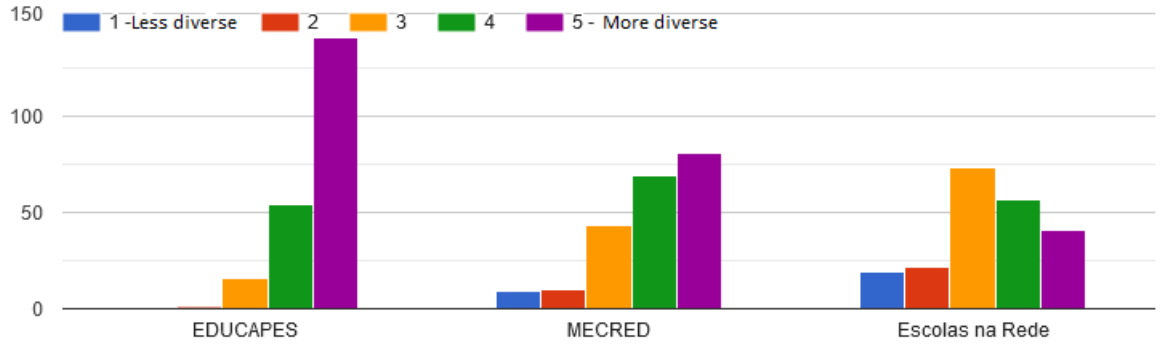


Figure 32 – Respondents on the OER diversity of the analyzed repositories.

Metadata Structure (Figure 34) and *Amount of Functionalities* (Figure 35) had similar results across the respondents. In both of them, EDUCAPES had the highest scores with the

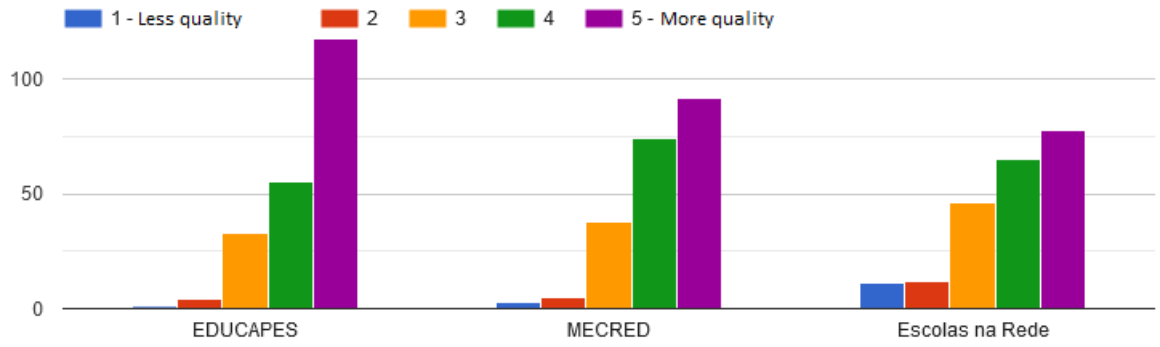


Figure 33 – Respondents on the OER quality of the analyzed repositories.

majority of the answers as 5 (116 for metadata and 105 for functionalities). On MECRED, the most of the respondents were splitted between 4 and 5 scores. Escolas na Rede had most of its answers in between scores 3, 4 and 5 among those two topics.

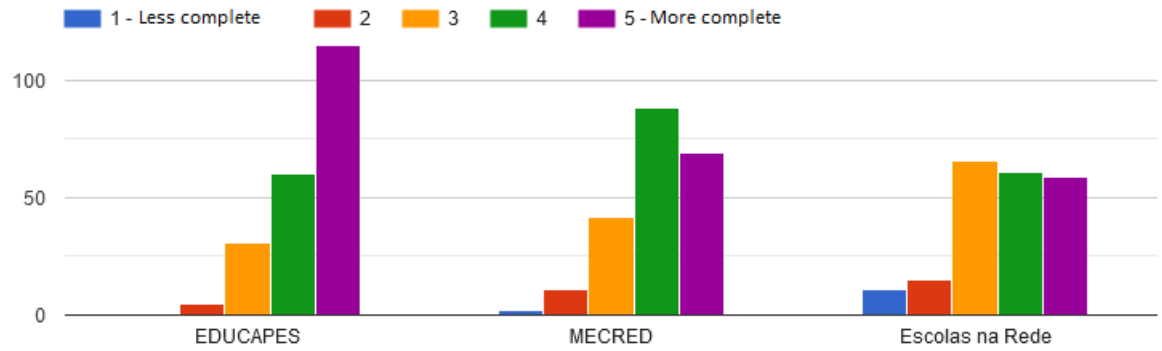


Figure 34 – Respondents on the metadata structure of the analyzed repositories.

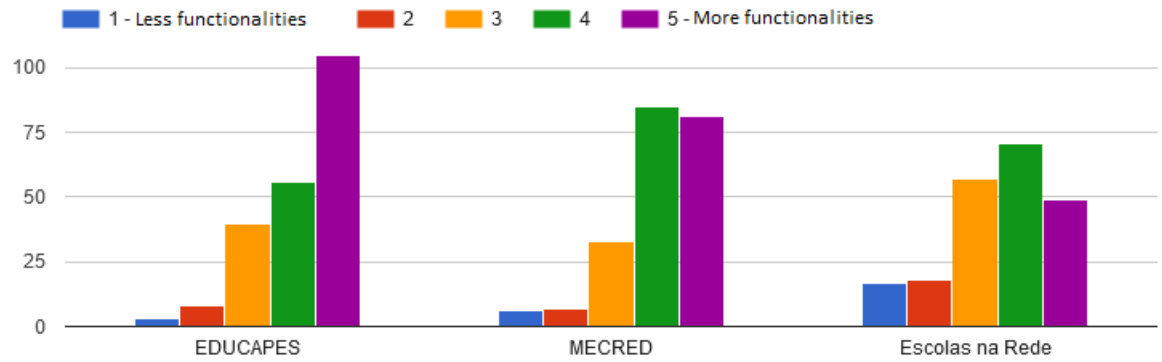


Figure 35 – Respondents on the amount of functionalities of the analyzed repositories.

Table 12 summarizes the results. As can be observed, EDUCAPES had the highest

averages when compared to the other repositories, with the highest scores in each of the qualities analyzed. MECRED came on second on each one of the qualities, achieving its highest score with OER Quality. Escolas na Rede had the lowest scores on every quality, with Ease of Usage being the worst result among all assessments. Finally, the difference between the Final Average for the highest rated (EDUCAPES - 4,34) and the lowest rated (Escolas na Rede - 3,39) was over a point.

Table 12 – Average score for each analyzed repository qualities.

Repository	Ease of Usage	Diversity	Quality	Metadata	Functionalities	Final
EDUCAPES	4,23	4,57	4,35	4,35	4,19	4,34
MECRED	3,73	3,96	4,16	3,99	4,07	3,98
Escolas na Rede	2,5	3,37	3,88	3,67	3,55	3,39

At the end of the course, the students had to choose their favorite repository and answer some questions (Figures 36 and 37). On MECRED, 29 out of the 30 respondents answered positively that they would like to return to the repository another time on both occasions. EDUCAPES had the largest number of answers (148), with 141 respondents stating that they would like to use it in the future to share an OER and 140 to search for OERs. Finally, Escolas na Rede had the lowest amount of answers (13), with 11 students positively answering the first question and 12 the second one. Comparing the total number of answers, 77.5% chose EDUCAPES as their favourite repository, followed by 15.7% that opted for MECRED and 6.8% for Escolas na Rede. The study had a total amount of 219 answers.

Figure 36 – “In the future, would you use this repository to share an OER of your authorship?”

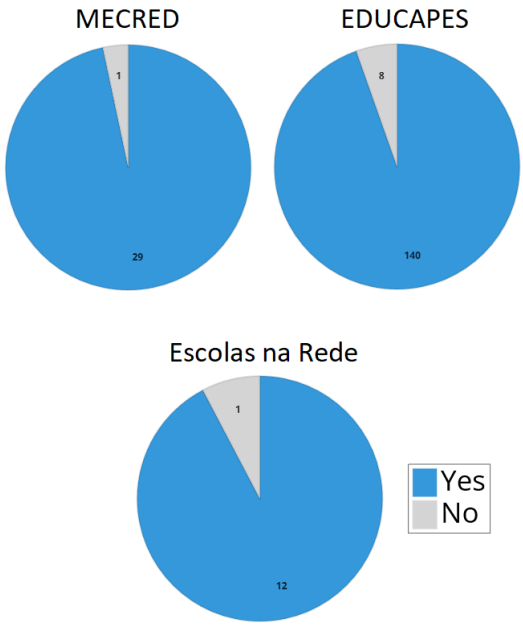


Figure 37 – "In the future, would you use this repository to search for an OER of your interest?"

5.2.3 Conclusions

The results of Survey 2 indicate a difference between the scores of the three assessed repositories. EDUCAPES had the best results in all qualities, followed by MECRED, and lastly Escolas na Rede, which had the lowest results on every quality. This ranking was also noticed on the final assessment, where EDUCAPES was chosen as the preferred one for the majority of the respondents, followed by MECRED and Escolas na Rede respectively. These results reinforced the idea that the higher the results of a repository on these qualities, the greater the chances that the repository will please its target audience: students in search of OERs and educators sharing their educational resources for free. Survey 2 helped to support the consolidation of our Capability Model, its results were used to validate if the chosen qualities were enough to define how capable a OA repository is.

5.3 Survey 3

5.3.1 Context and Objectives

The third survey was applied at the final phase of the model development. The project had already shifted to the Capability Model for Open Access Repositories, in an attempt to reduce the barrier to people unfamiliar with maturity models, and enabling the maintainers to focus on improvement points that they find more important. At the first versions of the model, the usability of the repositories had not been taken in consideration. However, the results of Survey 2 pointed out the need of considering "usability" as part of the model being developed. Therefore, a SUS Questionnaire (BANGOR *et al.*, 2008) was applied in order to assess the usability of

the targeted OA repositories. Additionally, Survey 3 was also important to understand how the same respondents would rate, in terms of importance, a selected number of qualities of a OA Repository. Each quality represents one of the process areas of CM-OAR.

Survey 3 was targeted to the same profile of respondents from the Survey 2: educators and graduated students in Computing Applied to Education. The 34 students had previously used the target repositories (MECRED, Escolas na Rede and Educapes) to search and share their own OERs. The main objectives of Survey 3 were the following:

1. To rate in a scale of importance, each one these OA Repository qualities: System Stability, System Usability, OER Diversity, OER Quality, Metadata Structure, User Traffic, and 5Rs Availability.
2. To evaluate the usability of the three OA Repositories that were considered in our previous validation: MECRED, Escolas na Rede and Educapes.

A total of 7, 11 and 14 respondents evaluated MECRED, Escolas na Rede and Educapes repositories respectively. Every respondent from Survey 2 was invited to participate and evaluate their favorite repository, but due to time constraints their participation rate was lower at Survey 3. All 34 respondents participated on the assessment of the qualities from objective 2 at the end. The results are summarized next.

5.3.2 Results

5.3.2.1 Importance Scale

The respondents needed to rate, in a scale of importance, several qualities of OA repositories:

'Based on your overall experience with OER repositories, rank the importance of each one of this characteristics:'

- **System Usability:** how difficult is to use the repository.
- **System Stability:** how often the repository is available and online.
- **OER Diversity:** how diverse the OER collection is.
- **OER Quality:** how much attention the repository pays to the quality of their available OERs.
- **Metadata Structure:** how the metadata is structured.
- **User Traffic:** how many users visit the repository per day/month.
- **5Rs Availability:** how many of the OER 5Rs are covered by the repository functionalities.

Each quality relates with a category from the proposed CM-OAR Model. The respondents had five possible answers, an scale from 1 to 5, where '1' means 'Low Importance' and '5' means 'High Importance'.

Figure 38 presents the results for all the targeted qualities.

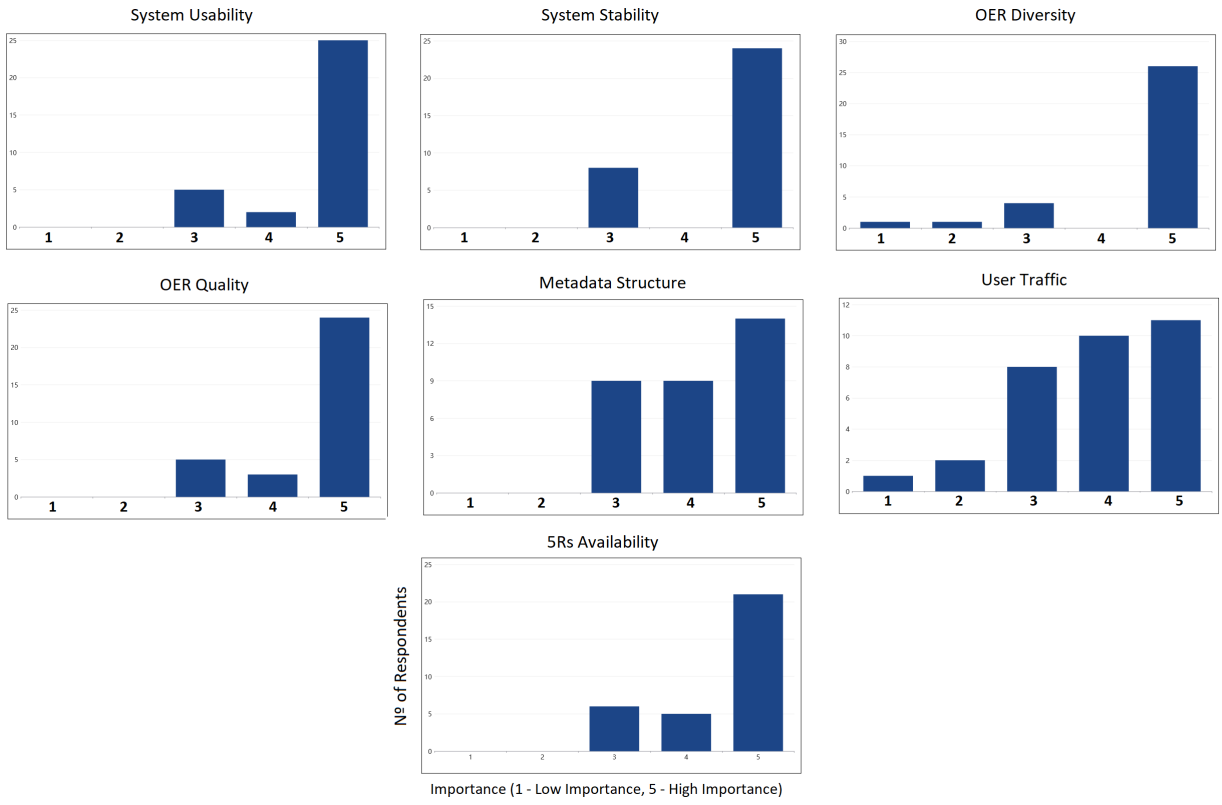


Figure 38 – System Usability, System Stability, OER Diversity, OER Quality, Metadata Structure, User Traffic and 5Rs Availability importance according to respondents.

Regarding 'System Usability quality, no respondents rated the quality as being importance 1. Five of them rated it as importance 3 and two rated as importance 4. Finally, 25 respondents rated the quality as of importance 5. On the 'System Stability' chart, we noticed that the majority of the respondents, 24, also assessed the quality as of importance 5.

'OER Diversity' had 1 respondent classifying it as importance 1, but in both 'OER Diversity' and 'OER Quality' more than 20 respondents classified them as importance 5.

'Metadata Structure' had their responses spread through importance 3, 4 and 5. In both 3 and 4 alternatives, nine responses were retrieved. Importance 5 was opted by 14 of the respondents. The quality with the most variance of answers was 'User Traffic', where every alternative was selected by at least one respondent. Importance 1 was selected one time, Importance 2 two times, Importance 3 eight times, Importance 4 ten times and Importance 5 eleven times. Finally, '5Rs Availability' had answers close to 'OER Quality' and 'System Stability', six answers at importance 3 and five answers at importance 4, but the majority, 21, of the respondents classified it as importance 5.

In Table 13 we show the average importance, according to the respondents, of each one of the researched repository qualities. As can be seen, 'System Usability' had the highest average with 4,63 points and 'User Traffic' had the lowest score, with an average of 3,88 points. Although the difference between the highest and lowest average is 0,75, the contrast is lower for other qualities, some of them distancing by less than 0,1 point. This indicates that, despite some qualities having higher importance, the difference between them is not that high for the respondents.

Table 13 – Average importance score for each quality according to respondents.

Quality	Average Importance
System Usability	4,63
System Stability	4,50
OER Diversity	4,53
OER Quality	4,59
Metadata Structure	4,16
User Traffic	3,88
5Rs Availability	4,47

After assessing the importance of usability by our respondents, we applied the SUS Questionnaire to the three repositories considered in our research (MECRED, Escolas na Rede and Educapes).

5.3.2.2 SUS Questionnaire

In its original version, SUS questions were written in English, but due to the profile of our respondents the questions were translated to Portuguese. In Table 14, we present the SUS original questions and the respective translation:

Each statement was rated from 1 to 5 (Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree) based on on the respondents experience operating the system. To calculate the score the following rules must accomplished (BANGOR *et al.*, 2008):

1. Odd numbered ID questions: subtract one from the user response.
2. Even numbered ID questions: subtract the user responses from 5.
3. Add up and multiply the value by 2.5.

At the end, each respondent have a score that varies from 0 to 100. The final score of each respondent is presented in Figure 39. The average score for each one of the targeted repositories is also shown at the end of each table.

As noticed, Educapes had the highest average score (76,6), followed by MECRED (74,1) and Escolas na Rede (66,7). Educapes and MECRED also had the highest individual score (97,5), while Escolas na Rede had the lowest (25).

Table 14 – SUS questions and their Portuguese adaptation

ID	English
1	I think that I would like to use this system frequently.
2	I found the system unnecessarily complex.
3	I thought the system was easy to use.
4	I think that I would need the support of a technical person to be able to use this system.
5	I found the various functions in this system were well integrated.
6	I thought there was too much inconsistency in this system.
7	I would imagine that most people would learn to use this system very quickly.
8	I found the system very cumbersome to use.
9	I felt very confident using the system.
10	I needed to learn a lot of things before I could get going with this system.
ID	**Portuguese**
1	Eu acho que gostaria de usar este repositório com frequência.
2	Eu acho o repositório desnecessariamente complexo.
3	Eu achei o repositório fácil de usar.
4	Eu acho que precisaria de ajuda de uma pessoa com conhecimento técnico para usar o repositório.
5	Eu acho que as várias funções do repositório estão muito bem integradas.
6	Eu acho que o repositório apresenta muita inconsistência.
7	Eu imagino que as pessoas aprenderão como usar esse repositório rapidamente.
8	Eu achei o repositório atrapalhado de usar.
9	Eu me senti confiante ao usar o repositório.
10	Eu precisei aprender várias coisas novas antes de conseguir usar o repositório.

Respondent	Score
1	95
2	67,5
3	27,5
4	75
5	92,5
6	87,5
7	52,5
Average	**74,1**

MECRED

Respondent	Score
1	52,5
2	85
3	82,5
4	77,5
5	35
6	25
7	80
8	40
9	85
10	87,5
11	97,5
Average	**66,7**

Escolas na Rede

Respondent	Score
1	92,5
2	85
3	67,5
4	42,5
5	82,5
6	50
7	95
8	92,5
9	97,5
10	80
11	80
12	45
13	82,5
14	80
Average	**76,6**

Educapes

Figure 39 – MECRED, Escolas na Rede and Educapes individual scores

In order to analyse SUS scores, (BANGOR *et al.*, 2009) proposed a grading score (Figure 40) for its interpretation. Although 0-100 system leads researchers to interpret the scores as percentages, Bangor *et al.* affirms that they are not. Their research estimated that a final score of 68 would be the average and the lowest one of the acceptable results. According to the grading scores, Escolas na Rede would be the only repository at the margin between 'not acceptable' and 'acceptable' result, reaching an 'OK' status. With an average final score higher than 74, MECRED and Educapes results were categorized as 'GOOD'.

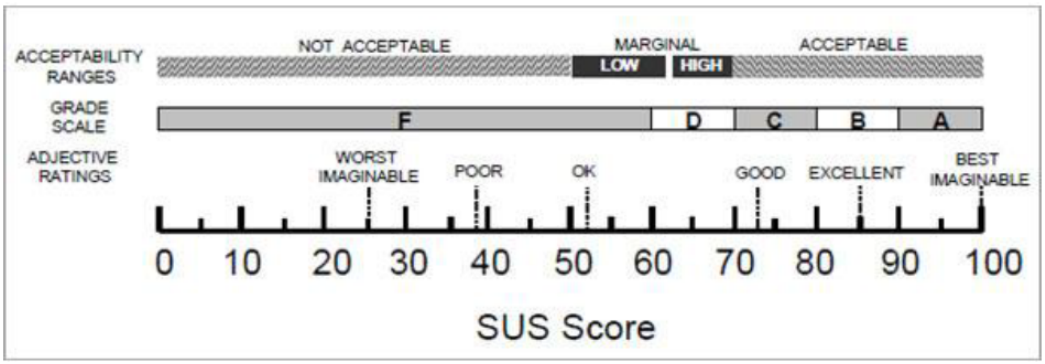


Figure 40 – Grade rankings of SUS scores from (BANGOR *et al.*, 2009)

Although their final averages scores all reached an almost positive status, each one of the repositories had at least one respondent categorizing their experience as 'POOR', which indicates that a good user experience is not always guaranteed in such repositories.

5.4 Conclusions

In this chapter we summarized the results of three surveys conducted to validate and evolve the CM-OAR model. All of them were used as "Research Input" on the our development method detailed in Chapter 4.

Results from Survey 1 were used in the second iteration of the development process, which marked the transition of a Maturity Model to a Capability Model. This change was done to reduce the entry barrier of the model and allow the repositories maintainers to focus on the improving the areas that they find more important.

Survey 2 was used to validate if repositories with higher capability levels were also the preferred ones by the target audience: students looking for OERs and educators sharing their educational resources for free. The results were used in the third iteration, and showed that, although our chosen characteristics at that time could define how capable a OA repository was, it also pointed out that usability should be assessed in its own key area.

In Survey 3 we could observe the impact of the System Usability for the OA repositories common users. The first segment indicates the importance of Usability when compared to other OA repositories characteristics. This characteristic was considered the one with the highest importance among the respondents. The other ones scored similar but with smaller results, which corroborates the narrative that usability should be took into consideration when evaluating an OA repository.

Finally, in Figure 41 we display the capability scores for the chosen repositories. As can be seen, MECRED and EDUCAPES have higher results when compared to Escolas na Rede. MECRED has better scores in 5Rs Availability and OER Quality, while EDUCAPES User Traffic is higher than the other ones. Escolas na Rede scored the lower results in four key areas:

System Usability, OER Diversity, OER Quality and User Traffic.

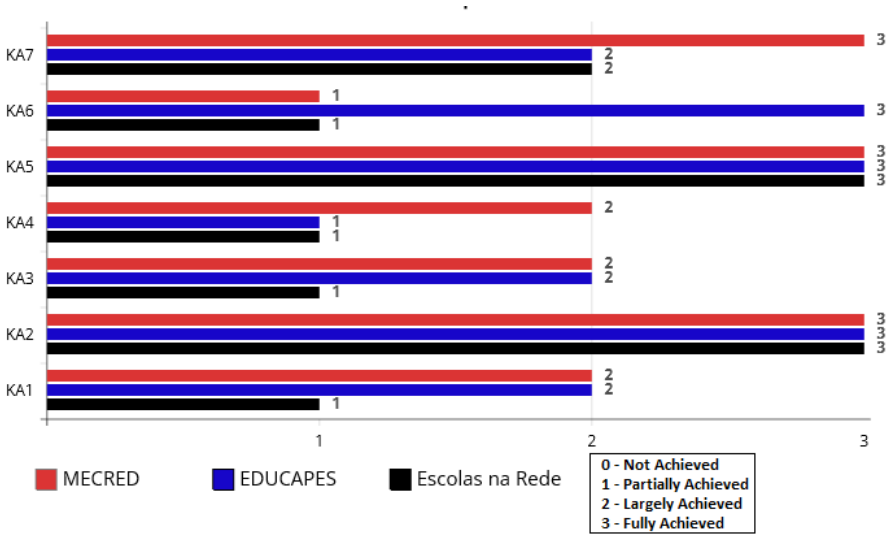


Figure 41 – Capability scores from the evaluated OA repositories

In the next chapter we summarize the main conclusions of our work, as well as the main perspectives for future work.

CHAPTER

6

Conclusions

In this Master's work we investigated OERs and its potential to improve education. We gathered the evolution of the movement through the years and the emergence of OA repositories as a mechanism to share resources to the public. One of the problems that these tools face is the lack of systematic processes to evidence the quality of their service to its potential users. In our work, we proposed a model to evaluate such repositories, providing benchmarks of improvement and points of comparison between the most successful ones.

Maturity models were examined with this purpose, as they are described as a way of controlling practices and processes that incrementally raise the quality of software development. But they are not necessarily tied to software development as they are also capable of being adapted to other areas of expertise. We performed a SMS to discover how these models were modified in order to better suit educational contexts. We found out that CMM (Paulk *et al.*, 1993), CMMI (TEAM, 2006) and SPICE (DORLING, 1993) were the most adapted models. One of the reasons for adaption was the excess of bureaucracy present in the original maturity models. Literature study, pilot testing, workshop and surveys were the most common methods of development. Finally, we noticed that no study was related to open educational resources, highlighting the importance and innovation of our work in this the area.

These observations were crucial to the development of our Capability Model for OA Repositories (CM-OAR) and were also reflected in our performed surveys. On Survey 1 (Section 5.1), we noticed the difficulty of the respondents when facing the technical definitions of maturity levels. We expect that the average user of our model does not need any previous knowledge on maturity and capability models.

Another challenge was how to adapt the processes and characteristics of OA repositories to the maturity setting. Although OA repositories are digital services, i.e., software that has repetitive development cycles, their educational processes are not repetitive or with clear beginnings and endings. Maturity models relies on repetition in order to provide the promised structured and

incremental improvements, OA repositories educational processes are not as repetitive to fit the maturity cycle. Taking into consideration these reflections, we decided to shift to a Capability Model, being strongly related to Maturity Models (the retrieved studies from the SMS often had both of them), but with simpler rules and easier to be adapted to the nature and needs of OA repositories. This representation also allows the organization to focus in which key areas they consider most important, creating individual paths to evolution and providing clear ways to compare with other repositories (TEAM, 2006).

The development of the CM-OAR Model was guided by a DSR (WINTER, 2008) inspired method of constant feedback and iterations. In each loop performed, we conducted exploratory surveys in order to validate and adapt the model. We ended with seven key areas of evaluation: System Usability, System Stability, OER Diversity, OER Quality, Metadata Structure, User Traffic, 5Rs Availability. Each of them was described as essential to assess the ability of an OA repository to provide its service. System Usability was the last one added to the list, often reminded by the survey respondents as one of the most important aspects of a repository when they needed to choose their preferred one. Our surveys reinforced the idea that, the higher the results of a repository on in the CM-OAR key areas of evaluation, the higher the chances for the repository to suit their target audience: students searching for OERs and educators sharing their coursewares for free. Additionally, three Brazilian OA repositories were evaluated using the Capability Model proposed: EDUCAPES, MECRED and Escolas na Rede.

6.1 Research Contributions

The main contribution of this work is the CM-OAR - Capability Model for OA Repositories. The model was proposed as an alternative to educational institutions that want to evaluate their own repositories, and once more repositories are evaluated, a showcase for educators and students to find the best ones in the community. Students can find more easily their resources of interest, educators can better spread their own knowledge to the target audience and maintainers can spot more clearly where to improve their own repositories. Encouraging the sharing and adoption of OERs not only improves the teaching of Computer Science, but also contributes to the formation of future citizens worldwide.

The results of our surveys are also contributions of this work. They were used to identify and rank the qualities that should be considered when categorizing an Open Access Repository. We also provided methods and metrics for evaluating each one of the proposed characteristics.

Finally, another contribution is the state-of-the-art of educational maturity models expressed in our performed SMS. We identified their inspirations, previous models and standards that influenced their design. Although some models pointed out which methods the authors used to designed them, several ones did not provide this information on their papers. This study was published in (OLIVEIRA; BARBOSA, 2019).

6.2 Research Limitations

This research was conduced aiming to avoid threats to validity, but some of its limitations are listed below:

1. Due to the COVID-19 pandemic, it was not possible to validate the proposed model in workshops, as commonly happened with other maturity and capability models. Experts in those models could indicate valuable points of improvement in our method. This step is important for a complete version of the Capability Model for OA Repositories.
2. CM-OAR was established mainly based on the feedback of students and teachers, but our development process still lacks the input of OA repositories maintainers. Their insight and experience could bring different points of improvement that the perspectives of teachers and students cannot fully cover.
3. Due to constraints of time, CM-OAR were only used to evaluate three OA repositories. For a better grasp of its potential there is a need of evaluating a larger number of open access repositories.
4. Although the respondents of Survey 2 and 3 had evaluated the characteristics of the three OA repositories, they did not applied the model themselves. It is necessary to promote the use of the CM-OAR Model to other educational experts in order to better understand its current limitations.

6.3 Future Work

Finally, regarding the perspectives for future work, we highlight the following areas:

1. **Model improvement:** the chosen method of design allows several iterations and rounds of improvement. The model must be not only evaluated by educators, but repository maintainers and students as well. These demographics are important to provide different perspectives that could be missed in this work. The assessment metrics could also be revised in this process.
2. **Evaluation of more repositories:** in this work we only evaluated three Brazilian repositories, in order to provide a preliminary validation of the CM-OAR Model. As highlighted before, the model needs to be applied to different repositories, particularly the international ones. This effort should also highlight points of improvement for future versions of CM-OAR.
3. **Create a platform to present the evaluated:** once more repositories are evaluated, we intend to develop a platform to expose the results, presenting and comparing the repositories with higher capability levels.

4. **Development of a set of guidelines:** in order to provide independence for any user to apply the proposed model, a set of guidelines should be developed detailing how to assess each one of the proposed key areas.

6.4 Publications

Following we list the publications produced during the Master's work.

- DONAIRE GONÇALVES OLIVEIRA, RAUL; FRANCINE BARBOSA, ELLEN. Modelos de Maturidade em um Cenário Educacional: Um Mapeamento Sistemático. RENOTE. **REVISTA NOVAS TECNOLOGIAS NA EDUCAÇÃO**, v. 17, p. 478-487, 2019.
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- OLIVEIRA, RAUL; BARBOSA, E. F. Open Educational Resources for Software Engineering: an Overview. In: **XXIV Congreso Internacional de Informática Educativa, 2019**, Arequipa. Nuevas Ideas en Informática Educativa, 2019. v. Vol 15. p. 90-99.
- FIORAVANTI, M. L. ; OLIVEIRA, R. D. G. ; AVELLAR, G. M. N. ; OLIVEIRA, C. D. ; BARBOSA, E. F. .An Analysis of ProjectEdu: A Mobile Learning Application for Software Project Management Education. In: **International Conference on Human-Computer Interaction, 2019, Orlando. Learning and Collaboration Technologies. Ubiquitous and Virtual Environments for Learning and Collaboration. Cham: Springer International Publishing, 2019**. p. 37-54.

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