PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
SCHOOL OF ENGINEERING

NOTEMYPROGRESS: AN EDUCATIONAL TOOL TO SUPPORT LEARNERS SELF-REGULATION STRATEGIES IN MOOCS

RONALD ANTONIO PÉREZ ÁLVAREZ

Thesis submitted to the Office of Graduate Studies in partial fulfillment of the requirements for the Degree Doctor in Engineering Sciences

Advisor :
MAR PÉREZ SANAGUSTÍN

Santiago de Chile, January, 2020

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This thesis is dedicated to my wife Cindy Rebeca, and my daughters Rubí and Raily, and in memory of my father, Carmen Pérez Pérez.

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RESUMEN

A pesar de que se ha demostrado que la autorregulación es una de las habilidades claves para que los estudiantes sean exitosos en un Curso Masivo Abierto en Línea (Massive Open Online Courses - MOOCs), las plataformas donde se ofrecen los MOOCs actualmente (ej. Coursera, edX, Udacity, FutureLearn, MiriadaX) no ofrecen los mecanismos suficientes para apoyar las estrategias que utilizan los estudiantes para autorregularse. Además, las soluciones encontradas en la bibliografía dirigidas a apoyar dichas estrategias en MOOCs, son aún escasas. Además, las pocas soluciones existentes no han evaluado el impacto sobre la autorregulación de los estudiantes debido, en parte, a la falta de métricas e indicadores. Con el fin de contribuir a esta problemática, esta tesis propone el diseño y evaluación de una solución tecnológica que apoye las estrategias de autorregulación de los estudiantes en MOOCs. Para alcanzar este objetivo se definieron dos preguntas de investigación: (1) *¿Qué características deben considerarse para el diseño de una herramienta educacional que apoye las estrategias de autorregulación efectivas para el aprendizaje en MOOCs*?, (2) *¿Qué efecto tendría la herramienta educacional en las estrategias de autorregulación de los estudiantes y en sus logros*?. La principal contribución de esta tesis es la herramienta NoteMyProgress, una herramienta web diseñada como un complemento a las plataforma MOOCs para apoyar las estrategias de autorregulación de los estudiantes. El diseño de la herramienta NoteMyProgress siguió la metodología basada en el diseño (Design-based Research) y su impacto fue evaluado en un caso de estudio con dos MOOCs ofrecidos por la Pontificia Universidad Católica de Chile en la plataforma Coursera. Esta tesis también contribuye con: un análisis de las métricas y funcionalidades utilizadas por las soluciones actuales para apoyar la autorregulación; y 3 de casos de estudio donde se evalúa el diseño e impacto de NoteMyProgress en la estrategias de autorregulación de los estudiantes en un MOOC.

Palabras Claves: Tablero, Compromiso, Cursos Masivos Abiertos en Línea, Autorregulación del aprendizaje, Herramientas, Análitica del aprendizaje.

ABSTRACT

Although self-regulation has been shown to be one of the key skills for learners to succeed in a Massive Open Online Course (MOOC), the platforms which currently offer MOOCs (e.g., Coursera, edX, Udacity, FutureLearn, MiriadaX) do not offer sufficient mechanisms to support the strategies used by these learners for the purpose of self-regulation. In addition, the solutions found in the literature which aim to support such strategies in MOOCs remain scarce. Moreover, the few solutions that do exist fail to assess the impact on learner self-regulation which is due, in part, to a lack of metrics and indicators. In order to contribute to efforts to overcome this problem, this thesis proposes the design and evaluation of a technological solution that supports the self-regulation strategies of learners in MOOCs. In order to achieve this objective, two research questions were devised: (1) *What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs?* (2) *What effect would the educational tool have on the self-regulation strategies of learners and their achievements?* The main contribution of this thesis is the NoteMyProgress tool, a web tool designed to complement MOOC platforms by supporting the self-regulation strategies of learners. The design of the NoteMyProgress tool was undertaken in adherence to the Design-based Research approach following the Interactive Design Learning method and its impact was evaluated in a case study with two MOOCs that are provided by the Pontificia Universidad Católica de Chile on the Coursera platform. Further contributions of this thesis include: an analysis of the metrics and functionalities used by current solutions to support self-regulation; and the elaboration of three case studies which evaluate the design and impact of NoteMyProgress on the self-regulation strategies of learners in a MOOC.

Keywords: Dashboard, Learning Engagement, Massive Open Online Courses, MOOC, Self-regulated Learning, SRL, Tools, Learning Analytics.

Chapter 1

Introduction

This thesis is framed within the domain of technology enhanced learning (TEL) and, more specifically, the field of learning analytics tools and self-regulated learning (SRL) in Massive Open Online Courses (MOOCs). The primary motivation of this thesis is to explore the opportunities of deploying learning analytics tools to support learner SRL strategies in MOOCs while, simultaneously, collecting data to enhance understanding of how learners use these types of tools. This chapter describes the main concepts, terms, and definitions of SRL in MOOCs. Moreover, it outlines the reasons that motivated the thesis as well as the main challenges identified, research questions proposed, objectives, methodology used, main contributions, and impact of its results.

1. INTRODUCTION

1.1 Motivation

Massive Open Online Courses (MOOCs) have been considered one of the main disruptive trends in higher education and are widely recognized as a genuine learning alternative (Cooper & Sahami, 2013). At the end of 2018 there were more than 101 million people registered worldwide on MOOCs on platforms including Coursera, edX, Udacity, FutureLearn and MiriadaX (Shah, 2019). Given the growing demand for MOOCs, several studies have focused on enhancing understanding of the motivation of learners to enroll in these online courses. Such studies indicate that learners have a broad range of motivations and reasons for taking a MOOC, including: obtaining a certificate by passing the course, acquiring new knowledge, professional development, learning new skills, meeting new people, studying an area relevant to their academic research or studies, improving their English, prestige of the institution providing the course, curiosity for online courses, general interest, seeing it as a challenge or as fun or viewing it as an opportunity to satisfy a taste for learning, among others (Carlos Alario-Hoyos, Estévez-Ayres, Pérez-Sanagustín, Kloos, & Fernández-Panadero, 2017; Kizilcec & Schneider, 2015; Littlejohn, Hood, Milligan, & Mustain, 2016). However, and despite the different reasons behind the motivation of learners to take a MOOC, the majority of those who are initially motivated to complete the course fail to do so (Kizilcec & Schneider, 2015).

According to recent studies, learners who are able to self-regulate their learning achieve greater engagement in MOOC activities (Littlejohn et al., 2016) and are more successful in fulfilling their goals (Kizilcec, Pérez-Sanagustín, & Maldonado, 2017; Lee, Watson, & Watson, 2019; Siadaty, Gašević, Jovanović, Milikić, et al., 2012; Thirouard et al., 2015; Veletsianos, Reich, & Pasquini, 2016). For example, strategies such as *goal setting* and *strategic planning*, as well as *time management,* have a positive effect on performance and fulfillment of learner goals (Kizilcec et al., 2017; Lee et al., 2019; Veletsianos et al., 2016). Self-regulation skills are even more relevant in terms of undertaking a MOOC, which is characterized by the large-scale and heterogeneity of participant numbers, a lack of guidance from a tutor during the course, and the flexibility of schedules over time (Kizilcec et al., 2017). However, self-regulation is not an easy skill to develop and learners who enroll in MOOCs do not generally know how to self-regulate their learning in order to succeed in the course (Kay, Reimann, Diebold, & Kummerfeld, 2013; Laplante, 2013). Moreover, learners with lower levels of formal education have difficulties in developing these types of strategies. Specifically, prior research indicates that learners have difficulties with metacognitive SRL strategies—planning and organizing to reach their goals; and strategies related to resource management— time management, seeking help and organizing their study environment (Kizilcec & Halawa, 2015; Veletsianos et al., 2016).

In order to support learners in the self-regulation process, current MOOC platforms have been developing and implementing a number of different solutions. For instance, to encourage learners to remain on the course throughout its entire lifecycle and support them in enhancing their organization skills, the courses have a start and end date. Furthermore, MOOC platforms support certain cognitive strategies, such as: reviewing material and repeating evaluations (*rehearsal*); supporting metacognitive strategies through assessment activities (*self-evaluation*); viewing pending activities and progress in evaluations using charts and calendars (*self-monitoring*); and incorporating time estimations to perform activities (*time management*). For example, Coursera provides learners with a visual overview of the estimated time duration for each week, a time remaining function in videos and readings, and deadline schedules for activities. In turn, edX recently introduced a notes module where learners are able to make notes on texts and subsequently review and organize those notes. However, according to recent research, these mechanisms appear to be insufficient in providing feedback to participants on their individual learning processes as well as support related to SRL strategies (Davis, Chen, Jivet, Hauff, & Houben, 2016; Davis et al., 2017; Hew & Cheung, 2014; Taejung, Hyunjin, & Gayoung, 2016). Thus, it is necessary to develop new tools to support SRL in online platforms (Müller & Faltin, 2011; Shih, Chen, Chang, & Kao, 2010). Indeed, the study of how support can be provided to strengthen SRL strategies in MOOC platforms highlights the existence of multiple issues that remain pending and unresolved.

This thesis focuses on exploring these challenges by means of two main research questions: **(1) What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs?;** and **(2) What effect would the educational tool have on the self-regulation strategies of learners and their achievements?**

1.2 Challenges

This section reviews how current literature has addressed the challenges involved in the development of tools to support SRL in MOOCs.

1.2.1 Self-regulated learning strategies in MOOCs

There are different theoretical models for understanding the cognitive, metacognitive, motivational and emotional aspects that occur during the process of self-regulation (Panadero, 2017). Panadero (2017) analyzes and compares six of the most commonly used SRL models: Zimmerman (Zimmerman, 2000); Boekaerts (Boekaerts, 2011); Winne and Hadwin (Winne & Hadwin, 1998); Efklides (Efklides, 2011); Pintrich (P. Pintrich, 1999); and Hadwin, Järvelä and Miller (Hadwin, Järvelä, & Miller, 2011). Each of these models proposes a different definition of SRL. For instance, Pintrich (1999) defines self-regulation as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, intentions and behavior, guided and constrained by their goals and the contextual features of the environment". This model defines a number of strategies related to the different phases of a self-regulation process that facilitate their understanding and identification based on observable behavior : (1) *Cognitive strategies* (rehearsal, elaboration, organization), which refer to activities that learners perform in order to execute simple tasks such as memorizing or more complex tasks that require the understanding of information; (2) *Metacognitive strategies* (goal setting, planning, monitoring, self-evaluation), which refer to activities performed by learners in order to monitor and reflect on their learning process; and (3) *Resource management strategies* (help-seeking, time management, regulation and organization of the study environment), which refer to the activities performed by learners in order to manage their learning environment and available resources. These strategies are organized into four phases of SRL (forethought, planning and activation; monitoring; control; and reaction and reflection) and a number of different SRL strategies (P. Pintrich, 2000, 2004). The strategies are related to a separate set of specific strategies that learners adopt while self-regulating their learning which, in turn, facilitates the reporting of qualitative relationships between the observable behavior of learners within the MOOC or technological environments and specific strategies.

Research shows that SRL is an indispensable skill in online learning contexts (Adam, Alzahri, Cik Soh, Abu Bakar, & Mohamad Kamal, 2017) and that individuals who are able to self-regulate their learning are more likely to succeed in completing their respective courses (Kizilcec et al., 2017; Siadaty, Gašević, Jovanović, Pata, et al., 2012). Moreover, research suggests that SRL has a direct effect on the engagement of learners with the learning activities in the MOOC. For example, Littlejohn et al. (2016) found that learners with high SRL profiles tend to be more engaged in activities and materials associated with their individual needs or interests, whereas learners with low SRL profiles are more focused on completing all activities and assessments in order to simply obtain a certificate and complete the course. I.e., depending on the level of their self-regulation profile, learners engage more or less strategically in course activities and materials. Kizilcec et al. (2017) found that learners who repeatedly participate in metacognitive strategies, such as *goal setting* and *strategic planning*, are more engaged in the evaluations proposed in the course and more likely to review the material studied. Maldonado-Mahauad et al. (2018) found that learners with similar self-regulation profiles can engage in the course material in different ways. For example, learners with a high self-regulation profile tend to be more engaged in video reading (comprehensive learners), whereas other learners with the same self-regulation profile become more involved with the assessments (targeting learners). These studies provide empirical evidence that the self-regulation strategies of learners, as well as their self-regulation profiles, can have a positive impact on their overall engagement with the course.

To support SRL in MOOC settings, researchers have begun to study the behavior of learners. This line of research has focused on the study of how SRL occurs in online settings and which SRL strategies are related to course achievements (Kizilcec et al., 2017; Milligan & Littlejohn, 2016). For instance, Milligan and Littlejohn (2016) found that learners use SRL strategies such as *goal setting*, *self-efficacy*, and *help-seeking* in order to undertake a MOOC. Veletsianos et al. (2016) found that learners use strategies that allow them to manage their time in order to carry out activities in a MOOC (take time from other activities). They also found that learners use strategies such as *note-taking* to study outside the platform as well as seeking help from websites beyond the MOOC. Kizilcec et al. (2017) found that *goal setting* and *strategic planning* can help to predict the levels of achievement of personal course goals.

Therefore, research indicates that strategies related to *time management*, *the definition of learning objectives or goals, strategic planning,* and *note-taking* are critical for addressing learning in MOOCs.

Challenge 1]: *How to* ***identify and design*** *mechanisms to support the* ***SRL strategies*** *that have proven to be* ***most effective*** *for learning in MOOCs, such as time management, goal setting, strategic planning and note-taking?*

1.2.2 Tools to support self-regulated learning

In traditional online learning, there is a considerable body of research that proposes tools to support SRL strategies (Azevedo et al., 2009; Nussbaumer et al., 2014; Winne, Nesbit, & Popowich, 2017). However, few studies propose solutions to support SRL learning in MOOCs (Carlos Alario-Hoyos, Estévez-Ayres, Sanagustín, Leony, & Kloos, 2015; Davis et al., 2017; Pérez-Álvarez, Maldonado-Mahauad, & Pérez-Sanagustín, 2018). In recent years, a common trend with regard to the study of SRL has been to develop technological tools that serve both to develop skills while capturing data to enhance understanding of how SRL is developed. Panadero (2016) describes this trend as the third wave of SRL measures, in which the data analyzed is captured by tools designed specifically to support the strategies of learners that serve both as a scaffold and as a measure of SRL. For example, the Mastery Grid system (Guerra, Hosseini, Somyurek, & Brusilovsky, 2016) and Learning Tracker (Davis et al., 2016) are tools designed to support SRL strategies in the online environment.

Both simultaneously track data to measure their impact on the SRL of course participants. Davis et al. (2018) proposed a widget for the edX platform which supports learners in setting weekly goals and provides real-time feedback on the progress of their planning, thereby encouraging them to become more engaged with the course. Guerra et al. (2016) proposed an intelligence interface that supports learners in navigating learning content, enabling them to monitor course progress and compare their performance against that of their peers.

However, and despite the fact that this new trend resulted in an increase of technological solutions for supporting and measuring SRL in online environments, recent research indicates a substantial mismatch between the goal of the tool and its evaluation (Jivet, Scheffel, Specht, & Drachsler, 2018), in addition to severe weaknesses regarding the evaluation of existing learning analytics tools (Bodily & Verbert, 2017; Pérez-Álvarez et al., 2018; Pérez-Álvarez, Pérez-Sanagustín, & Maldonado-Mahauad, 2016; Schwendimann et al., 2017; Verbert et al., 2014). Accordingly, there is a gap in the literature in terms of studies that measure the impact of the learning analytics solutions for supporting SRL and their final purpose: promoting behavioral changes among learners. A review of current solutions is required to provide an overview of the current state of development of tools that support SRL (including an assessment of what can be gained from each solution and what these solutions have in common) in order to understand how to move forward in the area.

In this context, the development of new tools to support self-regulation in MOOC environments is a challenge that remains unresolved. A lack of evaluations in this field to measure the impact on SRL inhibits understanding as to what characteristics should be considered in the design of new tools and how self-regulation strategies that learners use with the interactions they perform with such a tool are related.

[Challenge 2]: *How to design and implement tools to support self-regulation time management, goal setting, strategic planning and note taking strategies?*
[Challenge 3]: *How to evaluate the effect of a tool that supports SRL strategies in a MOOC on the interaction of learners with the course, in addition to its relationship to self-regulation strategies?*

1.3 Research questions and objectives

This research proposal addresses two main research questions and three specific objectives.

1.3.1 Research question (RQ)

RQ1. What **characteristics** should be considered in the **design of an educational tool** that **supports** effective **self-regulation strategies** for learning in **MOOCs**?

Research question 1 aims to define a set of characteristics that will serve as the basis for the design of an educational tool that supports self-regulation strategies, which the literature shows are useful for learners undertaking a MOOC.

RQ2. What **effect** would the **educational tool** have on the **self-regulation strategies of learners and their achievements**?

Research question 2 aims to define a set of measures to assess the effect of the educational tool on the self-regulation strategies of learners and their achievements in the real learning context of MOOCs.

1.3.2 General objective

The general objective that guides this research in order to address the two research questions is as follows: *To propose and evaluate the design and implementation of a technological solution to support the self-regulatory strategies of learners in MOOCs and maximize their success in the course.*

1.3.3 Specific objectives research

The general objective is divided into specific objectives related to the posed research questions:

Objective 1. To design and implement a technological solution to support self-regulation strategies for learners learning in MOOCs.

Objective 2. To evaluate the technological solution developed in a MOOC in terms of its usability and adoption.

Objective 3. To evaluate the impact of the proposed technological solution on the behavior of learners on the platform and its relationship with self-regulation strategies, and their learning outcomes.

1.4 Methodology

This thesis followed the design-based research (DBR) approach (Reimann, 2011). This methodology combines empirical research on education with theories geared towards the design of learning environments. This methodological approach was selected for three main reasons: (1) to propose a technological solution driven by educational considerations; (2) to understand the impact of analytical frameworks and solutions in real environments; (3) for its interactive nature to adapt to the changing field of research which this project encompasses. This approach is composed of three phases: **phase 1**, analysis; **phase 2**, design and implementation; and **phase 3,** evaluation.

It should be pointed out that DBR is not a methodology in itself, so it can sometimes be applied less rigorously. To systematically and rigorously apply the DBR approach, we followed the interactive learning design (ILD) framework (Bannan-Ritland, 2003). This framework organizes the research process into four phases: (1) *Informed exploration*, which studies the needs, available theories and audience; (2) *Enactment*, which consists of the design of the technology; (3) *Evaluation of local impact*, which analyzes the impact of the technological intervention at the local level; and *(4) Evaluation of broader impact*, which considers the dissemination and discussion of findings and the adoption of the technological intervention by a wider audience. Figure 1-1 shows how the ILD framework was applied to the research project to design and evaluate the tool proposed.

In the *informed exploration phase*, we conducted three systematic literature reviews (Pérez-Álvarez et al., 2018, 2016) which focused on analyzing current tools designed to support SRL strategies in online learning environments. The literature reviews were conducted to address four research questions: ***1.** What are the theoretical SRL models considered as a theoretical framework for the design of the tool?;* ***2.** What are the SRL strategies that current tools aim to support?;* ***3.** What functionalities do current tools use to support self-regulation learning strategies in online environments?*; and ***4.** Which measures are proposed to evaluate the impact of the tool in the self-regulation of learners?* Moreover, the *informed exploration phase* also included the review of literature related to the analysis of the most effective SRL strategies for learners in MOOCs. The process and results of this phase are described in Chapter 2.

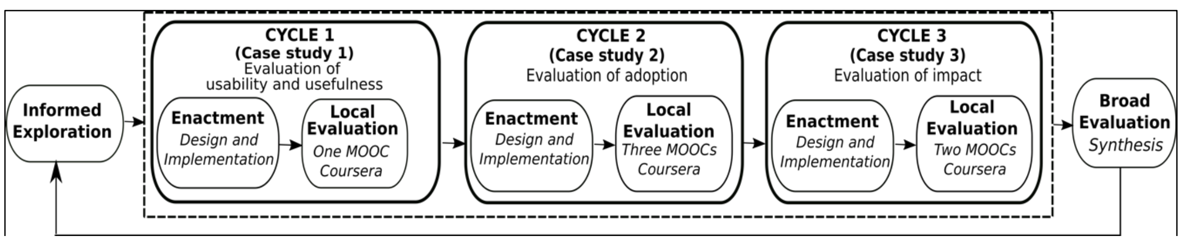

Figure 1-1: Cycles of the ILD framework undertaken in this thesis.

The *enactment phase* used results obtained in the *informed exploration phase* to define the design of the NoteMyProgress (NMP) tool. NMP is a web-based tool designed to support the SRL strategies of learners in MOOCs (Pérez-Alvarez, Maldonado-Mahauad, & Perez-Sanagustin, 2018) and can be used as a complement to MOOC platforms. Figure 1-1 shows that the *enactment phase* was performed in three different cycles of the IDL framework. In each cycle, a new version of the NMP tool was designed. The process and results of the three cycles are described in Chapter 3.

For the *evaluation of local impact phase,* we conducted three case studies (see Figure 1-1). Importantly, case studies provide valuable information regarding the influence of technology in a particular context to address "how" and "why" questions (Rowley, 2002; Yin, 2003). Furthermore, case studies are a useful means for monitoring a software project within an authentic situation and collecting data over time with a research objective (M. V. Zelkowitz & Wallace, 1998; M. V. Zelkowitz, 2009). Thus, case studies, beyond aiding learning about the educational situation itself, are important instruments for researchers to understand the implications of specific interventions in the context of a particular case (Stake, 1995). In the case studies outlined in this thesis, the object of study was the NMP. The three case studies were conducted in three different cycles in the ILD framework. In the first cycle (*Cycle 1*), case study 1 was conducted to assess usability and usefulness. This case study evaluated the tool in one MOOC on Coursera with 11 learners and 5 experts. The case study was driven by two questions: ***1.*** *What is the level of usability of the NoteMyProgress tool in a MOOC learning environment? and* ***2.*** *What are the perceptions regarding the implementation of NoteMyProgress as a tool to support self-regulation strategies of learners?* The results of this first cycle enhanced understanding of the level of usability of the tool and its usefulness in supporting SRL strategies for learners. Moreover, these results were used to improve and update the version of the tool. For the second cycle (*Cycle 2*), a second case study was conducted using the improved version of the tool. The objective of this cycle was to assess the adoption of the tool by learners in a real-world environment. Case study 2 evaluated the tool in three MOOCs on Coursera with 126 learners. The case study was driven by the research question: *What is the level of adoption of the NoteMyProgress tool in a MOOC learning environment?* Finally, in the third cycle (*Cycle 3*), a third case study was conducted to evaluate the impact of the third version of the NMP on the engagement of learners in SRL strategies, course content and performance. Case study 3 evaluated the NMP in two MOOCs on Coursera with 263 learners. The case study was driven by the research question: *How does the use of the NMP as a complement to a MOOC course affect the engagement of learners with course content and performance*. The process and results of the three case studies are described in Chapter 4.

Finally, in the *broad evaluation phase,* the main findings are discussed in conjunction with future work related to the research questions that drove this thesis, all of which are presented in the Chapter 5.

1.5 Contributions

This section summarizes the original contributions of the thesis. Table 1-1 introduces the overall contributions of the thesis as a whole and includes the following aspects: the relevant research question (subsection 1.3.1); the objective (subsection 1.3.3); a description of each contribution; the challenges it addresses (section 1.2); the chapter in which it is presented; and the type of publication in which each respective contribution was disseminated (subsection 1.6.1).

[Contribution 1] Analysis of the main functionalities of existing tools to support SRL in online learning. Due to a lack of literature on the current state of development of tools which support SRL (including research that looks into what can be gained from each type of solution and what these solutions have in common), this thesis has contributed with three systematic literature reviews. Specifically, these literature reviews have analyzed (1) the main functionalities of the selected tools, (2) the SRL models used as the theoretical umbrella, (3) the SRL strategies supported, (4) the visualizations used (in cases where they were used), and (5) the indicators used to support SRL in an online environment. In addition, the literature reviews also analyzed how existing proposals have measured the impact of the tools on SRL strategies. The results of this contribution have been published in three articles: (1) **[C1] - XLII Conferencia Latino Americana de Informática CLEI 2016**, (2) **[C4] - Thirteenth European Conference on Technology Enhanced Learning 2018**, and (3) **[J3] - Computer & Education Journal.** These publications form part of Chapter 2 of this thesis.

[Contribution 2] Design of a tool to support SRL strategies in MOOCs. This contribution outlined the process followed to design the NoteMyProgress (NMP) tool, which adhered to the design-based research (DBR) methodology. The design of the NMP was based on: (1) the lessons learned from the literature review process (Pérez-Álvarez et al., 2018, 2016), which helped in terms of analyzing the main features of the proposed tools to support SRL in MOOCs; and (2) the results of three case studies conducted in different MOOCs provided by the Pontificia Universidad Católica de Chile on the Coursera platform. The most relevant aspect of this NMP is that each of its functionalities was designed to support a particular self-regulated learning strategy. Moreover, it facilitated the *posterior* analysis of the impact of the NMP on SRL strategies. The design process of the NMP tool was published in two articles: (1) **[J1] - Journal of Universal Computer Science,** and **[C2] – Twelfth European Conference on Technology Enhanced Learning 2017.**

[Contribution 3] Identification and classification of student activities beyond the MOOC. In this contribution, the NMP tools were used to collect data about learner activities undertaken in and beyond MOOCs during a learning session. This contribution analyzed data from 572 learners in 4 MOOCs in order to understand: (1) what activities learners engage in beyond the MOOC, and (2) how these relate to their course performance. It analyzed the frequencies of learner activities in and beyond the MOOC in addition to any transitions between the activities. Subsequently, it analyzed the time spent beyond the MOOC content as well as the nature of this content. Finally, it predicted which transitions would produce the more accurate results in relation to the final grades of learners. The findings of this contribution were published in two articles that may serve certain future lines of research as a result of the work produced by this thesis: (1) [C6] - **First Learning Analytics Latin America Conference 2018**, and **[C7] - Fourteenth European Conference on Technology Enhanced Learning 2019**.

[Contribution 4] Tracking learner activities in Coursera MOOCs. This contribution provided an analysis of how to track learners undertaking a MOOC on Coursera in order to understand their behavior. Specifically, it analyzed the URL patterns extracted from 13 MOOCs offered by the Pontificia Universidad Católica de Chile on Coursera. These results aim to provide guidance to other researchers in evaluating the behavior of learners at MOOCs on Coursera and in applying learning analytics techniques. The results contributed to the design of the NMP tool and were published in **[C5] – Second International Conference MOOC-Maker 2018.**

Table 1-1: Summary of contributions of this thesis

					Publications									
					Journal			Conference						
	Specific Objetive	**Contribution**	**Challenge**	**Chapter**	**J1**	**J2**	**J3**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Research Question 1	**What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs?**													
	[Obj. 1]	**[Cont. 1]** Analysis of the main functionalities of existing tools to support SRL in online learning.	1,2	2			x	x			x			
	[Obj. 1]	**[Cont. 2]** Design of a tool to support SRL strategies in MOOCs.	1, 2	3	x				x					
	[Obj. 1]	**[Cont. 3]** Identification and classification of student activities beyond the MOOC.	1	5									x	x
	[Obj. 1]	**[Cont. 4]** Tracking learning activities in MOOC.	1	3								x		
	[Obj. 2]	**[Cont. 5]** A case study to analyze and to evaluate tool usability and adoption to support SRL in MOOCs.	2	3	x					x				
Research Question 2	**What effect would the educational tool have on the self-regulation strategies of learners and their achievements?**													
	[Obj. 3]	**[Cont. 6]** A case study to measure tool impact on SRL strategies, learner engagement and performance in MOOCs.	2	4		x								

[Contribution 5] A case study to analyze and evaluate tool usability and adoption to support SRL in MOOCs. As a part of the design process of the NMP tool, a case study was conducted to evaluate the usability and adoption of its first beta version. The aim of this contribution was to gain an understanding of which functionalities that had been added to the tools were subsequently used by learners. Furthermore, the contribution presented the results of the interaction of learners using visualizations which were used to provide feedback to learners. The results of this contribution were published in two articles: (1) [C3] - **Twelfth European Conference on Technology Enhanced Learning 2017,** and **[J1] - Journal of Universal Computer Science.**

[Contribution 6] A case study to measure tool impact on SRL strategies, learner engagement and performance in MOOCs. This contribution provides new empirical results and findings with regard to the relationship between engagement and SRL scaffolding. In addition, it proposes a set of novel indicators with which to measure the relationship between SRL scaffolding and engagement. Specifically, the contribution broadens the current body of literature by analyzing the question of: *How does the use of the NMP as a complement to a MOOC course affect the engagement of learners in course content and performance?* It compares the level of involvement with the course resources (frequency of interaction with video-lectures, assessment activities and supplementary materials) between learners who are using the NMP tool voluntarily and those who are not using it at all. In addition, the self-reported SRL profiles of learners were analyzed to understand whether they influence either general involvement with course content and/or the usage of the NMP. Accordingly, engagement was analyzed in a holistic manner by considering the frequency of interactions with both course content and the functionalities of the NMP that supports the self-regulation strategies, i.e., goal setting and strategic planning, self-evaluation, time management and organization. The results of this contribution are, at the time of writing, under review in the journal **[J2] IEEE Transactions on Learning Technologies.**

1.6 Impact

The contributions and main results of the case studies described in this thesis have an impact at different levels: (1) at an academic level, through scientific publications and collaborations with other institutions; and (2) at the national and international levels.

1.6.1 Academic impact

This thesis provides a number of key contributions by broadening current knowledge about the development of tools used to support SRL strategies in MOOCs as well as offering a number of solutions to measure their impact. First, the thesis provides an in-depth analysis of the design and evaluation of tools that support SRL in online learning by means of three systematic literature reviews. Such analysis affords a clearer overview of the considerations that should be taken into account in the design and evaluation of these tools used to support SRL strategies and outlines a set of lessons learned to facilitate future research into tools for supporting SRL. Second, the thesis presents the design process of a tool (NoteMyProgress) which is used to support SRL in MOOCs. This design process began with the selection of the SRL model and concluded with an evaluation of its impact on the self-regulation of learners. Consequently, future designs may utilize this process as a reference point on which to build their own work. Third, the thesis proposes novel indicators with which to measure the relationship between SRL scaffolding and engagement. The functionalities of the NMP are related to specific SRL strategies proposed in the SRL model of Pintrich (P. Pintrich, 1999, 2004) and these associations provide a new alternative for conducting evaluations beyond the usability and adoption of tools. Finally, the thesis gives rise to new empirical results to help researchers enhance their understanding of the relationship between learner engagement and SRL scaffolding.

The results of the impact of the thesis are reflected in the number of scientific publications undertaken, which in this case is a total of 10 (see Table 1-2), as well as the number of citations achieved since 2017 (40 citations).

Table 1-2: Summary of academic contributions of this thesis

	Article	Type of publication	Status
1.	**[J1] Pérez-Álvarez, R.,** Maldonado-Mahauad, J., Pérez-Sanagustín, M. (2018): Design of a tool to support self-regulated learning strategies in MOOCs, **Journal of Universal Computer Science (JUCS),** 24(8), 1090-1109	Journal	Published
2.	**[J2] Pérez-Álvarez, R.,** Maldonado-Mahauad, M., Sharma, K., Diego Sapunar-Opaso, D., Pérez-Sanagustín, M. (2019): Characterizing learners' engagement in MOOCs: An observational case study using NoteMyProgress tool for supporting self-regulation. **IEEE Transaction on Learning Technologies**. Under review.	Journal	Under review
3.	**[J3] Pérez-Álvarez, R.,** Jivet, I., Scheffel, M., Verbert, K., Pérez Sanagustín, M. (2019)**:** Self-regulated learning and learning analytics tools design: literature review. **Computer & Education**. In progress.	Journal	In progress
4.	**[C1] Pérez-Álvarez, R.,** Pérez-Sanagustín, M., & Maldonado-Mahauad, J. (2016): How to design tools for supporting self-regulated learning in MOOCs? Lessons learned from a literature review from 2008 to 2016. In Proceedings of the 2016 42nd **Latin American Computing Conference, CLEI 2016** (pp. 1–12).	Conference (full paper)	Published
5.	**[C2] Pérez-Álvarez, R.,** Maldonado-Mahauad, J. J., Sapunar-Opazo, D., & Pérez-Sanagustín, M. (2017): NoteMyProgress: A tool to support learners' self-regulated learning strategies in MOOC environments. In **Springer, Cham**, 460–466.	Conference (short paper)	Published
6.	**[C3] Pérez-Álvarez,** R., Pérez-Sanagustín, M., Maldonado-Mahauad, J. (2017): NoteMyProgress: Supporting learners' self-regulated strategies in MOOCs**. In. Springer, Cham,** 517-520.	Conference (demo)	Published
7.	**[C4] Pérez-Álvarez, R.,** Maldonado-Mahauad, J., and Pérez-Sanagustín, M. (2018): Tools to support self-regulated learning in online environments: literature review,. In **Springer, Cham,** 16–30.	Conference (full paper)	Published
8.	**[C5] Pérez-Álvarez, R.,** Pérez-Sanagustín, M., Maldonado, J. (2018): How to map learning activities through URLs? The case of Coursera platform, **II International Conference MOOC-Maker** (MOOC-Maker 2018), 2224, 25-34**.**	Conference (full paper)	Published
9.	**[C6]** Sapunar-Opazo, D., **Pérez-Álvarez, R.,** Maldonado-Mahauad, J., Alario-Hoyos, C., Perez-Sanagustín, M. (2018): Analyzing learners' activity beyond the MOOC. **First Conference on Learning Analytics in Latinamerica**, 120-127.	Conference (full paper)	Published
10.	**[C7]** Pérez-Sanagustín, M., Sharma, K., **Pérez-Álvarez, R.,** Maldonado-Mahauad, J., Broisin, J. (2019): Analyzing learners' behavior beyond the MOOC: an exploratory study. **Springer, Cham,** 40-54.	Conference (full paper)	Published

Publication of academic reports for international projects

Certain results and findings arising from this thesis have been reported on by means of publications and academic reports stemming from two international projects: (1) The MOOC-Maker project (funded by the Erasmus+ program from the European Commission), the main purpose of which was to develop capabilities for the construction of management capacities of MOOCs in higher education and conduct research into the initiatives undertaken (MOOC-Maker, 2018); (2) LALA project, the main purpose of which is to improve the quality, efficiency and relevance of higher education in Latin America in addition to building local capacities to design, adapt, implement and adopt learning analytics tools to improve academic decision-making processes (LALA, 2019). In turn, the academic reports that relate specifically to this thesis are as follows:

1. **Ronald Pérez-Álvarez**, Jorge J Maldonado, Ricardo Rendich, Mar Pérez-Sanagustín, Diego Sapunar (2017): Observatorio MOOC UC: la adopción de MOOCs en la educación superior en América Latina y Europa. Proceedings of the EMOOCs workshop, in Spanish.

2. Mar Pérez-Sanagustín, Jorge Maldonado-Mahauad, **Ronald Pérez-Álvarez** (2017): Ingeniería UC Online. Organización, infraestructura, procesos, investigación e impacto en torno a los MOOCs. Proceedings of the International Conference MOOC-MAKER 2017.

3. Mar Pérez Sanagustín, Isabel Hilliger, Jorge Maldonado-Mahauad, **Ronald Pérez**, Luís Ramírez, Pedro Muñoz-Merino, Yi-Shan Tsai, Margarita Ortiz, Tom Broos, Paola Pesantez, Eliana Sheihing, Alexander Whitelock-Wainright (2018). The LALA framework. LALA Project Erasmus+ Learning Analytics for Latin America.

4. Mar Pérez-Sanagustín, Jorge Maldonado-Mahauad, **Ronald Pérez-Álvarez** (2018): UC Online Engineering. Proceedings of the XIII Latin American Conference on Learning Technologies (LACLO).

5. Margarita Ortiz, Alberto Jimenez, Ricardo Maya, Pedro J. Muñoz-Merino, Pedro Manuel Moreno-Marcos, Jon Imaz Marín, Carlos Delgado Kloos, Miguel Ángel Zúñiga Prieto, Marlon Ulloa, **Ronald Pérez Álvarez**, Mar Pérez-Sanagustín, Valeria Henríquez, Julio Guerra, Rafael Ferreira Leite de Mello, Tom Broos, Martijn (2019) Millecamp. Design of learning analytics tools. LALA Project Erasmus+ Learning Analytics for Latin America.

Report number 5 in the aforementioned list includes a description of the NMP as part of a set of learning analytics tools developed by Latin American universities that will be disseminated among the wider LALA community. This community is comprised of 64 institutions that could adapt and utilize the NMP for their own purposes. Resources related to the NMP are outlined in Appendix A.

Research visit

As part of the activities undertaken to compile this thesis, I performed a research internship at the Human-Computer Interaction (HCI) research group at KU Leuven University, Belgium. This research group was founded by Erik Duval, one of the leading exponents in research on learning analytics. The duration of the internship was three months, from 1 September 2018 to 27 November, and I worked under the direction of Dr Katrien Verbert, PhD. Dr Verbert, an associate professor at the Department of Computer Science, is a leading expert in human-computer interaction, recommendation techniques, data visualization and visual analytics. Her research interests include context-aware recommendation, user interfaces for recommender systems and applications in technology enhanced learning and digital humanities.

During the internship I worked on the design of the NMP and obtained valuable feedback which was used to measure the impact of the tool. Moreover, this experience enabled me to review visualizations and indicators used in the learning analytics dashboard and MOOC platforms. Based on a literature review, my team and I organized a design workshop in which HCI experts worked on the design of visualizations to contribute to the development of a new version of the NMP that focuses not only on learners, but also on teachers. Finally, during the internship I began joint research with Dr Verbert to analyze learning analytics dashboards for supporting self-regulated learning. The results of this joint research form part of journal article J3 (see Table 1-2).

1.6.2 National and international impact of the research

The results of the research conducted in the elaboration of this thesis have also had an impact at a national and international level:

- **At a national level:** This thesis was part of the national FONDECYT Initiation project called "Self-regulated Learning Strategies in MOOC-based Environments" (ID 11150231). In this national project, in conjunction with the European Erasmus+ MOOC-Maker project, approximately 30 MOOCs were developed for the Coursera and Open edX platforms. On one hand, these courses represent an opportunity for Chilean and non-Chilean learners to enhance their professional preparation. On the other hand, they served as a means by which to set the experimental scenarios evaluated in this thesis. The NMP was used in a certain number of the MOOCs produced in the MOOC Maker project in order to support SRL strategies. At present, the NMP is used in four MOOCs created by the Universidad de Chile and it was used as a complement for the course *Organizacion y Comportamiento en la Empresa* (Organization and Behavior in a Company) created by the Pontificia Universidad Católica de Chile. This particular course was organized in accordance with a blended learning methodology.

- **At an international level:** The solutions and experimental settings generated as a result of this thesis have had an international reach. Learners from 10 countries in Latin America and Europe participated in the experimental settings conducted with the NMP. Moreover, I participated as a researcher in two European Erasmus+ projects that allowed me to disseminate the NMP in different countries and to distinct institutions, including: (1) the MOOC-Maker project, with nine partners in all - three European and six Latin American (MOOC-Maker, 2018); and (2) the LALA project, with seven partners - three European and four Latin American (LALA, 2019).

Finally, the NMP represents one of the multiple sets of learning analytics tools developed in the LALA project, all of which aim to guide and promote the implementation and design of learning analytics tools to improve academic decision-making processes in Latin America.

1.6.3 Document structure

This thesis document is organized into five chapters. Throughout, descriptions are provided of articles that have already been published or sent for review to ISI (Web of Science) journals as well as international peer-review conferences with proceedings.

This **Chapter 1** is an introductory chapter that provides the reader with a broad view of the pertinent research area. It introduces the reasons that motivated the thesis in addition to the main challenges identified, research questions posed, objectives identified, methodology used, main contributions and the impact of the results.

Chapter 2 outlines the tasks related to the *informed exploration phase* of the interactive learning design (ILD) framework in order to contribute to ***Objective 1.*** *To design and implement a technological solution to support self-regulation strategies for learners in MOOCs.* Furthermore, this chapter describes the results related to *RQ1. What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learners in MOOCs?* The main results were reported in three systematic literature reviews. In this thesis, which follows the design-based research methodology, three iterative cycles were conducted to guide the design of the NMP. Prior to each new design, one literature review was performed (*informed exploration phase*) to define the functionalities, visualizations and indicators that best contribute to supporting SRL strategies in MOOCs. These literature reviews aimed to analyze the functionalities, SRL models, SRL strategies, visualizations and indicators used to design tools which support SRL in online environments *[Cont. 1 - Obj. 1].* Moreover, the literature reviews analyzed how such proposals have previously measured the impact of tools on SRL strategies.

Chapter 3 presents the NMP tools and describes the design process and usability evaluation of the tool as part of the *enactment phase* and *evaluation of local impact phase*. The chapter contributes to answering *RQ1. What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs?* Specifically, this chapter describes the main functionalities that were added during the design of the NMP in order to support effective SRL strategies used by learners in MOOCs *[Cont. 2, 3, 4 – Obj. 1]*. Furthermore, the chapter outlines the results obtained from the evaluation of the usability and adoption of the NMP tool *[Cont. 5 – Obj. 2].*

Chapter 4 describes a case study used to evaluate the impact of the NMP on the self-regulation strategies of learners and their achievements, which forms part of the *broad evaluation phase*. This chapter contributes to answering *RQ2. What effect would the educational tool have on the self-regulation strategies of learners and their achievements?* Specifically, the chapter details a set of indicators used to link SRL strategies with NMP functionalities and learner engagement *[Cont. 6 – Obj. 3]*. In addition, it documents the results obtained from this evaluation *[Cont. 6 – Obj. 3]*.

Chapter 5 presents the main conclusions and discussions of the thesis. It also examines the different aspects that should be taken into account as part of future work on this line of research.

Finally**,** the thesis includes an appendix section that contains a list of resources available in relation to the NMP. It also contains the first page of each of the relevant publications presented as part of this thesis in order to provide a complete reference for the work undertaken.

Chapter **2**

Analysis of Tools Designed to Support Self-regulated Learning in Online Environments

This chapter discusses the results of the *informed exploration phase* in order to contribute towards ***Objective 1.*** *To design and implement a technological solution to support self-regulation strategies for learners in MOOCs.* Concretely, this chapter contributes to answering ***RQ1***. *What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learners in MOOCs?* The main results of this phase were reported in three systematic literature reviews. However, this chapter outlines the content and follows the structure of the third journal article [Table 1-2; J3], which summarizes the lessons learned from the two initial literature reviews. The aim of these literature reviews was to analyze the functionalities, SRL models, SRL strategies, visualizations and indicators used to design tools to support SRL in online environments *[Cont. 1 - Obj. 1]*. Moreover, they aimed to analyze how proposals made in the literature have successfully measured the impact of tools on the SRL strategies of learners. This chapter is divided into five sections. Section 2.1 presents the context of the literature reviews. Section 2.2 describes the methodology used to conduct the literature reviews. Section 2.3 outlines the results. Section 2.4 analyzes the main results. Finally, section 2.5 presents the conclusions of the *informed exploration phase*.

2. ANALYSIS OF TOOLS DESIGNED TO SUPPORT SELF-REGULATED LEARNING IN ONLINE ENVIRONMENTS

2.1. Introduction

To support SRL in online environments, researchers have generally followed two lines of research: (1) online SRL behavior analysis, and (2) the proposal of tools to support and understand SRL. The first line of research has focused on studying how SRL occurs in online environments and how the SRL strategies of learners relate to course achievements (Kizilcec et al., 2017; Milligan & Littlejohn, 2016). The second line of research is aimed at leveraging the potential of technological tools to develop skills while also capturing data to enhance understanding of how SRL is developed. Panadero (2016) describes this latter line of research as the third wave of SRL measures, in which the data analyzed is captured by tools designed specifically to support learner strategies that, in turn, serve both as a scaffold and as a measure of SRL. In this chapter, the latter line of research is adopted in order to understand how current tools support SRL online environments.

Specifically, this chapter presents the results of three systematic literature reviews focused on analyzing current tools that are designed to support SRL strategies in online learning environments. The final objective of this chapter is to provide an overview of the progress made in the field of SRL support in online learning environments.

2.1.1. Importance of the review

Current literature provides certain examples of the latest tools available for scaffolding SRL, and which focus of different aspects, in online environments. Some such reviews focus on analyzing the effect of SRL scaffolds on learner performance. For example, Devolder et al. (2012) and Zheng (2016) reviewed 28 and 29 articles, respectively, to compare the effectiveness of different types of scaffold in computer-based learning environments that support self-regulated learning, with resultant comparisons based on the effects reported in the articles. Wong et al. (2019) reviewed 51 papers in order to understand the effect of approaches to support SRL strategies in online learning environments. In these reviews, the authors analyzed a number of different SRL scaffoldings such as prompts, metacognitive feedback, strategies, tools or integrated support systems, and guides. Devolder et al. (2012) found that prompts are the most effective scaffolding to have been reported in research to support SRL. Wong et al. (2019) also reported similar results stating that prompts have a positive effect on both SRL and academic success. Zheng (2016) reviewed six tools based on the effect reported on the academic performance of learners and found that integrated SRL tools with multiple functions are the most effective scaffolding in terms of supporting SRL. Wong et al. (2109) reviewed ten tools and found that supporting SRL by embedding various features online appears to be effective in enhancing SRL strategies and learning outcomes. These reviews consider tools to be part of the scaffolds analyzed by focusing on the reported effect of the tools rather than the features included in the design thereof to support SRL strategies.

One review that focuses on the design of the tools is that undertaken by Garcia et al. (Garcia, Falkner, & Vivian, 2018). In this case, the authors reviewed 30 articles on e-learning platforms that support computer science in order to understand whether the original strategies of the Zimmerman SRL model (Zimmerman, 2000) had been addressed. They found that 10 of the 14 strategy categories are supported in these platforms, while 4 categories related to environment structuring and seeking social assistance are not covered by any e-learning platform. Moreover, they highlighted emotional regulation as one additional strategy category that was not included in the Zimmerman SRL model. This review is limited to the Zimmerman SRL model and analyzes tools that were not necessarily designed to support SRL.

2.1.2. Objectives and research questions

The aforementioned literature reviews highlight a number of tools that act as a useful scaffold for SRL in online environments(Devolder, van Braak, & Tondeur, 2012), (Zheng, 2016), (Wong et al., 2019). However, this prior work has placed greater emphasis on the effect of the scaffold rather than the design of the tools in terms of functionalities. As a consequence, it remains unclear as to what type of functionalities are used to support SRL strategies of learners and whether and to what extent these are aligned with theoretical SRL models. In this literature review, emphasis is placed on examining how the concept of self-regulation is adopted from the tool design stage onwards and what indicators are used for measuring purposes. I.e., (1) what is the relationship between the functionalities of the tools and the self-regulatory strategies they support, and (2) which indicators are used to measure the impact of the tool on learner behavior?

Specifically, four research questions are addressed in this literature review: (1) ***RQ1.*** What are the most common theoretical SRL models considered as a theoretical framework for the design of the tool? (2) ***RQ2.*** What are the SRL strategies that current tools aim to support? (3) ***RQ3***. What functionalities do current tools use to support self-regulation learning strategies in online learning environments? and (4) ***RQ4.*** Which measures are proposed to evaluate the impact of the tool in the self-regulation of learners?

2.2. Methodology

A systematic review method was used as the methodological approach. Importantly, a systematic literature review helps to identify, evaluate and interpret relevant information in relation to a particular research question, topic or phenomenon of interest (Kitchenham, 2004). Kitchenham (2004) proposes organizing a systematic review in accordance with three phases: (1) planning the review, which consists of identifying the need for the review and developing a relevant protocol; (2) conducting the review, which consists of identifying research related to the research question, selecting primary studies, evaluating study quality, extracting and monitoring data and synthesizing data; and (3) reporting the review, which consists of recording the results obtained in order to contribute to the topic or research question addressed. In this thesis the phases proposed by Kitchenham were followed, although the phase to determine the quality of the respective study was omitted. This is primarily due to the fact that the interest of the authors was to consider any publication that matched the search criteria.

2.2.1. Search process and data collection

The search process was conducted across five of the most commonly used databases in technology enhanced learning (TEL): Scopus, ACM Digital Library, IEEE Explorer, Springer Link and Science Direct. These databases work by indexing the relevant conference proceedings in relation the field of TEL, such as those from the European Conference on Technology Enhanced Learning (ECTEL) and the Learning Analytics & Knowledge Conference (LAK).

The following keywords were used to formulate the search queries: Self-regulated Learning, Self-directed Learning, Tools, System, Dashboard, Online, MOOCs. This query is expressed symbolically as (Self-regulated Learning, Self-directed Learning) AND (Tools, System, Dashboard) AND (Online OR MOOCs). The first part of the query focuses on detecting articles related to self-regulation; the second part identifies tools proposed or implemented; and the third part identifies the research context. Figure 2-1 shows the process followed for the search and selection of each article.

Three researchers participated in the review process. Two reviewed and selected the articles and the third intervened if the first two had doubts about the inclusion of a particular paper. A total of 1,829 articles were retrieved as a result of the search criteria. Subsequently, articles were selected based on their titles/abstracts and keywords. From this pool of articles, any that failed to meet the exclusion criteria were omitted. The exclusion criteria included: articles that were not written in English; articles that did not describe a tool; articles that supported self-regulation but not through a tool; articles that described a tool that supports self-regulation but not in an online environment; articles that addressed the use of tools such as social networks and e-portfolios to support self-regulation but did not propose any original development; and articles that supported SRL for non-learner users, such as workers or teachers. At the end of this process, 43 articles were selected. Duplicates were then eliminated (11 in all) and an analysis of each article was undertaken. In order to broaden the range of the tools analyzed, relevant articles cited in the reference sections of the original papers selected were also identified and evaluated (7 in all).

A total of 39 articles were subsequently considered for review. This final selection included articles that describe tools designed to support learner self-regulation in both traditional online learning environments and MOOCs. Articles which concerned the same tool were included, although for analysis purposes they were considered a single tool. Ultimately, analysis was conducted on 23 tools that focus on supporting SRL in an online environment.

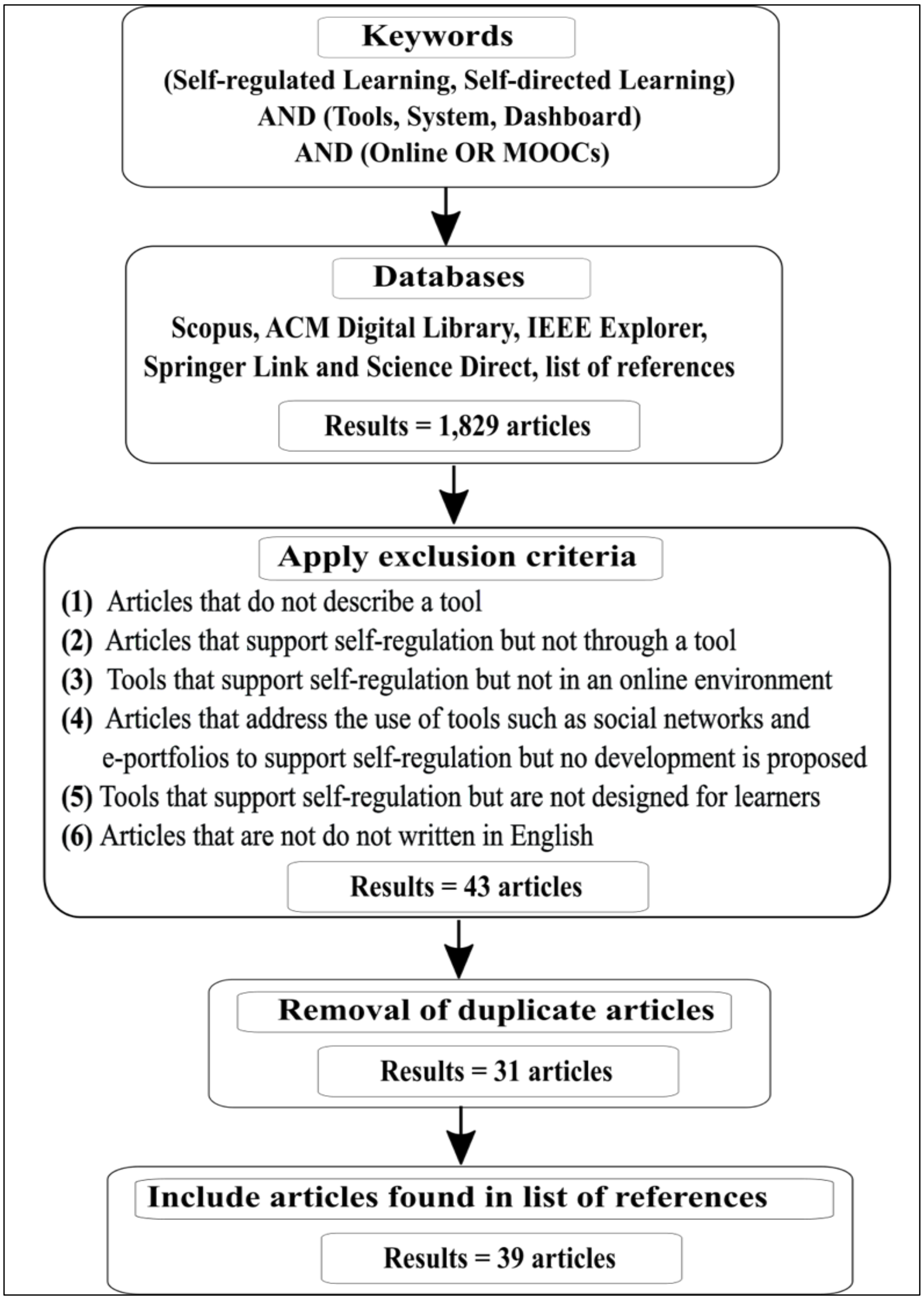

Figure 2-1: Article selection process

2.2.2. Data classification and analysis

The software NVivo 12 was used to classify and analyze the data, primarily because of its ability to conduct article organization and text coding to facilitate subsequent analysis. In order to answer the research questions pertinent to the literature review, six analysis categories were defined : to answer ***RQ1***, the category (1) *SRL models* was defined; to answer ***RQ2***, the category (2) *SRL strategies* was defined; to answer ***RQ3***, the categories (3) *visual feedback*, (4) *functionality*, and (5) *indicators* were defined; and to answer ***RQ4***, the category (6) *evaluation measure* was defined. The *SRL models, SRL strategies* and *visual feedback* categories were constructed from codes that emerged during the review process. Furthermore, five subcategories related to the initial *SRL models* category emerged during the process, in addition to eight subcategories for the *SRL strategies* category and 11 subcategories for the *visual feedback* category. Regarding the three remaining analysis categories (*functionality*, *indicators* and *evaluation measures*), a set of subcategories were defined in accordance with classifications devised in previous literature reviews (see Table 2-1).

To answer ***RQ1***, an *SRL model* category was used. Given the diversity of *SRL models*, this literature review did not adopt a specific *SRL model* for the purposes of reporting. Consequently, the initial *SRL models* analysis category was used to identify the SRL models as emerging codes that had been specifically described by their respective authors as a framework for their tool design. If authors did not specify the SRL model used, these tools were added to the subcategory *not specified*.

To answer ***RQ2***, we used the category *SRL strategies*, from which the relevant subcategories were constructed. In turn, these took the name of the self-regulation strategies indicated by the authors (emerging codes) as a reference point.

To answer ***RQ3***, three categories were used: *visual feedback*, *functionality* and *indicators*. In the *visual feedback* category, all types of visual displays found in the articles used to provide feedback to learners were reported. All the displays were classified using codes emerging from the literature review. The *functionality* category was used to determine the type of scaffolding the tools provide to support SRL among learners. In this case, three subcategories proposed by Bodily and Verbert (2017) were used: *class comparison, recommendations* and *interactivity*. Furthermore, four additional subcategories were defined: *content navigation, input form, text explanations* and *collaboration*. The *indicators* category was used to identify the kind of indicators that were utilized to display the data to learners and, in turn, was divided into the following six subcategories proposed by Schwendimann et al. (2017): *action-related, content-related, results-related, social-related, context-related* and *learner-related*.

To answer ***RQ4***, six evaluation subcategories proposed by Jivet et al. RQ1 used. *metacognitive, cognitive, behavioral, emotional, self-regulation* and *tool usability*. These subcategories initially proposed 12 evaluation criteria; however, in this literature review, five new criteria were incorporated (*impact on effectiveness, impact on efficiency, workload, impact on course engagement* and *impact on social engagement*), leaving a total of 17 criteria for article analysis. The criteria included in each evaluation subcategory are listed in Table 2-1. The *metacognitive* subcategory groups together criteria that aim to evaluate the effect of the tool on the understanding of the information displayed therein, agreement with this information, and the impact it had on learner awareness and reflection. The *cognitive* subcategory groups criteria that aim to evaluate the effect of the tool on learner efficacy, effectiveness and performance with respect to learning activities, as well as the workload associated with the use of the tool by the learner. The *behavioral* subcategory groups criteria that aim to evaluate the effect of the tool on learner behavior with respect to their engagement with the course and social activities, their use of the tool and other types of observed behavior. The *emotional* subcategory groups criteria that aim to evaluate the effect of the tool on learner motivation and impact on affect. The *self-regulation* subcategory consists of one criterion that specifically aims to evaluate the effect of the tool on the SRL strategies of learners. Finally, the *tool usability* subcategory groups criteria that focus on evaluating the tool itself, including its usability, usefulness and corresponding learner satisfaction.

Table 2-1: Categories and subcategories used in to code the articles

Subcategory	***Definition***
1. Functionality category	
Class comparison	If tool includes a system that allows learners to compare their data with data of other learners (Bodily & Verbert, 2017).
Recommendations	If tool includes a system that provides a recommendation to a learner (Bodily & Verbert, 2017).
Interactivity	If tool offers learners the possibility of clicking around to explore their activity (Bodily & Verbert, 2017).
Content navigation	If tool allows learners to access course content through the tool interface.
Input form	If the tool uses forms for data entry.
Text explanations	If tool appends text to explain the data display in a visualization.
Collaboration	If tool includes a system that allows learners to share materials or knowledge.
2. Indicators category, proposed by (Schwendimann et al., 2017)	
Action-related	Indicators that provide information about the actions performed by the learner.
Content-related	Indicators that show feedback on the content the learner interacted with or produced.
Results-related	Indicators that provide information about the outcome of learner activities.
Social-related	Indicators that show how learners interacted with others.
Context-related	Indicators that provide information about the context in which the learning took place.
Learner-related	Indicators that present information which describes the learner.
3. Evaluation measure category, proposed by **(Jivet et al., 2018)**	
Metacognitive	Three criteria are considered in this subcategory: **(1)** *understanding* of the information display on the tool, **(2)** *agreement* with the information, **(3)** *impact of the tool on awareness and reflection*.
Cognitive	Four criteria are considered in this subcategory: **(1)** *impact on effectiveness*, related to the accuracy and completeness for goal achievement, **(2)** *impact on efficiency*, related to the optimal use of resources for goal achievement, **(3)** *impact on performance*, related to grades, quality of learning outcomes or assessment of learning artefacts, **(4)** *workload*, related to mental and effort resources used to accomplish the task.
Behavioral	Four criteria are considered in this subcategory: **(1)** *impact on course engagement*, **(2)** *impact on other behavior*, **(3)** *impact on social engagement*, **(4)** *usage of the SRL tool*.
Emotional	Two criteria are considered in this subcategory: **(1)** *impact on affect*, **(2)** *impact on motivation.*
Self-regulation	One criterion is considered in this subcategory: **(1)** *impact on SRL*, related to the impact of the tool on the SRL of learners.
Tool usability	Three criteria are considered in this subcategory: **(1)** *satisfaction*, **(2)** *usability*, **(3)** *usefulness*.

Two researchers conducted the coding of the articles. The articles were divided among researchers, although three articles were reviewed by both researchers in order to facilitate estimations related to overall percentage of agreement. The percentage of agreement between the two researchers was 99.76 and with a Cohen's Kappa = 0.37. Although the kappa value is low, there is a high degree of agreement on the coded items. The differences that generate a low kappa value are analyzed in this thesis and can be explained primarily due to the size of the text selected by each coder. However, the same codes were identified by the coders in the analyzed articles, thereby confirming the reliability of the classification.

2.3. Results

From the 39 articles analyzed, 23 tools were proposed. Table 2-2 describes these 23 tools.

Table 2-2: Description of tools designed to support SRL in online environments.

	Article	Description
A1	(Huang et al., 2015)	A system that aims to improve learner performance through several theory-based functionalities, such as real-time screen-sharing, synchronous demonstration and learner portfolio monitoring.
A2	(Nussbaumer et al., 2014)	A framework that enables both widgets and learners in the same space to interact with one another. This framework provides 15 SRL widgets to support learners to search for information, activity planning, goal setting, etc.
A3	(Azevedo, Johnson, Chauncey, & Burkett, 2010)	Learning environment designed to detect, model, trace and foster learner SRL with regard to the human body system. Learners can generate several sub-goals for the session, self-evaluate their knowledge and monitor their learning process.
A4	(Siadaty, Gašević, Jovanović, Milikić, et al., 2012)	The *Learning-B* environment is a prototype that aims to support self-regulation in workplace learning. In this environment learners select the competences to learn and the learning path to follow in order to reach their learning goals.
A5	(Yau & Joy, 2008)	A framework which uses the learning schedule of learners and available time contexts in order to suggest appropriate materials based on these factors, at the time of usage.
A6	(Kopeinik et al., 2014)	Plugin for Moodle to support SRL online. This plugin recommends content according to the current competence state of the learner.
A7	(Mohamed, Yousef, Chatti, Danoyan, & Thüs, 2015)	A video annotation tool for MOOCs that allows collaborative annotation and supports self-organization.
A8	(Pérez-Álvarez, Maldonado-Mahauad, Sapunar-Opazo, & Pérez-Sanagustín, 2017)	A plugin and web app to support learner SRL in MOOC environments by setting interactive goals and visualizations relevant to their learning activity and with regard to course resources.
A9	(Alexiou & Paraskeva, 2015)	A goal-setting plugin to facilitate the capacity of individuals to self-regulate learning and strengthen motivation and self-efficacy in an ePortfolio.
A10	(Thirouard et al., 2015)	A tool designed to motivate learner participation in MOOCs, which works through interactive assessment to solve industrial problems.
A11	(Marquez-Barja et al., 2014)	This project aims to promote SRL through the use of a federation of high-performance testbeds and by building unique learning paths based on the integration of rich linked-data ontology.
A12	(Winne & Hadwin, 2013)	Supports learning with resources available on the Internet. Seeks to support SRL processes by tracking learner searches and creating notes and terms about information in web pages.
A13	(Davis et al., 2016)	A widget for the edX MOOC platform that supports learner SRL by displaying indicators related to their performance.

A14	(Guerra et al., 2016)	Seeks to integrate SRL with motivation theories as well as in social comparison. Uses a matrix to show the content of learner progress.
A15	(Onah & Sinclair, 2017)	A MOOC learning platform that encourages learners to define their learning goals and establish learning paths.
A16	(Tang & Fan, 2011)	A tool that integrates web 2.0 (RSS, Tag, Wiki, Blogs) services to support planning and management.
A17	(Carlos Alario-Hoyos et al., 2015)	Proposes the design of a mobile application to support planning through guidance and advice on MOOCs.
A18	(Tabuenca, Kalz, Drachsler, & Specht, 2015)	A mobile application that tracks the time invested by learners in learning activities in order to support time management.
A19	(Shih et al., 2010)	A tool to support collaboration, self-monitoring, goal-setting and strategic planning.
A20	(Chang, Tseng, Liang, & Liao, 2013)	A web-based portfolio for planning objectives or milestones and assessing progress.
A21	(Wang, Peng, Cheng, Zhou, & Liu, 2011)	A tool that supports the development of SRL skills through interactive knowledge maps.
A22	(Sambe, Bouchet, & Labat, 2018)	Proposal of a widget for MOOC platforms to support learners in the different phases of the self-regulation process through a combination of visualization techniques and prompts.
A23	(Davis, Triglianos, Hauff, & Houben, 2018)	Tool to support learners in setting weekly goals by providing real-time feedback on the progress of their planning.

RQ1. *What are the most common theoretical SRL models considered as a theoretical framework for the design of the tool?*

Taking into account all articles, 61% (17 of 23) explicitly mention a specific model as a reference for guiding their design decisions. Regarding those which mention a supporting theoretical SRL model, 52% (12 of 23) adopted the Zimmerman model (Zimmerman, 2000), 17% (4 of 23) the Pintrich model (P. Pintrich, 2004), 8.7% (2 of 23) the Winne and Hadwin model (Winne & Hadwin, 1998), and 4.3% (1 of 23) the Schunk model (Schunk, 2005) (see Table 2-3). Although the majority of the authors use one of these four models as their reference point, one study utilized all four models for defining tool functionalities, while the remaining three used three of them simultaneously.

While the majority of authors take a theoretical model as a reference from which to define their tools, very few of them actively justify their theoretical choice. For example, Dimache et al. (2015), Huang et al. (2015), Nussbaumer et al. (2014) and Shih et al. (2010) explicitly claim to have used the Zimmerman model because they contend it is the one that best represents learning as a cyclical process. However, Huang et al. (2015) choose the Pintrich model because it clearly defines the strategies associated with each of the four phases of the SRL process, which are "observable actions" that can be subsequently linked to particular learning activities within the tool.

RQ2. *What are the SRL strategies that current tools aim to support?*

Table 2-3 shows the eight SRL strategies most frequently supported by the tools analyzed. The strategies that were supported by two or fewer than two items have not been included in Table 2-3. The three most supported SRL strategies were *goal setting*, 60% (14 of 23); *monitoring*, 47% (11 of 23); and *self-evaluation*, 43% (10 of 23). The remaining five SRL strategies, *help seeking*, *organization*, *strategic planning*, *time management* and *self-reflection* are supported by the same percentage of tools: 30% (7 of 23). From the list of articles analyzed, it has been observed that the majority of the proposed tools were designed to support more than two strategies, while some of them are able to support many more. For example, Nussbaumer et al. (2014) proposed a solution for supporting seven strategies. Nevertheless, there are certain exceptions. For example, it can be seen that four articles propose a solution for supporting one SRL strategy: Thirouard et al. (2015) and Onah & Sinclair (2017) support *self-evaluation*, while Alario-Hoyos et al. (2015) support *strategic planning* and Yau & Joy (2008) support *time management*.

RQ3. *What functionalities do current tools use to support self-regulation learning strategies in online learning environments?*

In order to understand how current tools are supporting SRL, a detailed analysis was undertaken of the functionalities proposed as well as the indicators and visualizations used for supporting specific strategies. Table 2-3 shows the functionalities (*functionality category* in Table 2-1), types of visual displays (*visual feedback category* [emerging codes]) and types of indicators (*indicators category* in Table 2-1) used per article and the total number of times they appeared within the overall list. In order to organize the information from the different articles, the distinct functionalities were grouped into separate categories.

For the functionality category, the following subcategories were defined: *content navigation*, for tools which allow learners to access course content through the tool interface; *input form*, for tools which use forms for data entry; *recommendations*, for tools which include a system that provides a recommendation to a learner; and *collaboration*, for tools which include a system through which learners are able to share materials or knowledge (see Table 2-1). The results in show that 56% (13 of 23) of the tools offer support by means of *content navigation* and *input form* functionalities, while 43% (10 of 23) provide support by means of *recommendations* and *collaboration*. Tools that provide support via a *content navigation* functionality allow learners to interact with learning activities such as evaluations, readings and practices by which they can navigate between the activities. Finally, 26% (6 of 23) provide support through an *interactivity* functionality, 21% (5 of 23) via a *class comparison* functionality, and 4% (1 of 23) through a *text explanation* functionality.

For the visualization category, 11 types of visual displays were identified in the papers analyzed: text, bar chart, table, line chart, network graph, pie chart, progress bar, gauges, heat map table, learning path and spider chart. Feedback provided through text was considered a type of visual display. Moreover, only the visual feedback identified in the papers or explicitly mentioned by authors were reported in this literature review. The results in Table 2-3 show that the 26% (6 of 23) of tools offer learners feedback through *text* display; 17% (4 of 23) used *bar charts* or *tables;* 13% (3 of 23) used *line charts*, *network graphs* or *progress bars*; 8 % (2 of 23) used *pie charts*; and 4% (1 of 23) used *gauges*, *heat map tables*, *learning paths* or *spider charts.* Furthermore, it can be seen in Table 2-3 that 52% (12 of 23) of tools used simply one type of visual display with which to provide feedback, while 26% (6 of 23) used more than two kinds of visual display, and 21% (5 of 23) did not provide any visual display. Tools without any visual display correspond to those that have not yet implemented any form of visualization or which do not include a description of the visualizations used.

Table 2-3: Subcategories of functionalities and articles

Subcategory	*Freq.*	*A1 (Huang et al., 2015)*	*A2 (Nussbaumer et al., 2014)*	*A3 (Azevedo et al., 2010b)*	*A4 (Siadaty et al., 2012)*	*A5 (Yau & Joy, 2008)*	*A6 (Dimache et al., 2015)*	*A7 (Mohamed et al., 2015)*	*A8 (Pérez-Álvarez et al., 20017)*	*A9 (Alexiou & Paraskeva, 2015)*	*A10 (Thirouard et al., 2015)*	*A11 (Marquez-Barja et al., 2014)*	*A12 (Winne & Hadwin, 2013)*	*A13 (Davis et al., 2016)*	*A14 (Guerra et al., 2016)*	*A15 (Onah & Sinclair, 2017)*	*A16 (Tang & Fan, 2011b)*	*A17 (Alario-Hoyos et al., 2015)*	*A18 (Tabuenca et al., 2015)*	*A19 (Shih et al., 2010)*	*A20 (Chang et al., 2013)*	*A21 (Wang et al., 2011)*	*A22 (Sambe et al., 2018)*	*A23 (Davis et al., 2018)*
SRL models category																								
Zimmerman	12	X	X	X			X			X		X		X		X				X	X		X	X
Pintrich	4	X		X					X	X														
Winne and Hadwin	2			X									X											
Schunk	1			X																				
Not specified	9				X	X		X			X				X		X	X	X			X		
SRL strategies category																								
Goal setting	14	X	X	X	X		X		X	X		X		X					X	X	X		X	X
Monitoring	11	X	X	X	X				X	X				X	X		X			X				X
Self-evaluation	10	X	X				X			X	X				X	X	X			X		X		
Help seeking	7		X	X				X					X				X			X		X		
Organization	7	X	X					X	X				X				X					X		
Strategic planning	7	X		X					X	X				X			X	X						
Time management	7		X			X			X	X				X					X				X	
Self-reflection	7		X				X					X		X						X	X	X		
Functionality category																								
Content navigation	13		X	X	X		X	X				X	X		X	X		X	X	X		X		
Input form	13	X	X	X	X	X			X						X			X	X	X	X		X	X
Recommendations	10		X		X	X	X					X			X			X	X	X		X		
Collaboration	10	X	X		X			X				X	X			X	X			X		X		
Interactivity	6		X						X			X		X	X							X		
Class comparison	5				X				X					X	X				X					
Text explanations	1													X										
Visualizations category																								
Text	6			X			X						X						X		X			X
Bar chart	4		X		X				X										X					
Table	4		X														X	X		X				
Line chart	3				X				X										X					
Network graph	3							X					X									X		
Pie chart	2								X										X					
Progress bar	3				X				X							X								
Gauges	1																							X
Heatmap table	1														X									
Learning path	1	X																						
Spider chart	1													X										
Indicators category																								
Action-related	13		X	X	X				X				X	X	X			X	X	X	X		X	X
Content-related	14	X	X		X		X	X	X		X		X	X	X	X		X				X	X	
Results-related	3	X																			X		X	
Context-related	1					X																		

For the *indicators* category, the following subcategories were defined: *action-related,* for tools which present information about the actions performed by the learner; *content-related,* for tools which provide feedback on the content the learner interacted with or produced; *results-related,* for tools which provide information about the outcome of learner activities; *context-related,* for tools which provide information about the context in which the learning took place; *social-related*, for tools which show how learners interacted with one another; and *learner-related,* for tools which present information describing the learner (see Table 2-1). To identify the indicators, the text and visualizations of the articles were reviewed. However, it should be noted that the tools may include other indicators that have not been mentioned in this literature review. Four of the six Schwendimann (Schwendimann et al., 2017) indicators were identified in the papers reviewed. The results in Table 2-3 show that 60% (14 of 23) used *content-related* indicators, 56% (13 of 23) used *action-related* indicators, 13% (3 of 23) used *results-related* indicators, and only 4% (1 of 23) used *context-related* indicators.

In order to enhance understanding about how each tool provides support in relation to each strategy, an analysis was undertaken of all tool functionalities, visualizations and indicators. Table 2-4 shows how the functionalities, visualizations and indicators support SRL strategies.

Goal setting. The goal-setting column in Table 2-4 outlines which functionalities, graphs and types of indicators were employed in the different articles in order to support the *goal setting* strategy. Four functionalities were used: *content navigation*, *input form*, *recommendations* and *class comparison*. Three of the tools used the *content navigation* functionality to allow learners to browse through the goals defined by teachers, such as learning activities or content to be learned, in order to identify competencies required by an organization for setting their individual goals. For example, to support the initial goal setting process, A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) shows a list of the competencies which are ranked by the company or organization in accordance with what is required for accomplishing their workplace duties. Nine tools used the *input form* functionality to enable learners to set their goals, interests or competencies. Three tools provided *recommendations*, such as learning activities or competencies, to support learning goals. For example, A2 (Nussbaumer et al., 2014) recommends the learning activities and content that learners should engage in on the basis of the user model (competencies and goals. Finally, one tool used the *class comparison* functionality to support learners during the goal setting process. Article A8 (Pérez-Alvarez et al., 2018) shows a set of learning-performed statistics about successful learners in previous editions of the course which aim to provide them with support in defining improved and more realistic goals.

Regarding the *visual feedback category*, five types of visualizations that were proposed for supporting the *goal setting* strategy were identified: (1) *text*, which was used by two tools to provide learners with feedback about their percentage of progress (Chang et al., 2013) or to show the list of goals and sub-goals (Siadaty, Gašević, Jovanović, Pata, et al., 2012); (2) *bar chart,* which was used by two tools to display, first, the progress of learners towards their goals (Pérez-Alvarez et al., 2018) and, second, shared knowledge in order for learners to adapt to the competencies required (Siadaty, Gašević, Jovanović, Pata, et al., 2012); (3) *progress bar*, which was used by one tool to show the progress of learners towards achieving their competencies (Siadaty, Gašević, Jovanović, Pata, et al., 2012); (4) *gauses chart*, which was used by one tool to enable learners to compare their goal setting with their goals reached (Davis et al., 2018); and (5) *spider chart*, which was used by one tool to display the progress of learners towards the goals set by the teacher (Davis et al., 2016).

Finally, regarding the *indicators category*, three of the subcategories were used for the *goal setting* strategy: *action-related*, *content-related* and *results-related*. Three of the tools used *action-related* indicators. For example, A8 (Pérez-Alvarez et al., 2018) provides a breakdown, by hour and by day, related to learners who proved most effective in completing the learning activities. The same paper also provides learners with indicators related to their performance over previous weeks and the performance of learners from previous editions of the course. Articles A8 (Pérez-Alvarez et al., 2018), A20 (Chang et al., 2013) and A23 (Davis et al., 2018) provide learners with feedback about their progress and the progress of other learners in terms of goals. Two tools, A13 (Davis et al., 2018) and A8 (Pérez-Alvarez et al., 2018) used *content-related* indicators to provide feedback about the interaction of learners with different categories of learning activities proposed in the course. Finally, A5 (Yau & Joy, 2008) used *context-related* indicators to show learning material based on concentration levels and frequency of interruptions in the different learner locations.

Monitoring. The monitoring column in Table 2-4 shows the functionalities, graphs and types of indicators that were employed in the different articles to support the *monitoring* strategy. Three functionalities were used: *input form*, *interactivity* and *class comparison*. Article A5 (Yau & Joy, 2008) used the *input form* functionality to allow learners to register the reason for interruptions during their study session as well as to monitor their behavior. Articles A8 (Pérez-Alvarez et al., 2018) and A14 (Guerra et al., 2016) used the *interactivity* functionality to enable learners to show or hide information about the performance of other learners and compare their own performance with others on the course. Finally, four tools used the *class comparison* functionality to allow learners to monitor their performance in comparison with other learners. For example, A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) allows learners to compare their performance with their course mates, A8 (Pérez-Alvarez et al., 2018) and A13 (Davis et al., 2016) allow learners to compare their performance with successful learners that took previous editions of the course, while A8 (Pérez-Alvarez et al., 2018) also enables learners to compare their performance with unsuccessful learners that took previous editions of the course .

Regarding the *visual feedback category*, three types of graphs were identified: (1) *bar chart*, which was used by two tools whereby A2 (Nussbaumer et al., 2014) shows the SRL strategies used by learners, while A8 (Pérez-Alvarez et al., 2018) outlines learner' progress with regard to learning activities; (2) *table*, which was used by A2 (Nussbaumer et al., 2014) to display the list of activities recorded by learners; and (3) *heat map table*, which was used by A14 (Guerra et al., 2016) to allow learners to follow their progress in learning activities.

Table 2-4: How functionalities, visualizations and indicators support SRL strategies

Subcategory	*Goal setting*	*Monitoring*	*Self-evaluation*	*Help seeking*	*Organization*	*Strategic planning*	*Time management*	*Self-reflection*
Content navigation	Browse the goals defined by teachers (A2, A3, A4) or competencies required by organizations (A4).		Activities change color according to learner progress (A14, A21).				Provide extra information about learning activities on the menu (A18).	
Input form	Set goals (A1, A3, A8, A19, A20, A22, A23) interests or competences (A2, A4, A22).	Register reason for interruptions (A5).	Location (A5).		Create notes (A8, A12) and terms for web pages (A12).	Select learning paths (A4), plan task execution (A8, A17, A19).	Plan tasks and time to spend (A8, A17), record time spent on learning activities (A18).	Add new reflections (A20).
Recommendations	Content based on learning goals or competencies (A2, A4), missing competencies (A4).		Widget for self-evaluation of learner knowledge (A2).	Peer and search widget (A2).	Widget for activities organization and note taking (A2).	Learning path (A4, A17).	Learning path (A4, A17), learning resources (A5, A6).	Widget for self-reflection on their activities (A2).
Collaboration				Add chats or forums (A2, A12, A15, A21), shared workspaces (A2, A12), resources and knowledge (A4, A7, A16, A19, A21) and answers (A1).				
Interactivity		Enable/disable social comparison feature (A8, A14).	Filter information to be analyzed (A8, A12).		Learner can move content order (A21).		Filter information to be analyzed (A8).	Show extra information (A13).
Class comparison	Show goal achieved by previously successful learners during goal setting process (A8).	Compare learner performance with other course mates (A4), previously successful learners (A8, A13), previously unsuccessful learners (A8), peers (A14).				Show performance indicators of previously successful learners during goal-setting process (A8).	Show time spent by previously unsuccessful learners (A8), previously successful learners (A8, A13), peers (A18).	

Text explanations								Show text with a data explanation (A13).
No Visualization	X				X		X	
Bar chart	X	X	X			X	X	X
Table		X					X	
Line chart							X	
Network graph			X		X			
Pie chart							X	
Progress bar	X		X					
Gauges	X							
Heat map table		X						
Learning path						X		
Spider chart	X					X	X	X
Action-related	Indicators about the most effective peer week by day and hour (A8), progress in goals (A8, A20, A23), learner performance (A8).	Indicators related to learner schedules (A19), learner behavior (A19), performance of other learners (A19, A14), progress on activities (A14).				Learning path (A4).	Time spent (A4, A8, A12, A13, A18, A22), procrastination time (A8, A13), time required by teacher (A8, A18).	Indicators about annotated text and concepts used (A2), interaction with learning resources (A19).
Content-related	Indicators related to learning path and shared knowledge (A4), goal setting to achieve learning activities (A8, A23), learning activities required by teacher (A8).	Indicators related to interaction with learning activities (A8, A13).	Indicators about progress on knowledge nodes (A21), progress on learning activities (A1, A8, A14, A15), interaction with learning activities (A8, 14).		Indicators about tags/terms highlighted in text and used by learners (A12), video clips created by learners (A7).	Indicators related to performance of other learners (A1, A13).	Indicators related to interaction with learning activity categories (A8, A22).	Indicators about content produced by learners (A2), prerequisite knowledge (A21), state of competencies (A6).
Results-related	Reason for interruptions (A5).		Grades of assessments (A1, A20, A21).					
Context-related							Location (A5).	

Finally, for the *indicators category*, two of the subcategories were used to provide learners with feedback and to support the *monitoring* strategy: *action-related* and *content-related*. Two tools used *action-related* indicators. For example, A19 (Shih et al., 2010) used *action-related* indicators to allow learners to monitor their schedule (learners who stick to the proposed learning schedule and time spent on learning activities) as well as to monitor their behavior (interruptions during a learning session and the frequency and quantity of interruptions). Article A14 (Guerra et al., 2016) used *action-related* indicators to show information about the progress of learners with regard to their learning activities. Two tools used *content-related* indicators. For example, A8 (Pérez-Alvarez et al., 2018) and A13 (Davis et al., 2016) used *content-related* indicators to provide feedback about learner interaction with learning activities (number of interactions and time spent on activities).

Self-evaluation. The self-evaluation column in Table 2-4 shows the functionalities, graphs and types of indicators that were employed in the different articles to support the *self-evaluation* strategy. Four functionalities were used: *content navigation*, *input form*, *recommendations* and *interactivity*. Two tools used the *content navigation* functionality to allow learners to evaluate their progress in the learning activities. Articles A14 (Guerra et al., 2016) and A21 (Wang et al., 2011) used different colors in the menu options to guide learners with regard to concepts that had been learned, concepts to be learned and concepts started. Article A5 (Yau & Joy, 2008) used the *input form* functionality to obtain learner location and select the best time in which to conduct the evaluations proposed in the course. Article A2 (Nussbaumer et al., 2014) used the *recommendations* functionality to recommend a widget to support learner self-evaluation. Finally, two tools used the *interactive* functionality to filter information and analyze learner performance. For example, A8 (Pérez-Alvarez et al., 2018) allows learners to filter information and analyze what they consider to be the most useful information.

Regarding the *visual feedback category,* three subcategories were identified that proposed support for the *self-evaluation* strategy: *bar chart, network graph* and *progress bar.* Article A8 (Pérez-Alvarez et al., 2018) used the *bar chart* to allow learners to self-evaluate their performance in learning activities (activities started, activities completed and activities required by teachers), as well as to self-evaluate their performance in comparison with that of other successful and unsuccessful learners in previous editions of the course. Article A21 (Wang et al., 2011) used *network graphs* to enable learners to self-evaluate their progress in learning activities (each node used a different color to show concepts learned, concepts to learn and concepts started). Finally, A8 (Pérez-Alvarez et al., 2018) and A15 (Onah & Sinclair, 2017) used the *progress bar* to allow learners to self-evaluate their progress on learning activities.

Finally, for the *indicators category*, two subcategories were identified: *content-related* and *results-related.* Five tools used *content-related* indicators to allow learners to evaluate their progress on learning activities (A1, A8, A14, A15, A21) or to evaluate the interaction of other learners with learning activities (A8, A14). For example, A1 (Huang et al., 2015) displays indicators about learning activities completed by learners. Furthermore, three tools used the *results-related* indicators to provide feedback on grades of assessments.

Help seeking. The help seeking column in Table 2-4 shows the functionalities, graphs and types of indicators that were employed in the different articles to support the *help seeking* strategy. Two functionalities were used: *recommendations* and *collaboration*. Article A2 used the *recommendations* functionality to provide learners with two types of recommendations: (1) that which recommends peers with similar competencies or goals, (2) that which recommends a widget to search for extra information in Wikipedia. Moreover, nine tools used the *collaboration* functionality to allow learners to communicate with other learners or teachers (via chats or forums) in order to share workspaces and undertake group tasks, to share resources and knowledge and to share answers to programming exercises. For example, A16 (Tang & Fan, 2011) allowed learners to share resources via RSS and Tag, as well as to engage in message dissemination through a blog, Wikipedia, and social network system.

Organization. The organization column in Table 2-4 shows the functionalities that were employed in the different articles to support the *organization* strategy. Three functionalities were used: *input form*, *recommendations* and *interactivity*. Two of the tools used the *input form* functionality to allow learners to take notes and select terms from web pages to identify relevant concepts in the text. For example, A12 (Winne & Hadwin, 2013) allows learners to create terms to build a lexicon of foundational concepts in the domain of study. Article A2 (Nussbaumer et al., 2014) used the *recommendations* functionality to recommend a widget to support learners to organize their learning activities and take notes. Finally, A21 (Wang et al., 2011) used the *interactivity* functionality to support learners to organize course content, and this tool enables learners to change the order of the content according to their particular interests.

For the *visual feedback category,* two subcategories were identified that proposed support for the *organization* strategy: *text* and *network graph*. Article A12 (Winne & Hadwin, 2013) used the *text* subcategory to show a list of the five tags most recently used by learners in order to support the organization of the tags created about the learning material. Two tools used the *network graph* subcategory. For example, A12 (Winne & Hadwin, 2013) used a *network graph* to help learners organize the concepts they should learn and recognize which learning concepts are related. Article A7 (Mohamed et al., 2015) used a *network graph* to show the relationship between different nodes extracted from the content of lectures.

Finally, for the *indicators category*, one subcategory was identified: *content-related.* Two tools used *content-related* indicators. Article A7 (Mohamed et al., 2015) used *content-related* indicators to present video clips created by learners from video lectures. Article A12 (Winne & Hadwin, 2013) used *content-related* indicators to highlight, in web pages, the tags or terms used by the learner.

Strategic planning. The strategic planning column in Table 2-4 shows the functionalities that were employed in the different articles to support the *strategic planning* strategy. Three functionalities were used: *input form*, *recommendations* and *class comparison*. Four tools used the *input form* functionality to allow learners to choose the best learning path to achieve their goals, and to support learners to define an execution plan to perform their learning activities. For example, A17 (Carlos Alario-Hoyos et al., 2015) allows learners to provide data about their preferences, motivations, perceptions and daily habits. Two tools used the *recommendations* functionality to recommend different learning paths and information to help learners improve their planning. For example, A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) recommends learning paths that other colleagues have used to achieve the same competencies or goals. Article A17 (Carlos Alario-Hoyos et al., 2015) proposes learning paths based on learner needs and course structure. Finally, one tool used the *class comparison* functionality. Article A8 (Pérez-Alvarez et al., 2018) displays statistical data on the performance of successful learners in previous editions of the course in order to support learners to plan their individual goals.

For the *visual feedback category,* three subcategories were identified that proposed support for the *strategic planning* strategy: *bar chart, learning path* and *spider chart*. Article A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) used the *bar chart* graph to shows learner progress along a learning path. Article A1 (Huang et al., 2015) used the *learning path* to enable learners to analyze the activities completed. Article A13 (Davis et al., 2016) used the *spider chart* to support learners to evaluate their performance.

Finally, for the *indicators category*, two of the subcategories were used to provide learners with feedback and to support the *strategic planning* strategy: *action-related and content-related*. Article A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) used *action-related* indicators to provide learners with information about learning paths (comments, rankings, tags, numbers of users, time taken by others to complete the learning path) and support them to choose their own learning paths. Two tools used *content-related* indicators to show information related to learner performance on the content or learning activities. For example, A13 (Davis et al., 2016) presents the number of videos accessed and number of quiz question attempted.

Time management. The time management column in Table 2-4 shows the functionalities that were employed in the different articles to support the *time management* strategy. Five functionalities were used: *content navigation*, *input form, recommendations, interactivity* and *class comparison*. Article A18 (Tabuenca et al., 2015) used the *content navigation* functionality to provide learners with extra information on the menu (the start date of learning activities and estimated time required for each activity). Three tools used the *input form* functionality. For example, A8 (Pérez-Alvarez et al., 2018) and A17 (Carlos Alario-Hoyos et al., 2015) used the *input form* to support learners to devise a schedule to perform their learning activities (days to study and time required for each activity). In addition, A18 (Tabuenca et al., 2015) used the *input form* functionality to allow learners to register their time spent on learning activities in order for them to monitor their performance. Four tools used the *recommendation* functionality. For example, A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) and A17 (Carlos Alario-Hoyos et al., 2015) recommend learning paths for learners, whereby in each learning path learners can see the time spent by course mates that followed each respective path and select the best route for them according to their own available time. Article A8 (Pérez-Alvarez et al., 2018) used the *interactivity* functionality to allow learners to filter information, presented in visualizations, in order to analyze how they are using their time on the course. Finally, three tools used the *class comparison* functionality to provide feedback on the time spent by other learners to perform learning activities and to support learners to compare their performances. For example, A18 (Tabuenca et al., 2015) shows the time spent by course mates on learning activities.

For the *visual feedback category,* six subcategories were identified that proposed support for the *time management* strategy: *text, bar chart, table, line chart, pie chart* and *spider chart*. Article A18 (Tabuenca et al., 2015) sent text notifications or prompts to help learners remain active on the course. Three tools used the *bar char* to allow learners to analyze their time spent on learning activities or sessions. For example, A4 (Siadaty, Gašević, Jovanović, Pata, et al., 2012) used the *bar chart* to show learner progress along a learning path. Two tools used the *table* to provide learners with information about planned tasks and respective deadlines. For example, A19 (Shih et al., 2010) shows a calendar in which the learning tasks and suggested dates for activities are marked. Three tools used the *line chart*. For example, A8 (Pérez-Alvarez et al., 2018) shows the relationship between learner procrastination and effective time on the course. Two tools used the *pie chart* to show the percentage of time spent by learners on a particular activity. For example, A8 (Pérez-Alvarez et al., 2018) presents the percentage of time spent on both learning activities and procrastination activities. Article A18 (Tabuenca et al., 2015) displays the percentage of time spent on each learning activity. Finally, A13 (Davis et al., 2016) used the *spider chart* to allow learners to analyze average time spent on assessments and per week.

Finally, for the *indicators category*, three subcategories were used to provide learners with feedback and to support the *time management* strategy: *action-related, content-related* and *context-related*. Six of the tools used *action-related* indicators. For example, A22 (Sambe et al., 2018) used *action-related* indicators to show time spent on different learning activities. Two tools used *content-related* indicators to provide feedback about learner interaction with the different activity categories. For example, A8 (Pérez-Alvarez et al., 2018) used *context-related* indicators to present time spent on video lectures, exams, forums and supplemental resources. Finally, A5 (Yau & Joy, 2008) used *context-related* indicators to support learners to select the optimal time for studying according to their location.

Self-reflection. The self-reflection column in Table 2-4 shows the functionalities that were employed in the different articles to support the *self-reflection* strategy. Four functionalities were used: *input form, recommendations, interactivity* and *text explanation.* Article A20 (Chang et al., 2013) used the *input form* functionality to allow learners to add their reflections about search tools, outlines for reflection guidelines and reflection prompts. Article A2 (Nussbaumer et al., 2014) used the *recommendations* functionality to recommend a widget that supports learners to self-reflect about their course activities. Finally, A13 (Davis et al., 2016) used the *interactivity* and *text explanations* functionalities. The former functionality shows extra information about performance indicators present in visualizations to support learner awareness. The latter functionality is used to display a text to help learners understand the information presented in the visualization.

For the *visual feedback category,* two subcategories were identified that proposed support for the *self-reflection* strategy: *bar chart* and *spider chart*. Article A2 (Nussbaumer et al., 2014) used the *bar chart* to support learners to be more aware of the activities being performed, while A13 (Davis et al., 2016) used the *spider chart* to allow learners to compare their performance with that of other learners.

Finally, for the *indicators category*, two of the subcategories were used to provide learners with feedback and to support the *self-reflection* strategy: *action-related* and *content-related.* Two tools used *action-related* indicators to provide information about text annotated by learners to highlight relevant concepts (Nussbaumer et al., 2014) as well as interaction with learning activities (Shih et al., 2010). Finally, three tools used *content-related* indicators. For example, A6 (Dimache et al., 2015) shows learner competencies and learning history to support reflection and awareness.

RQ4. *Which measures are proposed to evaluate the impact of the tool in the self-regulation of learners?*

Table 2-5 shows the criteria used to evaluate the tools included in this review. Evaluations of different criteria were identified, including: (1) those which measure changes in learner behavior; (2) those which measure metacognitive and cognitive skills; (3) those which consider emotional measures of learners; (4) those which measure self-regulated strategies in general; and (5) those which simply measure tool usability. Results show that 43% (10 of 23) of the evaluations measured tool usability by utilizing criteria related to learner perceptions about tool usability, satisfaction and usefulness. However, only 13% (3 of 23) conducted evaluations to measure the impact of the tool on the SRL strategies of learners. In these three articles, the authors used a self-reported questionnaire as the evaluation instrument to measure and identify the SRL strategies of learners. The main findings from the self-regulation evaluation show that learners who used the tool experienced a positive effect on their time management skills (Tabuenca et al., 2015) and that learners who used the goal setting functionality offered by the tools experienced a positive effect on their overall SRL (Chang et al., 2013; Shih et al., 2010).

A total of 39% (9 of 23) of evaluations measured changes in learner *behavior*. For example, certain articles analyzed the study planning behavior of learners (Davis et al., 2016), others analyzed navigation pattern behavior (Guerra et al., 2016; Siadaty, Gašević, Jovanović, Pata, et al., 2012), some the interaction patterns of learners when using the tool (Davis et al., 2016; Dimache et al., 2015), and further examples analyzed time management behavior (Alexiou & Paraskeva, 2015). The findings of these evaluations show that: **(1)** learners who used the tool experienced greater levels of engagement with learning activities than those who did not use it (Davis et al., 2016, 2018; Guerra et al., 2016); **(2)** learners who used the tools experienced greater levels of engagement in structured and unstructured time management activities (Alexiou & Paraskeva, 2015); **(3)** learners who used the tool were able to plan their time commitments more effectively (Davis et al., 2018); **(4)** learners who showed a high proportion of non-sequential patterns attained greater knowledge (Guerra et al., 2016) and were able to perform SRL activities such as time management, goal setting, self-evaluation and organization (Azevedo et al., 2010; Nussbaumer et al., 2014; Pérez-Alvarez et al., 2018; Tabuenca et al., 2015); and **(5)** learners tended to spend up to 45 minutes of 60-minute sessions using ineffective strategies such as learning strategies and monitoring (Azevedo et al., 2010).

Furthermore, 39% (9 of 23) of the evaluations measured criteria related to cognitive and metacognitive skills. For example, A6 (Dimache et al., 2015) measured the level of knowledge attained by learners to evaluate learner effectiveness, whereas A2 (Nussbaumer et al., 2014) measured the increment of learner knowledge as a metacognitive skill. The main findings were as follows: **(1)** the competition rate among learners who used the tools was higher than that of learners who did not use it (Davis et al., 2016; Dimache et al., 2015; Thirouard et al., 2015); **(2)** learners who used the tools achieved better performance levels (Shih et al., 2010); **(3)** learners who used the tool performed better in terms of their learning tasks and planning (Davis et al., 2018); and **(4)** learners who used the tool showed greater levels of interaction with distinct problems while learners who did not use it tended to repeat the same mistakes (Guerra et al., 2016).

Finally, 13% (3 of 23) of the evaluations measured criteria related to the emotional state of learners. For example, (Davis et al., 2018; Guerra et al., 2016; Shih et al., 2010) measured the impact on learner motivation. The results show that: **(1)** the tool encourages learners to use supplementary multimedia materials (Shih et al., 2010); and **(2)** there are significant differences between the motivational profiles of learners (Guerra et al., 2016).

Table 2-5: Evaluation measures used to evaluate the tools

Criteria	*Freq.*	*A1 (Huang et al., 2015)*	*A2 (Nussbaumer et al., 2014)*	*A3 (Azevedo et al., 2010b)*	*A4 (Siadaty et al., 2012)*	*A5 (Yau & Joy, 2008)*	*A6 (Dimache et al., 2015)*	*A7 (Mohamed et al., 2015)*	*A8 (Pérez-Álvarez et al., 20017)*	*A9 (Alexiou & Paraskeva, 2015)*	*A10 (Thirouard et al., 2015)*	*A11 (Marquez-Barja et al., 2014)*	*A12 (Winne & Hadwin, 2013)*	*A13 (Davis et al., 2016)*	*A14 (Guerra et al., 2016)*	*A15 (Onah & Sinclair, 2017)*	*A16 (Tang & Fan, 2011b)*	*A17 (Alario-Hoyos et al., 2015)*	*A18 (Tabuenca et al., 2015)*	*A19 (Shih et al., 2010)*	*A20 (Chang et al., 2013)*	*A21 (Wang et al., 2011)*	*A22 (Sambe et al., 2018)*	*A23 (Davis et al., 2018)*
1. Behavioral subcategory																								
Impact on course engagement	3													X	X									X
Impact on social engagement	0																							
Impact on other behavior	6			X			X			X				X	X									X
Usage of SRL tool	6		X	X					X						X				X					X
2. Cognitive subcategory																								
Impact on effectiveness	3						X				X				X									
Impact on efficiency	0																							
Impact on performance	5	X												X	X				X					X
Workload	1		X																					
3. Metacognitive subcategory																								
Agreement	0																							
Impact on awareness, reflection	0																							
Understanding	1		X																					
4. Self-regulation subcategory																								
Self-regulated learning	3																		X	X	X			
***5.* Tool usability subcategory**																								
Satisfaction	3						X														X	X		
Usability	6		X					X	X						X				X			X		
Usefulness	8		X		X			X	X						X				X	X	X			
***6.* Emotional category**																								
Impact on affect	0																							
Impact on motivation	3														X					X				X

2.4. Discussion

This chapter reports on the analysis of tools designed to support SRL in online environments in order to enhance understanding on how to develop tools that support these strategies in MOOCs. As a result of this analysis, two implications that could help inform the development of future tools to support self-regulation strategies in MOOC-type learning environments are highlighted in this section.

Implications for the design of tools to support SRL

The purpose of supporting the SRL strategies of learners is clear in all the tools analyzed. However, the design of the tools does not seem to be clearly connected to this purpose. Results show that many of the studies do not explicitly specify the SRL theoretical model used to guide the tool-design process. The articles studied generally address the concept of self-regulation and how self-regulation contributes to learner achievement, but they fail to specify clearly how exactly the tool supports self-regulation. Similar findings were presented by Jivet et al. (2018) in their review of learning analytics tools. In that research, the authors contend that studies do not define the educational concept they are seeking to support with the tool. Although the tools included in this review define SRL as an educational concept to support learners, there is a mismatch between the educational model, the design of the tool and its evaluation. Each SRL model presents differences in how learners regulate their learning and in the self-regulatory activities that are carried out (Panadero, 2017). Consequently, prior to the design process, the designer should choose the right SRL model to guide the design of functionalities implemented in the tool in order to support the SRL activities of learners. Likewise, the studies which indicate the SRL model used as the basis for supporting learner self-regulation do not describe a clear association between the functionalities of the tool and the phases or SRL strategies that the tool seeks to support. The lack of association between the design of the tool and the SRL model makes it difficult to track the self-regulatory activities that the learner performs with the tool. This work hypothesized that the aforementioned lack of association can explain why the studies are not conducive to producing evaluations to measure the impact of the tools on SRL.

Moreover, the description of the tools reported in the articles reviewed focuses on explaining the features or mechanisms included in the tool, without offering sufficient detail about how the activities performed by the learners with these mechanisms support specific SRL strategies. Results show that tools include different functionalities, such as input form, recommendations, interactivity, content navigation or collaborations. There are certain functionalities for which it could be easier to establish an association with a specific SRL strategy. For example, the input form functionality could be linked to the goal setting strategy. However, in order to contribute to achieving a better understanding of how the functionalities support SRL, studies should provide an improved description about this relationship. Although this chapter has presented an analysis of how tool functionalities, visualizations and indicators support SRL strategies, these associations were not made explicit in the studies. Thus, such relationships were merely inferred from the main purposes and evaluations disclosed in the articles.

Overall, it is necessary to design a tool according to a theoretical-based model. This will enable functionalities to be defined and integrated within the tool in line with the strategies expounded in the model.

Implications for defining SRL indicators and evaluating the tools

Results show that the majority of the indicators used to evaluate the tools are not related to self-regulated strategies. Most of the studies used indicators related to learner performance, effectiveness, engagement with course activities or interaction with the tool. However, in order to understand whether the current tools affect the SRL strategies of learners it is necessary to define indicators to measure SRL strategies. Siadaty, Gašević, & Hatala (2016) proposed an approach to establish some type of relationship between the scaffolding provided by the tool and the SRL strategies. They associate the functionalities of the tool with one or more SRL strategy/strategies. Subsequently, learner interactions with the different functionalities serve as a proxy for measuring the strategies that learners are deploying. This approach has been used by other researchers in the area of TEL (Milikic, Gasevic, & Jovanovic, 2018) to relate functionalities with SRL strategies. Nevertheless, this approach has not been used to define indicators to measure the impact of tools on the SRL strategies of learners. Thus, further experiments are needed to implement the Siadaty et al. (2016) approach and a new perspective is required to measure SRL strategies.

Moreover**,** results show that the majority of the tools were evaluated in terms of usability, satisfaction and usefulness. Only three studies conducted evaluations related to the impact on the SRL of learners. Although these studies used self-reported questionnaires as the instruments with which to evaluate the impact of the tool on learner SRL, they are lacking in terms of evaluations that relate learner activities with the tool functionalities and SRL. Thus, new evaluation proposals are required to understand how the tool contributes to supporting self-regulation and learner performance. For example, and since *goal setting* is one of the most common strategies supported in the tools analyzed, evaluations could focus on analyzing behavioral patterns based on the traces of learners with regard to their goal setting, the fulfillment of their goals, the gap between the goals established and reached, or the percentage of the goals achieved. The interaction of learners with the SRL mechanisms implemented in the tools should be monitored in order to identify correlations with performance. In addition, researchers should consider what the association is between the activities performed by the learners with the tool and the SRL strategies from the very initial phases of the process in order to facilitate evaluation processes.

2.5. Conclusions

This chapter has provided a detailed overview of the current state of the development of tools designed between 2008 and 2018 to support SRL in online environments. Concretely, an exhaustive analysis was undertaken of the main functionalities, SRL models, SRL strategies, visualizations and indicators used by tools to support SRL in online environments. Results indicate that there is a lack of approaches to define this relationship between tool functionalities and SRL strategies, which makes it difficult to conduct interventions to evaluate the impact of the tool on the SRL strategies of learners. Furthermore, evaluations of the impact of tools should be based on both self-reported questionnaires and genuine interaction patterns of learner activity in the online environment, with the specific tool and in terms of their learning outcomes or performance.

In the MOOC context, certain tools already exist that have been designed to support SRL. However, most of these have not been evaluated in terms of impact on learner strategies. The design of future tools should therefore be based on a clear relationship between learner activities and SRL strategies in order to facilitate measurements of their impact. Moving forward, the major challenge in the MOOC context will be how to measure the impact in the short and medium term, since the majority of courses are only 5 to 10 weeks in length.

2.6. Limitations

Although a significant number of data sources were considered for the systematic search, there is a possibility that certain publications that propose or implement tools have been left out of the study, which we accept as a limitation. A further limitation is that we have only reported data provided by the authors in the articles; for example, we report the indicators and functionalities described in the review articles or which were detected in the available screenshots. Consequently, tools may include visualizations, indicators or functionalities that were not reported on in the articles.

Chapter **3**

NoteMyProgress (NMP)Tool

This chapter presents the NoteMyProgress (NMP) tool and activities related to *Enactment* and *Evaluation of local phases* of Interactive Learning Design (ILD) in order to contribute with ***Objective 1.*** *To design and implement a technological solution to support self-regulation strategies for learners in MOOCs* and ***Objective 2.*** *To evaluate the technological solution developed in a MOOC in terms of its usability and adoption.* Also, this chapter presents the results related to *RQ1. What characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs.?* The content of this chapter shows the contributions of the journal articles [Table 1-2; J1, J2, C5] and the conference article [Table 1-2; C5]. This chapter was structured into five sections. Section 3.1 presents an introduction. Section 3.2 describes the requirements identified to design NMP. Section 3.3 describe the SRL model used to design NMP. Section 3.4 presents the architecture of the NMP tool. Section 3.5 describes de design process follow to design the NMP release version. Finally, section 3.6 presents conclusions. The results of this chapter can help designers and programmers in the development of new tools to support SRL in MOOCs.

3. NOTEMYPROGRESS (NMP) TOOL

3.1. Introduction

This chapter describes the NoteMyProgress (NMP) tool, a web-based tool designed to support learners self-regulated learning (SRL) strategies in MOOCs (Pérez-Alvarez et al., 2018). Specifically, the design of NoteMyProgress is based on: (1) requirements extracted of the *exploration phase*; and (2) the results of two case studies conducted in three MOOCs aimed to evaluate tools' usability and adoption. Following the design-based research (DBR) approach, we designed the first beta version of NMP and evaluated its usability (Cycle 1 - Case study 1). Then we improved the first version and designed a second version to evaluate its adoption (Cycle 1 - Case study 1).

3.2. Requirements

As a result of the Informed *exploration phase* presented in Chapter 2, we identified five key requirements to be considered in the design of NMP:

- **(R1)** ***Complement existing platforms***; the design of the tool should provide support to learners in different MOOC platforms, taking advantage of the features offered on each platform and focusing on the development of complementary features aimed at supporting SRL strategies.
- **(R2)** ***Supporting effective self-regulated learning strategies***; the design is aimed at offering features that support the following strategies: *goal setting*, *strategic planning*, *time management*, *self-evaluation, and note-taking*, which have proved to be effective for MOOC learners (Kizilcec et al., 2017; Milligan & Littlejohn, 2016; Veletsianos et al., 2016).
- **(R3)** ***Provide comprehensive support for learners***; studies as that of Veletsianos et al. (2016) show that learners use external resources such as taking notes, searching in other information sources, among others. The NMP design should support learners while they carry out their activities, both inside and outside the learning platform. At the same time, the tool should provide support to learners in any type

of course offered, without being limited to a specific area or subject, and support learners in different learning activities planned in the course.

- **(R4)** ***Provide different perspectives for information analysis***; one of the assumptions shared by most models of SRL is that it is an active process, where learners oversee their learning process (P. Pintrich, 2000). From the perspective of an active process, learners must have the opportunity to gain a more in-depth analysis of how they are doing in their learning process. The visualizations that provide feedback to learners about their learning process must allow interaction, so that learners, according to their own objectives and needs, can monitor the aspects that are relevant to make decisions and improve their behavior.
- **(R5)** ***Offer the learner goals*, *standards or comparison criteria for the analysis of their behavior;*** an appropriate process of self-monitoring and control over their learning process requires learners to have goals or standards with which they can compare their performance, to assess whether their learning process should remain the same or if a certain change needs to be made (P. Pintrich, 1999). The design of the tool must integrate different comparison values to support the learners' self-regulated learning process.

3.3. NMP SRL model

For the design of the NMP tool, we adopted the Pintrich model (1999, 2000, 2004). The Pintrich model was adopted for three reasons. Firstly, differently from Zimmerman's model, Pintrich's model combines four phases of SRL (forethought, monitoring, control, and reflection) with four areas for regulation (cognition, motivation, behavior, and context). This combination of phases and areas is the basis for defining a broader group of SRL sub-processes, which facilitates the analysis of self-regulation. Secondly, these sub-processes defined by Pintrich are, at the same time, related to a set of specific strategies that learners adopt while self-regulating their learning (cognitive, metacognitive, and resource management). This classification of strategies facilitates large-scale qualitative research and report of the relationships between learners' actions within the MOOC or technological environment and specifics strategies (Kizilcec et al., 2017). Thirdly, Pintrich model is a well-established model in the community, which have been used in prior work to study SRL in MOOCs for both, defining instruments to measure SRL in these learning environments (Jansen, van Leeuwen, Janssen, Kester, & Kalz, 2017; Magen-Nagar & Cohen, 2017), and to analyze how different strategies manifest in records of interaction with course content (Carlos Alario-Hoyos et al., 2017; Kizilcec et al., 2017; Maldonado-Mahauad, Pérez-Sanagustín, Kizilcec, Morales, & Munoz-Gama, 2018). Therefore, and based on this prior work, the Pintrich model (P. Pintrich, 1999) was selected as a suitable model for establishing a relationship between specific SRL strategies and the activities conducted by learners in a MOOC.

To design the functionalities and visualizations incorporated in NMP, we took into consideration those SRL strategies defined by Pintrich (1999) that were reported as the most effective for learners in MOOCs in prior work (Kizilcec et al., 2017; Milligan & Littlejohn, 2016; Veletsianos et al., 2016). These strategies are *goal setting, strategic planning, time management, self-efficacy, help-seeking* and *organization (note-taking),* and *self-reflection*. In addition to that, the indicators, and visualizations provided in each of NMP functionalities were defined based on the results of a systematic literature review in which we analyzed and classified the indicators used in 22 tools designed for supporting SRL in online settings (Pérez-Álvarez et al., 2018). Therefore, all functionalities in NMP were designed to support a specific SRL strategy. In this way, and following Siadaty et al. (Siadaty, Gašević, & Hatala, 2016) approach, we can directly relate learners' interactions with NMP functionalities with a particular SRL strategy. Figure 3-1 shows the NMP functionalities and the SRL strategies supported.

- *Goal and Planning panel*, provides learners with an open form to define goals per week (number of videos to watch, the number of evaluations to be made, the days they plan to study, and the amount of time they plan to invest in the course) and shows a set of statistics and visualizations for supporting their strategic planning (the most effective day of the week, the average of videos seen per week, the average time spent per week in the course content, the average time spent per week by other successful learners' in previous editions of the course,);

- *Time monitoring panel*, provides learners with eight visualizations about how they have their time invested in each of the course's activities and how efficient they were completing them;
- *Note taking*, where learners can create notes about the course, edit, delete, and download them;
- *Effectiveness evaluation panel*, provide learners with four visualizations to self-reflect about effectiveness completing the activities in the course, and four visualizations to compare their performance with the goals set by the teacher in the course design;
- *Social comparison* offers an interactive visualization to compare learners' performance with the performance of learners from previous editions.

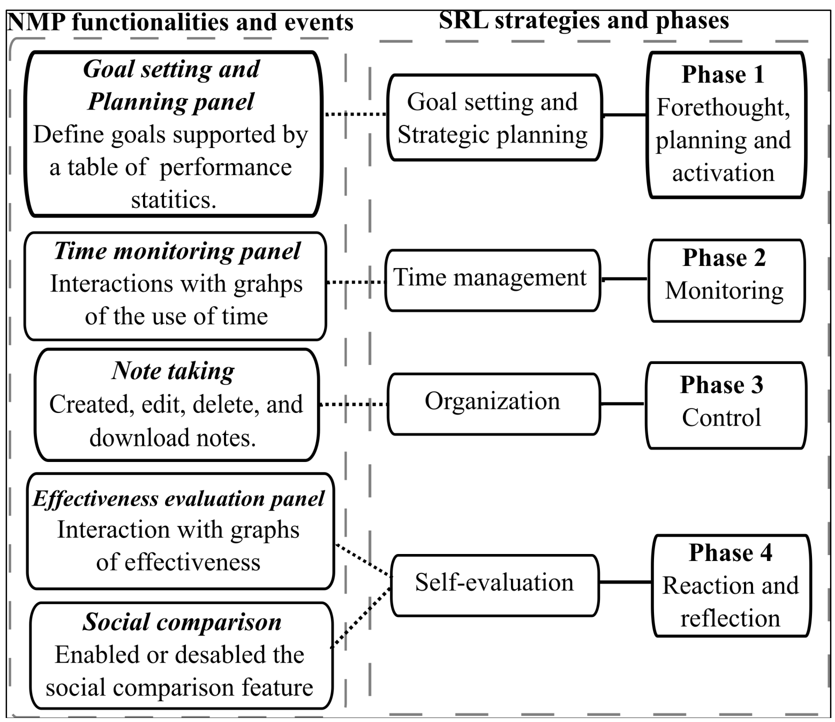

Figure 3-1: Association between SRL strategies and NMP functionalities

3.4. NMP architecture

NMP is a tool designed to complement MOOCs platforms and takes advantage of the learning and administration functionalities they offer. NMP has two main components: (1) a plugin developed in Javascript (Google Chrome), which collects information about the learning activities of learners in the MOOCs platform; and (2) a dashboard developed in Ruby (2.3.1) on Rails (5.1.3), which analyzes the collected data and creates interactive visualizations (d3.js version 3) that help the user to follow his learning process. Figure 3-2 presents NMP architecture.

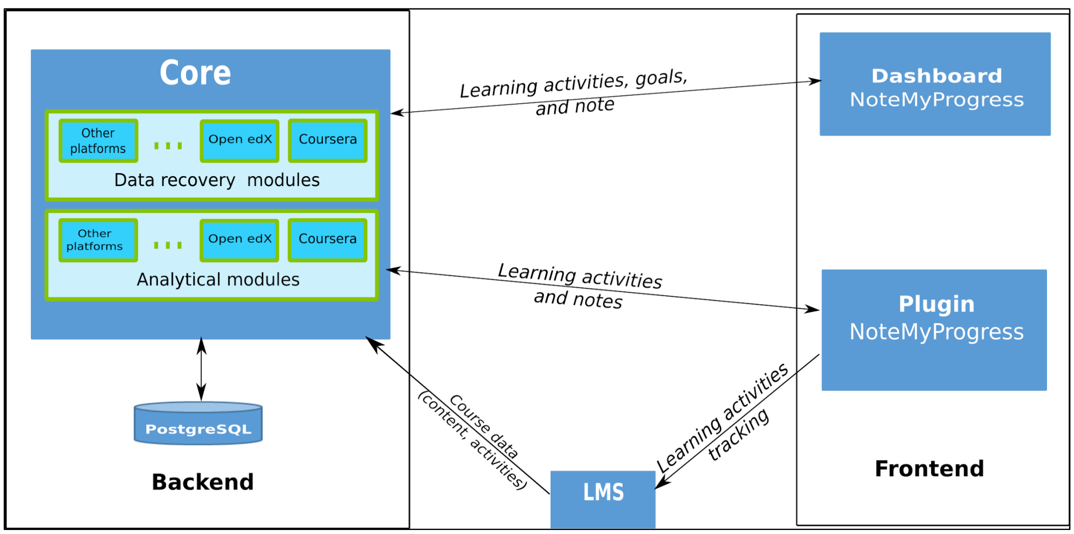

Figure 3-2: NMP Architecture

Once a learner starts his working session in the MOOCs platform, the NMP plugin tracks the URLs visited and stores them to identify the activities the learner performs on the course. A session is defined as a set of adjacent events or visited pages whose time difference is less than a set threshold - 30 minutes- (Kovanović et al., 2015; Liu et al., 2015). The URLs are sent to the NMP dashboard, where they are analyzed and decoded in the modules corresponding to the source MOOCs platform. In other words, the URL is treated in order to identify which course activity corresponds to and, thus, be able to track the learners' activities in the MOOC without necessarily embedding NMP into the MOOCs platform. For instance, the Coursera MOOC platform uses a specific hierarchy of level in its URLs (Pérez-

Álvarez, Maldonado-Mahauad, & Pérez-Sanagustín, 2018). Figure 3-3 shows the hierarchy used by Coursera. The learner data model is stored in a PostgreSQL 9.5 database. The NMP dashboard uses the information from the learner model and displays the information to the learners.

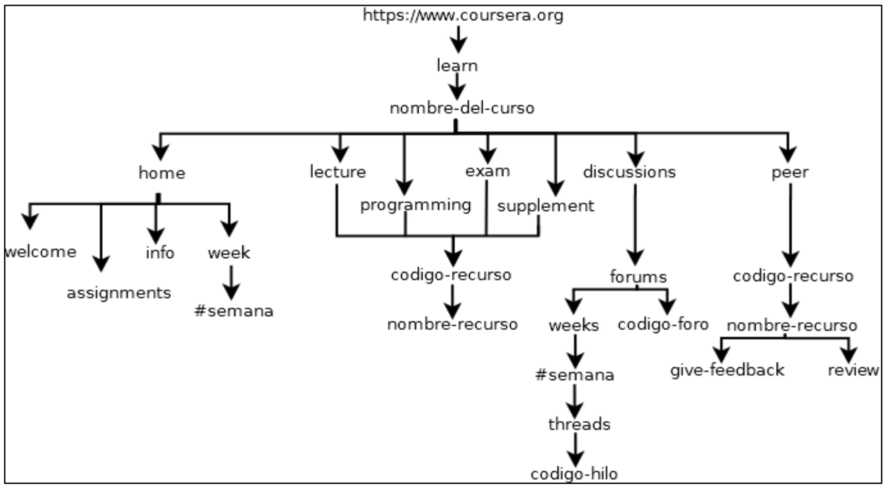

Figure 3-3: Hierarchy of levels of the components of the URLs of Coursera

NMP uses two types of data sources: (1) NMP log files and (2) external APIs (collect external MOOC platform data). Logfile data is stored through the NMP Plugin when the learner initiates a study session in the MOOC platform. This information is supplemented by information on the progress of the learners' activities in the course offered by the MOOC platform. Data retrieved from these data sources are classified and stored in the database. Indicators are then generated and used to visualize data related to learners' actions in their study sessions in the MOOC platform. For example, for an MOOC platform such as Coursera, the indicators are number of videos initiated and completed, evaluations initiated or completed, sessions completed, time invested in study sessions, among others. These indicators are organized by objectives to offer learners a visualization of their commitment to the course, their performance, and their efficiency during their work sessions. The first version of NMP was designed for Coursera's MOOC platform, but its architecture could be adapted to any other MOOC platform.

3.5. Design process of NMP

NMP design took into account the lessons learned in the *exploration phase*. Also, following the Design-Based Research (DBR) methodology, we designed the first version of NMP and evaluated its usability (Cycle 1 - Case study 1). Then we improved the first version and designed a second version to evaluate its adoption (Cycle 1 - Case study 1). This section describes the cycles performed and the mains findings.

3.5.1. Cycle one – Case study 1

In cycle one, we conducted activities related to *enactment* and *local evaluation phases* of the IDL framework. In this cycle, we carried out case study 1 to assess the usability and usefulness of the tool according to two driven questions: *RQ1. What is the level of usability of the NMP tool in a MOOC learning environment?*; *RQ2. What is the perceived implementation of NMP as a tool to support learners' self-regulation strategies?* The results of this first cycle allowed us to understand the level of usability of the tool and its usefulness in support of SRL strategies for the learners. The results of this first cycle were used to improve the version of the tool.

3.5.1.1. Enactment phase

In this phase, we designed the beta version of the NMP. It also promotes learners' awareness about the learning process and interaction within the course, so they can make decisions and adjust their behavior throughout the course (Pérez-Álvarez, Maldonado-Mahauad, et al., 2017; Pérez-Álvarez, Pérez-Sanagustín, & Maldonado-Mahauad, 2017). The first beta version of NoteMyProgress was designed to complement the current MOOC platforms (R1). The Plugin component allows the learner to use our tool within any platform. However, for this first version of the tool, only support for the Coursera platform was developed. The visualizations and functionalities implemented in the tool were aimed at supporting the strategies of *time-management* and *organization* (R2). The main interface of the plugin includes a graph (Figure 3-4.a) that shows the time spent by the learner on learning activities (within the platform) and the time of procrastination (activities outside of the platform). The version includes a notebook (Figure 3-4.b) so that the learner can take notes on the relevant content. These two features also provide support for the learner within the learning platform (R3). The dashboard supports the leaner outside the learning platform (R3) and incorporates various visualizations (Figure 3-5) aimed at supporting the aforementioned SRL strategies (R2). In this version, we defined a set of indicators to generate visualizations that provide feedback to learners: (1) *time spent in the platform*; (2) *time spent outside the platform* – procrastination; (3) *time spent per activity category* – videos, assessments, forums; (3) *time required per activity category*; (5) *number of different activities started per activity category,* Figure 3-5.a; (4) *number of activities required per activity category,* Figure 3-5.b. This version used the goals proposed by the teacher in the learning activities, as a criterion for comparison of learner performance (R5).

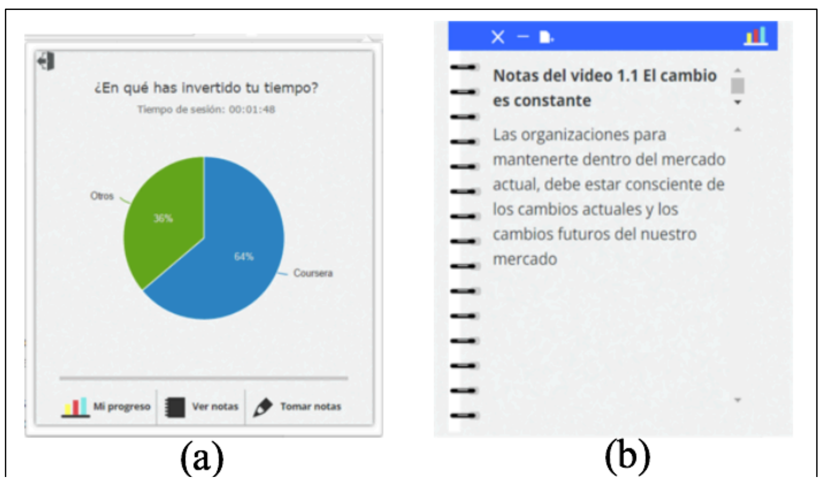

Figure 3-4: main Plugin Interface and Notebook of NMP beta version

The architecture of the beta version was designed to be adapted to any MOOC platform (*R1*). Specifically, a plugin was designed to be installed in the browser and thus could be used with any platform. Currently, the tool was implemented to recognize the structure of URLs on the Coursera platform, but it could be used on other platforms. The visited URLs represented the activities carried out by the learner during their study session. The learner had to enable tracking upon logging into a study session in progress. Before installing the plugin, learners had to accept the informed consent, which explained the information that would be saved and the tracking that the plugin would carry out. The data collected by the plugin were constantly sent to the dashboard. The dashboard is a web application developed in Ruby 2.3.1 with Rails 5.1.3 to support learners outside the MOOC platform (*R3*). The dashboard has several modules for data analysis, one of which is specialized in the interpretation of each MOOC platform, which aims to provide support for learners. The analysis module groups together the activities in sessions and stores them in a PostgreSQL database. For the storage of the information processed by the analysis modules, we define a learner model that integrates the collected activities of different platforms. This learner model is independent of the original data platform to facilitate the integration of the tool with other MOOCs platforms (i. e. edX, Open edX).

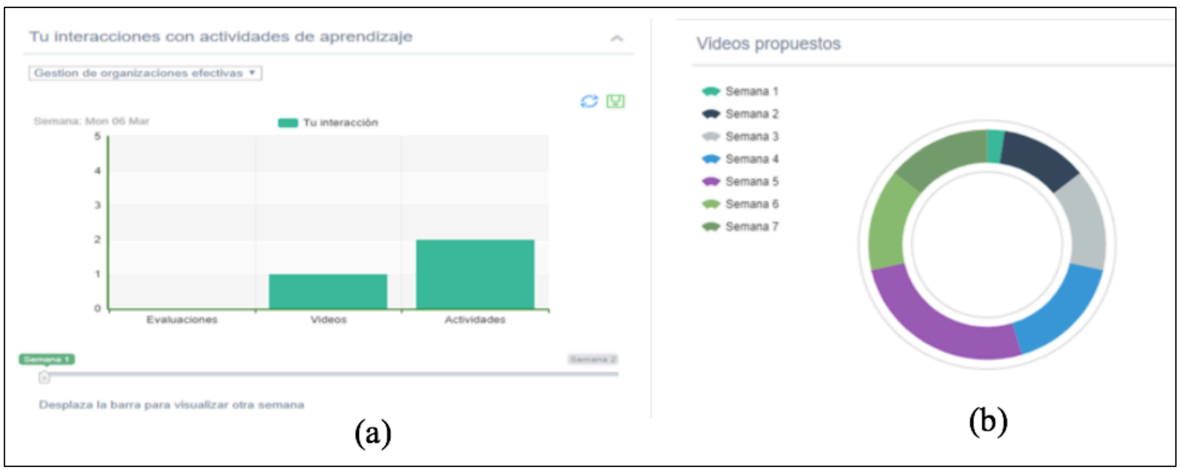

Figure 3-5: examples of visualizations of the NMP first beta version

3.5.1.2. Local evaluation phase: evaluation of usability and usefulness

In this phase, we evaluated the usability and usefulness of the beta version of NMP.

Participants, sample and procedure

The case study 1 performed was conducted in the course Gestión de Organizaciones Efectivas, offered by Pontificia Universidad Católica de Chile on the Coursera platform. This course is structured in seven-week and was launched in October 2015. The case study was performed only in the first two weeks of the course (week 3-4, March 2017). Four experts (Females = 1, Males = 3) from three countries and seven learners (Females = 3, Males = 4) from four countries (Mexico, Ecuador, Costa Rica, Colombia) participated to assessing the usability of the tool. Based on the demographic data, the ranges of the age of the learners were one under 25, three between 25 and 35, and three between 36-45. Of the seven learners, six with a bachelor's degree or higher and one from secondary education. The experts' group was limited to four evaluators in consideration of the suggestions made by (Nielsen & Molich, 1990), who indicates that the ideal number of experts to complete an evaluation is between three and five. The experts were selected for having experience in systems development, interface usability and design, and MOOCs. Learners participated voluntarily in the evaluation. The same seven learners participated in the usefulness assessment.

The experts were invited to participate via email. The mail was sent to five experts. However, only four agreed to participate in the evaluation. The experts enrolled as learners in the course and were asked to carry out certain learning activities to feed data to the tool. The experts received a guide with the activities to be carried out on both the platform Coursera and the NMP tool. The learners, which enrolled during the evaluation period, were sent an email during the first week of the course, explaining the case study and inviting them to participate in the evaluation. The plugin was shared with the MOOC participants through a Google drive folder. The participants should, voluntarily, download and install the plugin manually, following an installation guide.

The usability of the tool was evaluated using a questionnaire designed according to the evaluation heuristics proposed by (Nielsen, 1995). We selected the heuristics evaluation approach because it is an appropriate, efficient, and highly effective usability evaluation method in the context of e-learning (Ssemugabi & de Villiers, 2007). All questions followed a 5-point Likert scale, where 1 represents "Totally Disagree," and 5 represents "Totally Agree." The average evaluation given by the learners and experts for each of the Nielsen principles was calculated.

To measure learners' usefulness perception of the tool, we designed a different questionnaire[1] addressing each functionality included in the tool. This instrument was specifically designed to get qualitative information about the main functionalities of the tool. The questionnaire is composed of 15 questions. Eight questions related to the different functionalities provided in the tool. For instance, "*The information shown in the visualizations is relevant to me."* These questions follow a 5-point Likert scale, where 1 is "Totally Disagree" and 5 is "Totally Agree." Moreover, the questionnaire has two open-ended questions asking about suggestions for new functionalities and general comments, four demographic questions, and one question aimed at knowing their consent to the use of a future version of the tool.

Both the usability and the usefulness questionnaire were delivered to the participants separately. The usability test was delivered once the participants finished the two weeks evaluation period. The usefulness questionnaire was delivered two days after completing the usability test. Twenty learners downloaded the tool, but only 11 completed the installation process. An invitation was sent by mail to the 11 learners who installed the tool, which seven completed the usability and usefulness questionnaires. Learners responded voluntarily to the invitation to fill out the questionnaires. In addition, three of the learners were also interviewed in order to learn more about their experience with the tool. And usefulness.

Results of Cycle 1

Table 3-1 summarizes the main findings of Cycle 1. At the end of the of Cycle 1, the averages usability evaluation of the tool given by the experts in all the evaluation principles were above 3.67 (Pérez-Álvarez, Pérez-Sanagustín, et al., 2017). The two principles with a lower average of the evaluation were the *user control and freedom (3.83)* and the *consistency and adherence to standards (3.67).* The averages usability evaluation of the tool given by the learners' in all the evaluation principles were above 3.86. The two principles with a lower average of the evaluation were the *visibility of system status (3.86)* and the *consistency and adherence to standards (3.95).* Most of the evaluation criteria regarding usefulness obtained

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[1] https://drive.google.com/open?id=1zsFGYqA6GMTCFNlhxlFhlmfUgdARCuhU

an average of above 3.71. The criterion with the least evaluation was: *Dialog boxes - messages that show the visualizations when the mouse is over them- display relevant information (3.71).* In addition, we got the following suggestions from the experts and learners: (1) improve the *visualizations* to give clarity to the information; (2) improve the interface of the notebook; (3) optimize the response time; (4) improve interaction with visualizations; (5) add more information about their interaction with the activities; and (6) add notifications on activities to carry out for each week. As a result of the learner interview analysis, the following suggestions were obtained: (1) improve the plugin installation process; (2) expand the functionalities.

The results indicate that experts and learners positively assess the usability of the tool. Likewise, learners considered the tool to be useful for supporting their learning process and that the visualizations are useful for reflecting on the use of time. However, one of the main problems encountered was the plugin installation process, which is the main component for learners' interaction with the dashboard. Of the 20 learners who downloaded this software tool, only 11 completed the installation process. This suggests that access and installation of the tool should be easy and intuitive for learners. Regarding the tool's design and functionality, we also detected certain limitations in the study. First, the obtained comments suggest that the tool's interface needs to be improved regarding the order of the displayed elements and content to give greater clarity to the information shown. Second, learners require the integration of additional functionalities that allow them to gain a more in-depth analysis of their learning and plan the completion of their activities.

Table 3-1: Results summary from Cycle 1 research (Case study 1)

Research Cycle	**Main results regarding the *NMP* evaluation**
Cycle 1: (Case study 1) Evaluation of usability and usefulness	• It is a usable tool • It is a useful tool for learners • The installation process should be simple • The need to improve the tool interface • The need to improve the visualizations

3.5.2. Cycle two – Case study 2

In cycle two, we conducted activities related to the *enactment* and *local evaluation phases* of the IDL framework. In this cycle, we carried out the case study 2 to evaluate the adoption of the second beta version of NMP. The research question used to guide the study case 2 was the following: *RQ3. What is the level of adoption of the NMP tool in the MOOC learning environment.?*. The results of this study case contribute to understanding how learners interact with the different functionalities of NMP.

3.5.2.1. Enactment phase

In this phase, we took into account lessons learned in cycle one to improve the first beta version of NMP and design a second beta version. In this second beta version, we improve visualizations and added explanatory text (ToolTipText components) to help learners to understand the information feedback. Figure 3-6 shows one example of the visualization of the number of different activities started per activity category. Another improvement in the second beta version was the installations process of NMP Plugin. The NMP plugin was uploaded to the Google Web Store, and learners received the link to download and installed it by pressing the install button. Finally, the second version of NMP tracked learners' interaction whit NMP functionalities and stores them a logfile.

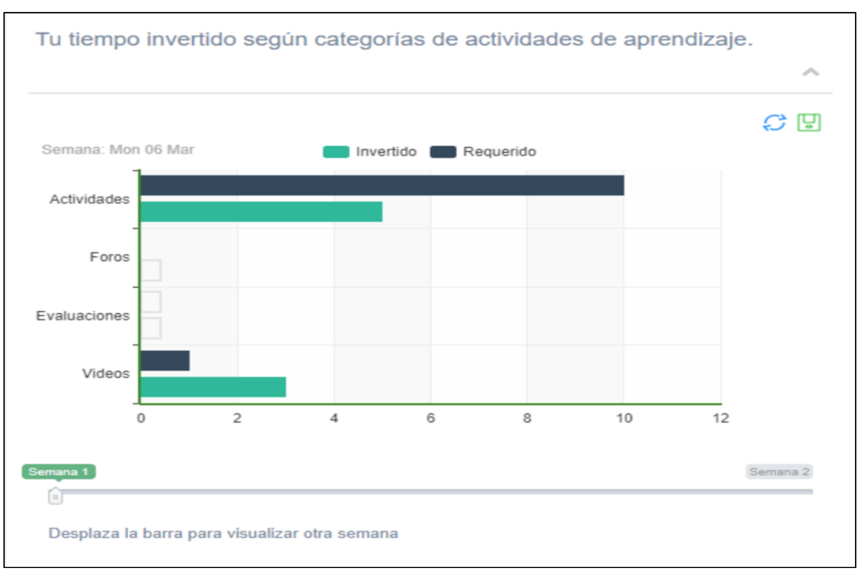

Figure 3-6: example of visualization of the NMP second beta version

3.5.2.2. Local evaluation phase: Evaluation of the adoption

Participants, sample and procedure

The case study 2 was conducted in three MOOCs: (1) Gestión de organizaciones efectivas, which has a duration of seven weeks; (2) Hacia una práctica constructivista en el aula, which has a duration of 10 weeks; and (3) Electrones en Acción, which has a duration of four weeks. All courses are offered by the Pontificia Universidad Católica de Chile on the Coursera platform. This case study had a duration of 2.5 months (April, May, June of 2017). A total of 126 learners (Males = 70%, Females = 30%) from 10 countries participated in the case study carried out in this cycle. The demographic information was obtained from the data report downloaded from the Coursera platform, which provides little demographic data on learners. All the learners who were enrolled during this time were sent an email in the first week of the course, explaining the case study and inviting them to participate in the evaluation. A total of 3,915 learners received the invitation email.

The method for data collection used in case study 2 was based on the logs generated by NMP. In the analysis of the logs, the following analysis variables were considered: the *number of entries*, *number of interactions with the different visualizations and functionalities, frequency of entries*. For the analysis of learners' interaction with the different visualizations and functionalities, we consider the three types of visualizations available in the tool (Time spent vs. Procrastination, Time spent per activity category, and Activities started). We count the number of learners' interactions with each of the visualizations' types. Moreover, we consider the interaction with note-taking functionality and counting the interaction number. To facilitate the understanding of the data, the data were classified according to the number of entries to the tool (1, 2, 3, 4, 5-8, 12-17). This classification allows analyzing the number of learners and the frequency of entering the tool. The entries were counted as the use of the tool in different periods of time, i.e. if a learner entered and carried out several consecutive interactions, we counted only one entry. Finally, with the aim of having an overview of learners' SRL strategies proposed in the Pintrich's model, the note-taking functionality was associated with the *organization* strategy, the learners' interaction with the time visualizations was associated with *time-management* strategy, and the learners' interaction frequency with the tools was associated with *self-monitoring* strategy.

Results of Cycle 2

Table 3-2 shows the results of the learners' frequency of entries to NMP. Most learners, 66 (52%), enter the dashboard only once, and the highest number of admissions is 17.

Table 3-2: Number and frequency of entries to NoteMyProgress beta version

# of entries	# of Learners	Frequency (days)
1	66 (52%)	-
2	22 (17%)	1.5
3	10 (8%)	2.5
4	6 (5%)	5
5 – 8	13 (10%)	5
12 - 17	3 (2.5%)	2.5

Table 3-3 shows the results of the interaction with the different functionalities of NMP. A total of eight learners used the note-taking feature, which created a total of 15 notes. There was a total of 196 interactions with the functionality for downloading notes, but we do not have the record of the number of notes downloaded. Although there was not extensive use of the note-taking functionality, it can be observed that the organization strategy is present among the activities that some of the learners perform. To analyze the data on learner interaction off the platform, we found that on average, 98% of the time used by the learners was spent on activities within the platform, and only 2% was used on procrastination activities. Moreover, we have observed that learners interact with time-management functionality, and they have interested in monitoring and to know how they use their time.

Table 3-3: Interaction with different visualizations of NMP beta version

Name	Type	# of interactions
Time spent vs. Procrastination	Visual	511
Time spent per activity category	Visual	459
Activities started	Visual	321
Downloading of notes	Functionality	196

The results obtained in research Cycle 2 (Table 3-4) show that there was a considerable increase in the number of learners who used the tool in Cycle 1 and Cycle 2, which suggests that the complexity of the installation process is an important limitation in the design of the tool. A high percentage of learners only entered the dashboard once, which is an indicator that the information shown in the visualizations is not entirely clear or meaningful for those learners. However, we noted that about 30% of learners had an interaction equal to or higher than three interactions with an average time frequency of 4.5 days. This indicates that learners connect or monitoring their learning at least once a week. Learners' interaction with the NoteMyProgress dashboard denotes the use of self-monitoring strategy, which allows learners to monitor their performance in the course. There is low use of the notebook; this data agrees with the suggestions obtained in Cycle 1 on improving the notebook interface. Considering the results of Cycle 2, we can obtain some conclusions for the definition of new requirements. First, learners require more information about their learning process that the regular use of the tool. Second, the factor of time is an important component of the process of monitoring the learners. Finally, we found that learners perform activities related to Pintrich's strategies, such as self-monitoring, time-management, and organization.

Table 3-4: Results summary from Cycle 2 research (Case study 2)

Research Cycle	Main results regarding the NMP evaluation
Cycle 2: (Case study 2) Evaluation of the adoption	• Many learners interact just once, due to a lack of clarity and to the relevance of the information displayed. • There was an increase in adoption regarding the number of learners who used the tool in cycle 1. • The average frequency of learner's entry was 4.5 days. • The greatest interaction occurred with visualizations that show information on time spent. • Learners perform activities related with Pintrich's strategies such as self-monitoring, time-management and organization

3.5.3. Cycle three – Case study 3

In cycle three, we conducted activities related to the *enactment* and *local evaluation phases* of the IDL framework. However, in this subsection, we only describe the activities related to the *enactment phase.* The evaluation of the NMP release version is described in Chapter 4. In this cycle, we design the release version of the NMP to evaluate the impact and answer the following research question: *What effect would the educational tool have in terms of improving learners' self-regulatory strategies and achievement?.*

3.5.3.1. Enactment phase

In this phase, we considered the results of the evaluations of the NMP beta version and designed the release version of the NMP. From the evaluation results of the NMP beta version, we obtained the following list of requirements that we believe should be taken into account for the design of a tool that supports self-regulation in MOOCs.

The first requirement is the design and implementation of a **usable tool** to assist the learner in understanding the feedback information shown by the tool. The installation process and access to the tool should consider the diversity of learners enrolled in the MOOCs. In addition, the tool interface must be standardized and organized to facilitate navigating and understanding of the information.

The second obtained requirement is that we should create an organization of indicators to improve the visualizations and provide greater clarity to the feedback information shown on the tool. Table 3-5 shows our proposal of indicators organized into three categories, which were defined considering the literature review and the results of the two case studies. The categories are *engagement*, *performance,* and *effectiveness. Engagement* is the follow-up activities that show learner interaction within the course. *Performance* is a follow-up to the activities that allow learners to view their progress during their learning process, including the attainment of personal goals set by the learner. *Effectiveness* is a follow-up to the activities which allow learners to view the periods in which they have an excellent performance. A subcategory added in NoteMyProgress for the display of indicators is the management of sessions. Learners can view their behavior grouped by study sessions. Each of the indicators was associated with a specific SRL strategy that can be supported by that indicator and some visualizations. The association of indicators regarding the strategies was based on the definition of each strategy of the Pintrich model.

Table 3-5: Types of data collected, indicators and strategies supported by each indicator TM = Time Management, O = Organization, SP = Strategic Planning, GS = Goal Setting, SE = Self-evaluation.

Type	Indicator	Description	Strategy supported
Engagement	time spent (course, session, category, procrastination)	time spent summarize	TM
	number of sessions	number of sessions achieved.	TM
	time required	total time estimated by the teacher to each category.	TM
	weeks on the course	number of weeks spent.	TM
	study frequency	average time among sessions.	
	notes took	number of notes taken in the course.	O
Performance	activities completed	number of different activities completed.	TM, SE
	activities started	number of different activities started.	TM, SE
	activities attempted	number of different activities attempted.	TM, SE
	activities required	number of activities proposed by the teacher.	TM, SE
	videos planned to watch	number of videos planned by the learner to watch during the week.	SP, GS
	time planned to spend	time planned by the learner to spend during the week.	SP, GS
	evaluations to be taken	number of evaluations planned by the learner to do during the week.	SP, GS
Effectiveness	most effective day	day of the week and time of the week in which most activities are completed.	TM, SP

Finally, the third identified requirement is that the tool should be equipped with **robust and interactive visualizations.** The interactive component added to the visualizations allows the learner to have the option of attaining a more in-depth analysis of their behavior and focus on the most relevant points according to their goals and personal needs.

The release version of the NMP offers support to the five requirements identified in the Exploration phase and results of the evaluations of the NMP beta. The functionalities designed for this release version support the following SRL strategies: *Goal setting and Strategic planning, Time management, Organization,* and *Self-evaluation* (see Figure 3-1). Also, in this version, we improve all NMP dashboard's visualizations and NMP Plugin. First, the new version of the NMP plugin includes a new notebook visual appearance of the notebook with a WYSIWYG (What You See Is What You Get) to offer editing facilities and encourage the use of the notebook (see Figure 3-7).

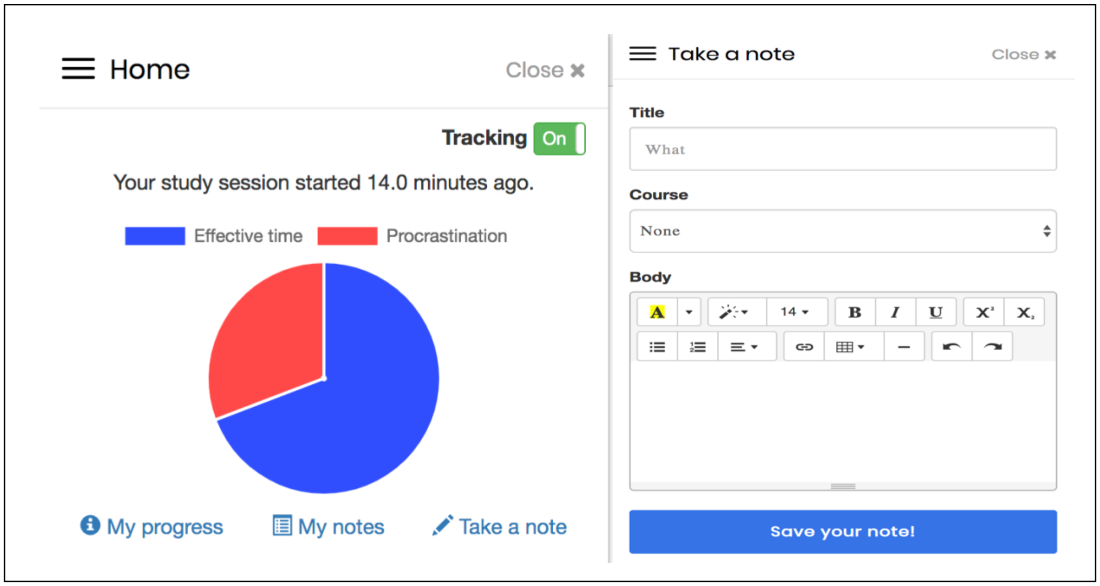

Figure 3-7: main Plugin Interface and Notebook of NMP release version

Second, the design of the visualizations allows learners to analyze information from different perspectives and time periods: session, activity category, day, month, or view a general outline of the learning process until the current week (see Figure 3-8).

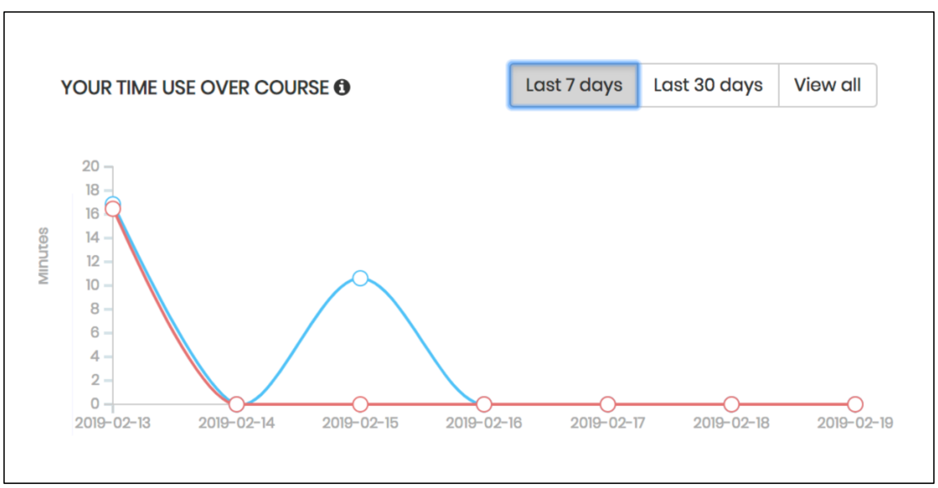

Figure 3-8: example of interactive visualization in NMP

Third, we added goal setting functionality. This functionality allows learners to define their personal goals for each week of the course. This functionality aims to make learners reflect on their degree of commitment to the course and the time available to achieve their individual goals. Figure 3-9 shows the form used to goal setting, her the learner can define the number of videos to watch, the number of evaluations to be carried out, time to spend, and the day planned for studying. In order to support the strategic planning of learners at the time of defining their goals. NMP presents a set of indicators of their performance in the previous week. Specifically, it provides information on their overall performance in the course so far, on the activities to be performed over this week, and on the performance of other learners who completed the course in previous editions (see Figure 3-10). the objective of these indicators is to help learner to plan their goals in a more strategic and informed manner.

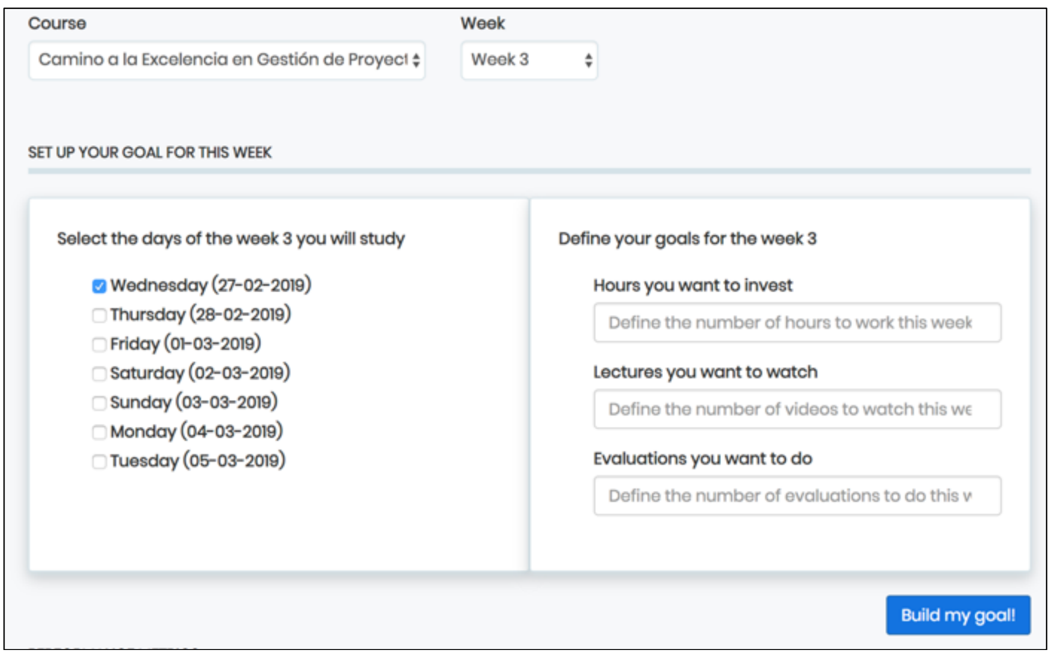

Figure 3-9: Goal seting interface

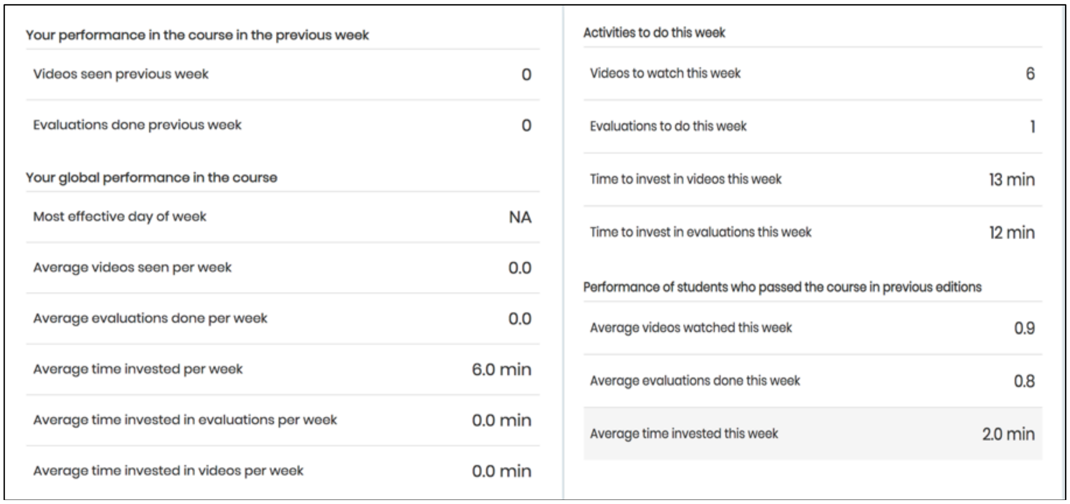

Figure 3-10: Performance metrics to strategic planning

Four, we integrated a functionality that provides learners a comparison (see Figure 3-11) of their performance with the rest of the learners in the course with data from previous courses. Social comparison has shown to have a positive effect on learner engagement and efficiency (Brusilovsky, Somyürek, Guerra, Hosseini, & Zadorozhny, 2015).

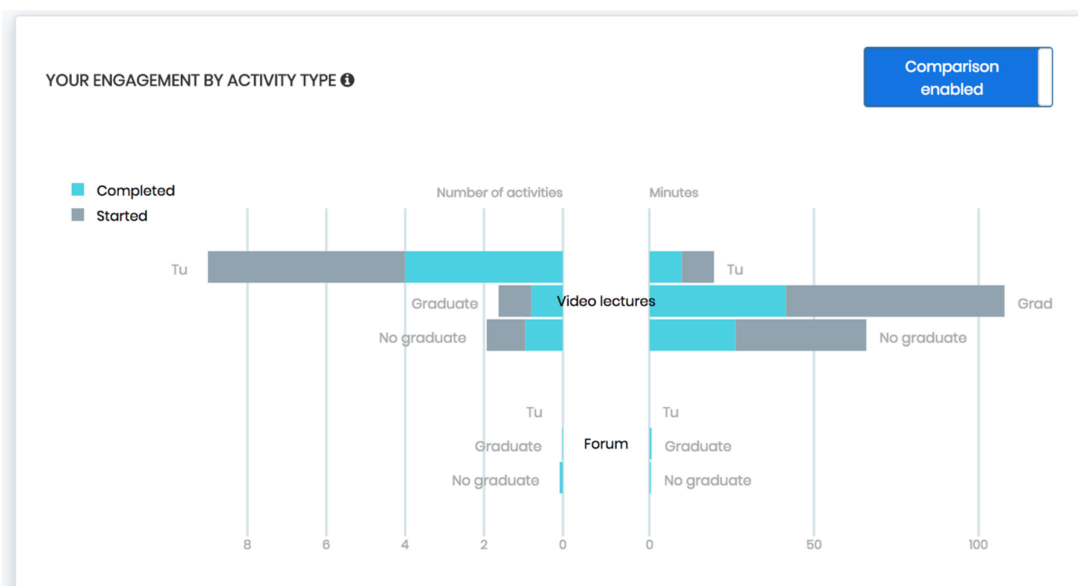

Figure 3-11: Social comparison visualization

Finally, the dashboard NMP is organize in two panel: the main panel show visualization related to learners' performance (see Figure 3-12), and secondary panel show visualization related to learners' effectiveness (see Figure 3-13).

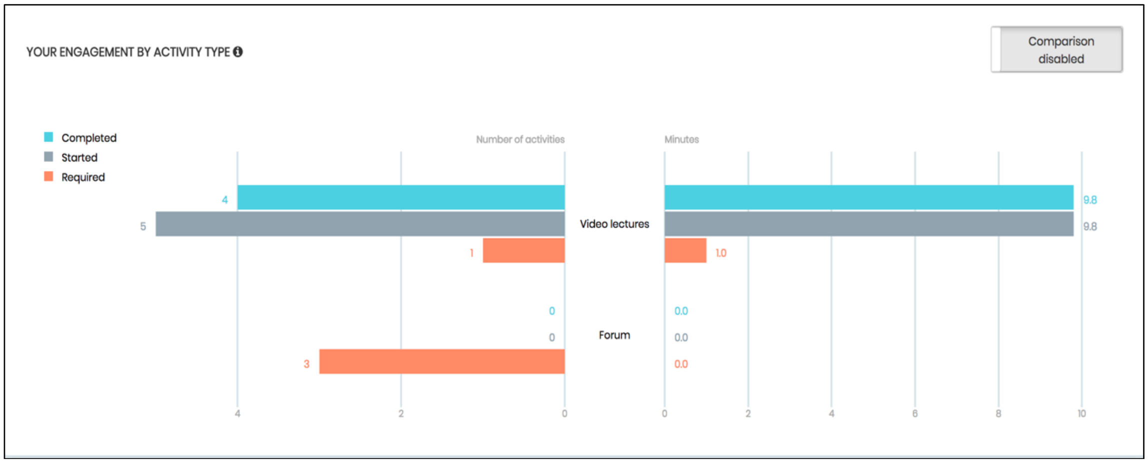

Figure 3-12: Example of visualization of learners' performance

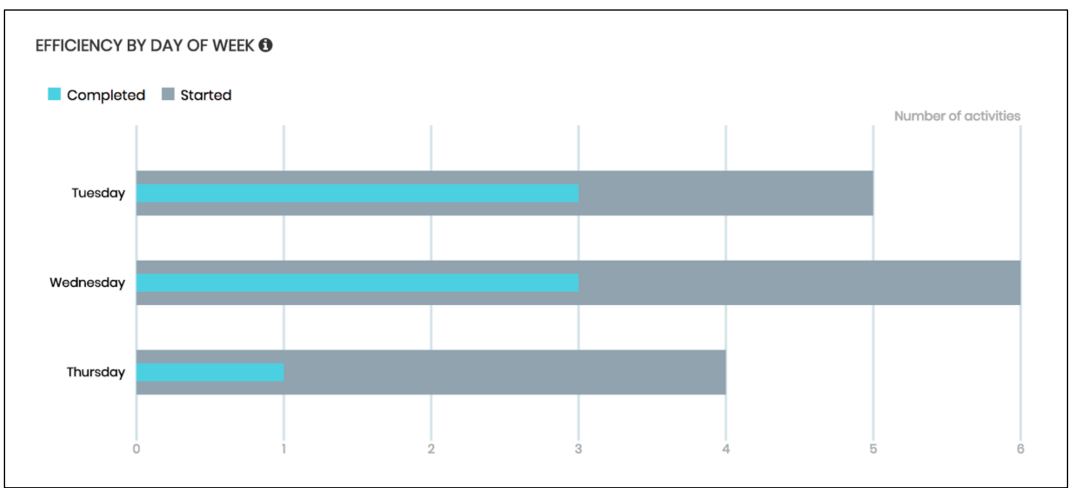

Figure 3-13: example of visualization of learners' effectiveness

3.6. Conclusions

This chapter presented the NMP tool, a tool designed to complement the current MOOC platforms and support learners' SRL strategies in MOOCs. Also, this charter presented the design NMP. To designed NMP we conducted three Cycles of the IDL framework, in each cycle, we performed a case study. In cycle one, we designed the first beta version of NMP and evaluated its usability. In cycle two, we designed a second beta version of NMP and evaluated its adoption. The results of these two cycles provide a list of useful requirements to design tool to support SRL in MOOCs.

The main conclusions of the design process suggest that a tool to support SRL in a MOOC must have the following requirements: (1) be a usable tool; (2) organize the indicators to be displayed; and (3) design robust and interactive visualizations. These requirements can be used as the basis to propose alternative designs for the support of SRL in MOOCs. As an example, and in order to propose an operationalization of these requirements, this article has presented the beta version of NMP. These requirements were used in cycle three to design the first release version of NMP. The design process of the release version of NMP followed a set of steps. First, we selected the SRL model, which was used to guide the design process. Second, we focus on those self-regulatory strategies which were shown to be most useful for the learners in the context of study. Third, we linked NMP functionalities to specific SRL strategies and define a set of indicators to measure the impact of the tool. Finally, we conducted a case study to measure the impact of NMP release version.

Chapter 4

Measuring the impact of NMP in learners' Engagement in MOOCs

This chapter performed tasks related to *local evaluation phase* of Interactive Learning Design (ILD) in order to contribute with ***Objective 3.*** *To evaluate the impact of the proposed technological solution on the behavior of learners on the platform and its relationship with self-regulation strategies, and their learning outcomes.* Specifically, this chapter shows the results of evaluation of the impact of NMP on engagement with SRL strategies and course' activities. Also, this chapter presents the results related to *What effect would the educational tool have on the self-regulation strategies of learners and their achievements.?* The content of this chapter shows the contributions of the journal article [Table 1-2; J2]. Moreover, this chapter keeps the same structure of the article. Section 4.1 presents an introduction about measures to evaluated learners' engagement in MOOCs. Section 4.2 analyze how the engagement has been measured in MOOC. Section 4.3 describes the observational case study. Section 4.4 shows the results of the evaluation. Section 4.5 presents a discussion of the results. Section 4.6 presents conclusions.

4. MEASURING THE IMPACT OF NMP IN LEARNERS' ENGAGEMENT WITH THE MOOC

4.1. Introduction

Studying the reasons of learner's engagement and disengagement with Massive Open Online Courses (MOOCs) has been one of the main lines of research in the past years (Ferguson & Clow, 2015; Kaveri, Gunasekar, Gupta, & Pratap, 2016; Kizilcec & Halawa, 2015; Kizilcec, Piech, & Schneider, 2013). Engagement in MOOCs is defined in the literature as the learners' involvement with the course content and with the tools available within the learning environment (Fredricks, Blumenfeld, & Paris, 2004; Stovall, 2003). Taking this definition as a basis, there are several researchers who have studied learners' reasons of greater engagement and disengagement in MOOCs. The results of this prior works showed that, while learners' personal intrinsic motivation (Kaveri et al., 2016), and prior knowledge (Kizilcec et al., 2013) has been related to greater learners' engagement, the lack of self-regulatory skills is one of the most attributed reasons for disengagement (Kizilcec & Halawa, 2015).

Only few in the literature actually evaluate and measure how learners' SRL strategies relate with engagement (Davis et al., 2017, 2018; Milikic et al., 2018). All these works follow a novel approach for studying SRL that Panadero (Panadero, Klug, & Järvelä, 2016) calls "the third wave of SRL measure" that consists on studying SRL taking advantage of computational systems that serve for both, scaffolding learners' SRL strategies and capturing data for measuring their self-regulatory process. Studies following this approach propose different measures for studying the relationship between engagement and SRL. Authors such as Davis et al. (Davis et al., 2017, 2018) propose high-level measures; that is, studying the relationship between engagement and SRL from an overall perspective by measuring the relationship between the number of learners' interactions with course activities and their interactions with the tool proposed for supporting SRL strategies. More recently, authors such as Milikić et al. (Milikic et al., 2018), inspired by the approach proposed by Siadaty et al. (Siadaty et al., 2016), went further and proposed micro-level measures; that is, an analysis of learners' interactions with the course content and their interactions with functionalities of the tool designed to support a particular SRL strategy.

This prior work is a starting point for analyzing what is the impact on MOOC learners' engagement when intervening with tools for scaffolding SRL. However, the number of studies analyzing this relationship is still scarce and have been conducted only in some MOOC platforms and using different indicators for measuring engagement in relation to specific SRL strategies. So, more empirical results are needed to better understand the relationship between SRL scaffolding and engagement in MOOCs. First, more analysis, in different learning platforms and with different tools for SRL scaffolding are required in order to enlarge the number of cases and data currently available in the literature. Second, particular interventions address certain SRL strategies, but not all of them, so more studies are needed for providing evidence regarding the effectiveness of some SRL strategies over others. And finally, it is important to enrich current literature with different measures of SRL, based on different indicators and combining different data sources.

In order to contribute with new empirical results and provide more evidence on the relationship between engagement and SRL scaffolding, we propose an observational case study using the tool NoteMyProgress (NMP) for intervening two MOOCs on Coursera. NMP is a tool that was designed and implemented in previous work (Pérez-Alvarez et al., 2018) to scaffold SRL strategies in MOOCs. Specifically, the present study contributes to the current body of literature by analyzing *how does the use of the NMP as a complement to a MOOC course affect the engagement of learners in course content and performance?*. We compared the level of involvement with the course resources (frequency of interaction with video-lectures, assessment activities, and supplementary materials) of those learners using NMP voluntarily and those not using it. In addition, we analyzed what the learners' self-reported SRL profiles are and whether this has an influence on both, the involvement with the course content and the usage of NMP. That is, we analyzed engagement in a holistic manner considering the frequency of interactions with both the course content and the functionalities of NMP supporting the self-regulatory strategies: goal setting and strategic planning, self-evaluation, time management, and organization.

Three contributions of this work are novel in relation to previous studies. Firstly, it is the first work that studies the relationship between SRL scaffold and engagement in MOOCs deployed in the Coursera platform. Since Coursera is a closed system, conducting interventions beyond introducing questionnaires or providing written guidelines to learners are difficult to carry out (Kizilcec, Pérez-Sanagustín, & Maldonado, 2016). In our study, we propose using NMP as a complementary tool of the Coursera platform for SRL scaffolding. Secondly, no changes were conducted in the course instructional design to scaffold learners' SRL strategies. Using NMP (SRL scaffolding) was completely voluntary, and no changes were done in the course activities for conditioning learners' behavior. And thirdly, this work proposes novel indicators for measuring the relationship between SRL scaffolding and engagement. These indicators are the results of cross-analyzing data from different sources, not only from the course and tools logfiles registering learners' interactions with the course and NMP as in previous works but also considering data from self-reported data about learners' SRL profile and their perception about the tool. All these three contributions, together with the results reported, expand current literature on the study of SRL scaffolding and engagement in MOOCs.

4.2. Measuring Engagement in MOOCs

Learners' engagement in MOOCs has been defined and measured in the literature in many different ways. Fredricks et al. (Fredricks et al., 2004) conducts a literature review on how learners' engagement have been studied and organize them into three dimensions depending on how it was measured: (1) behavioral measures, which is associated with participation in curricular and extracurricular activities and is crucial for achieving positive academic outcomes; (2) cognitive measures, related to the use of cognitive skills to understand complex ideas; and (3) emotional measures, associated with positive and negative learners' reactions to learning factors and resources. However, and despite the diversity of definitions and measures, researchers agree with the definition of engagement proposed by Stovall (Stovall, 2003), who defines engagement as the learners' level of involvement with their learning process or tools available in the learning environment, both internal and external.

According to this definition, researchers have used variety indicators for measuring engagement, such as autonomy, execution, social, delivery, participation, collaboration, cooperation, questioning, organization of the environment, and fun (Siadaty, Gašević, Jovanović, Milikić, et al., 2012). Most of the works studying engagement in MOOCs use as its main data source the information collected through the platform log files (Bodily & Verbert, 2017). These log files have different characteristics depending on the learning platform, where the experiment is carried out. However, most of them capture the learners' interaction with the resources, as well as the time in which they do it. Generally, previous studies in MOOCs used these log files as the only source of information to analyze the learners' engagement (Schwendimann et al., 2017). From these log files, several indicators are defined and then used to understand the level of learners' engagement or disengagement with the course (Anderson, Huttenlocher, Kleinberg, & Leskovec, 2014; Cruz-Benito, Therón, García-Peñalvo, & Pizarro Lucas, 2015; Ferguson & Clow, 2015; Hayati, Tahiri, Idrissi, & Bennani, 2016; Kaveri et al., 2016; Kizilcec et al., 2013; Rodrigues, Luis Cavalcanti Ramos, Carlos Sedraz Silva, & Sandro Gomes, 2016). Table 4-1 presents some examples of indicators used in prior work to measure engagement in MOOC organized according to its granularity into low and high.

Studies analyzing engagement using low-level granularity indicators propose sub-activities of a specific activity within the MOOC or in complementary tools external to the course to study the learners' behavior. For example, Hayati et al. (Hayati et al., 2016) and Davis et al. (Davis et al., 2018) analyzed the learners' interaction within the course platform with the lectures such as *start*, *pause*, *resume*, *stop*, *slide_enter*, *slide_exit, fast-forward, rewind, scrub*. Anderson et al. (Anderson et al., 2014) used as an engagement indicator the frequency of interaction with the lectures and the assessment activities in the course to classify the learners in groups accordingly. Similarly, Sunar et al. (Sunar, White, Abdullah, & Davis, 2016) studied the behavior of learners who followed other learners in the forums in relation to their behavior with the other activities of the course and the completion of the course. Their results show that learners who follow other learners in the forums increase their probability of completing the course. Other researchers use similar low-level metrics but analyzing frequencies of learners' interaction not only within the platform but with MOOC's external or complementary tools. Alario-Hoyos et al. (C. Alario-Hoyos, Muñoz-Merino, Pérez-Sanagustín, Delgado Kloos, & Parada G., 2016) analyze the learners' interactions with social network tools such as Facebook or Twitter and found a moderate relationship between the number of learners' contributions in the social tools and their engagement with the course. Similarly, Davis et al. (Davis et al., 2018) consider indicators of learners' interaction with SRLx tool to identify the relationship between its use and interactions with the course. The authors show that there is a relationship between the number of learners' interactions with the SRLx tool and their engagement with the course content; however, they do not attribute these results directly to the use of the tool.

Table 4-1: Engagement indicators

	Indicators	
	Within the MOOC Platform	**With Tools/Platforms complementing the MOOC**
Low-Level Granularity Indicators	• Frequency of interaction with lectures (*start*, *pause*, *resume*, *stop*, *slide_enter*, *slide_exit, fast-forward, rewind, scrub*) (Hayati et al. (Hayati et al., 2016), Davis et al. (Davis et al., 2018), Kaveri et al. (Kaveri et al., 2016), Sunar et al. (Sunar et al., 2016)) • Frequency of interaction on Online forums (Kaveri et al. (Kaveri et al., 2016), Sunar et al. (Sunar et al., 2016), Davis et al. (Davis et al., 2018), Rodrigues et al. (Rodrigues et al., 2016), Anderson et al. (Anderson et al., 2014), Kizilcec et al. (Kizilcec et al., 2013)). • Frequency of interaction with assessment activities (quizzes, exams…) (Hayati et al. (Hayati et al., 2016), Davis et al. (Davis et al., 2018)) • Social network interaction (Alario-Hoyos et al. (C. Alario-Hoyos et al., 2016)) • Time spent on the course activities (Davis et al. (Davis et al., 2018)). • Performance (*grade*, *max_grade*, *percent_grade*, *answers*, *num_attemps*, *firts_submit* and *last_submit*) (Hayati et al. (Hayati et al., 2016)).	• Number of interactions with external tools (number of videos & quizzes and hours planned to spend on the course that week) (Davis et al. (Davis et al., 2018)). • Motivation expression (*submission text*) (Davis et al. (Davis et al., 2018)).
High-Level Granularity Indicators	• Patterns of interaction with lectures and assessment (Kizilcec et al. (Kizilcec et al., 2013)).	

Other researchers analyze learners' engagement using high-level granularity indicators, which group low-level indicators into more complex behaviors. This is the case of the work of Kizilcec et al. (Kizilcec et al., 2013), who grouped different interactions into patterns of interaction that they then related to self-regulation strategies to analyze the level of learners' engagement with the course.

In this observational study, build upon this prior work and proposes to measure engagement using low-level external and internal indicators previously proposed in the literature. On the one hand, we use the Coursera MOOC platform log files to analyze the learners' interactions with the lecture resources and assessment activities. On the other hand, we use NMP log files to analyze the learners' interactions with the different features that it offers. To study engagement from learners' interaction with both the course material and NMP activities allows us to extract quantitative indicators such as frequency of interaction with NMP's functionalities, time invested and participation in course learning activities, and grades obtained (Rodrigues et al., 2016) that we then relate with learners' SRL strategies.

4.2.1. SRL measures

One of the most adopted methods for measuring SRL strategies are the self-reported mechanisms (surveys, interviews). These methods provide a static measure of learners' SRL profile in a particular moment of the course but are limited for capturing learners' strategies during their whole learning process (Milikic et al., 2018). In order to move forward these static measures, some researchers have been exploring different approaches that propose developing tools for scaffolding SRL strategies. These scaffolds are used both to support learners' SRL strategies and to capture their traces for analyzing their behavior during their learning process (Panadero et al., 2016). One of the main challenges of this last approach is to relate learners' actions with the scaffolding tool with the SRL strategies they are developing. Siadaty et al. (Siadaty et al., 2016) proposed an approach to establishing this type of relationship. They refer to self-regulatory phases as macro-level processes, which are composed of micro-level processes that relate to different SRL strategies. To establish an association between the scaffolding offered by the tool and the SRL strategies, Siadaty et al. (Siadaty et al., 2016) associate the different functionalities of the SRL scaffold or tool with one or more SRL strategies. Then, the interactions of the learners with the different strategies become a way of measuring the learners' strategies they are deploying. The approach proposed by Siadaty et al. (Siadaty et al., 2016) has been used by other researchers in the area of TEL (Milikic et al., 2018) to relate functionalities with micro-events related to SRL.

In this study, we took the Pintrich's SRL model (P. Pintrich, 1999) and definition of strategies as the theoretical framework to relate the learners' self-regulatory profile and activities to the observable behavior captured through log files of their interaction with the tool NMP. That is, each of the functionalities of NMP (described in Chapter 3) is related (from its design) with one or various SRL strategies as defined by Pintrich. So, we can identify learners' strategies from the analysis of their interactions with the tool at a micro-level. Then, we can study how these interactions relate with learners' activities in the course to extract indicators for measuring the relationship between the SRL strategies and learners' engagement with the MOOC.

4.3. Observational Case Study

Observational case studies provide valuable information regarding the influence of technology in a particular context to address "how" and "why" questions (Rowley, 2002; Yin, 2003). For Zelkowitz & Wallace (M. V. Zelkowitz & Wallace, 1998; M. V. Zelkowitz, 2009) case studies are also a good means for monitoring a software project within an authentic situation and collecting data over time with a research objective. In this paper, we propose an observational case study as the evaluation method that fits our research scope. The intervention here consists of the deploying NMP in two MOOCs in Coursera in order to analyze its effect on learners' SRL strategies and engagement with the course resources. Specifically, we tackle the following research question: *How does the use of the NMP as a complement to a MOOC affect the engagement of learners in course content and performance*?

4.3.1. Context: MOOCs and participants

This study was conducted in five different editions of two MOOCs offered by Pontifical Catholic University of Chile on the Coursera platform from April 2018 to July 2018. These MOOCs were: MOOC one titled “Gestión de organizaciones efectivas”, and MOOC two named “Camino a la Excelencia en Gestión de Proyectos”. The two courses focus on different target audiences, which facilitates the diversity of the study participants. Table 4-2 shows the information of the courses considered in the analysis, the duration in weeks, the number of lectures in the course, the number of assessments, and the number of supplemental activities performed. The supplemental activity type corresponds to a category assigned by the Coursera platform to refer to textual readings used to describe activities, case studies, give instructions, or welcome messages.

All learners enrolled in the course were invited, by email, to use the NMP tool to support their self-regulation strategies. In each course, two emails were sent; one during the first, initial, week of the course and another during the second week. The link to the plugin was offered through email and in the first had access to the plugin, its installation was voluntary, and they did not receive any kind of remuneration for their participation in the study. All learners who voluntarily accepted to download and use the plugin completed a Consent form that was previously validated by the Ethical Commission of the University. The learners who downloaded the plugin could use it freely throughout the course. In addition, at the beginning of the course, participants were invited to complete a questionnaire to measure their self-regulation profile. At the end of the course, participants who used NMP were invited to answer a questionnaire for collecting their perception about the tool. Details on the questionnaires and their characteristics are described in section B. *Instruments and Data Collection.*

Table 4-2: course description and learners' status

Course	Course Content	Edition	Enrolled	Completers	Answers SRL questionnaire	Participants sample	
						NMP Group	NoNMP Group
[MOOC 1] Gestión de organizaciones efectivas.	7 Weeks 42 Lectures 6 Assessments 7 Supplementary materials	1 2 3 4 5	657 618 512 689 919	62 53 41 41 41	61	24	37
[MOOC 2] Camino a la Excelencia en Gestión de Proyectos.	5 Weeks 26 Lectures 4 Assessments 0 Supplementary materials	1 2 3 4 5	2,738 2,728 2,992 3,167 4,032	172 117 114 155 194	202	67	135
Total:			19,052	990	263	91	172

Of 19,052 learners who enrolled in any of five editions of the two MOOCs, 638 downloaded NMP. However, for the purpose of this study, we only selected as the data sample 263 learners that answered the SRL questionnaire completely and registered, at least, an interaction with at least one resource of the course and one assessment. 64 % were males and 36% females, from 25 different countries. 54% have a bachelor level of education, 33% have a master level of education, 10.4% have a secondary level of education, and 1.7% have a doctoral level of education. Within the data sample, we separated those that used NMP (N=91) (called NMP Group) and those who did not (N=172) (called NoNMP Group). See Table 4-2 for information about the number of learners enrolled in each edition of the course. From this group, 57 learners answered the questionnaire to evaluate NMP.

4.3.2. Instruments and data collection

We used four data collection methods:

SRL Questionnaire. This instrument was created for measuring learners' self-regulatory profile. It is based on four questionnaires available in the literature which measure SRL in different contexts (Littlejohn et al. (Littlejohn et al., 2016), MSLQ by Pintrich et al. (P. R. Pintrich, Smith, Garcia, & Mckeachie, 1993), OSLQ by Barnard et al. (Barnard, Lan, To, Paton, & Lai, 2009) and LASSI (two editions) by Weinstein et al. (Weinstein & Palmer, 2002). The final instrument consisted of 25 questions related to six SRL strategies. The strategies were evaluated on a 5-point Likert scale, where 1 is "Not at all true for me" and 5 is "Completely true for me". The questions are organized into groups of three to four questions measuring the following SRL strategies: Self-efficacy (six statements), Goal Setting (five statements), Study Environment Management (three statements), Organization (four statements), Help-Seeking (four statements) and Time Management (three statements). The reliability of the questionnaire was validated in prior work (Kizilcec et al., 2017).

EFLA Questionnaire. The Evaluation Framework for Learning Analytics (EFLA) is an instrument designed to evaluate learning analytics tools according to three different dimensions: Data, Awareness and Reflection, and Impact (Scheffel, 2017). The instrument consists of eight questions: two question related with the Data dimension, four questions for the Awareness and Reflection dimensions, and two for the Impact. All items were evaluated on a 10-point Likert scale, where 1 is “strongly disagree” and 10 is ‘strongly agree’. Each dimension is evaluated with a score in a range of values between 0 and 10, and the final EFLA score is presented in a range of values between 0 and 100. Apart from these eight questions included in EFLA, we also added at the end one open question to collect learners’ personal opinion about the tool.

Coursera Log files. These log files record the interactions that learners have with the platform’s resources and the moment in which said interaction takes place. For this study, we only considered the interactions with the lectures, the summative evaluation activities (the exams), and the supplemental activities. Training assessment activities or peer reviews were not taken into account.

NMP Log files. NMP collects information in three different log files, one corresponding to the learners’ interactions with the *dashboard*, another corresponding to their activity with the *Plugin* and another corresponding to *the Goals form* that includes the learners’ learning objectives per week. *The dashboard log file* records the learners’ interactions with the different visualizations of the dashboard offered by the tool, the available navigation options, and the moment in which these interactions occur. *The Plugin log file* captures the learners’ interactions with the plugin functionality that allows learners to take notes. Specifically, all interactions with these notes are captured: delete, edit, search, and download. *The log file of the goal setting form* registers the individual goals that the learners plan to achieve in a specific week.

Learners grades in the MOOC. Correspond to the learners' final grades at the end of the MOOC provided by the Coursera platform based on the grade registers.

4.3.3. Measures

The data collected from both the Coursera and NMP log files were used to generate the engagement measures that we used for evaluating learners' level of engagement with the course and the NMP. These measures, together with the results of the SRL questionnaires and the learners' final notes, were used to prepare the dataset used for the final analysis.

Engagement measures. We defined two different types of engagement: (1) learners' engagement with learning activities in the MOOC, and (2) learners' engagement with NMP. *To measure learners' engagement with MOOC activities,* we defined seven indicators based on the number of learners' interactions with the video-lectures, assessment activities, and supplementary material (see Table 4-3).

To measure the engagement of learners with NMP, we define a set of indicators based on learners' interaction with the tool. In this study, we used this association as a basis for grouping learners' interactions with the different functionalities of NMP and a specific self-regulation strategy. Table 4-3 summarizes the list of indicators used to measure learners' engagement with the course and with NMP. Notice that, for the indicators related with NMP, we also indicated which SRL strategy they are related to:

- For the **Time management** strategy, we defined the indicator *time_vis_interaction*. This indicator collects the frequency of learners' interactions with any of the eight visualizations available at the *time monitoring panel* that shows their time investment in all course activities.

- For the **Goal Setting** strategy**,** we defined the *goal_interaction* indicator. It captures the number of times a learner interacted with the *goal setting and planning panel*. Learners can define goals once per week, so the maximum number of interactions per learners with this functionality will be equivalent to the number of weeks in the course.

- For the **Organization** strategy, we defined the *note_interaction* indicator. It indicates the number of times a learner interacted with the *note taking* functionality implemented in NMP, which can be to create, edit, delete, search, or download a note.

Table 4-3: Metrics to measure engagement

Engagement with learning activities in MOOC	
Indicators	**Description**
exams_interacted	Frequency of interaction with summative training activities: exams
lectures_started	Frequency of interaction of start of visualization of lectures, but without completing it.
lectures_completed	Frequency of interaction with the lectures that the learners ends
lectures_interacted	Frequency of interaction of the learners with a lecture once initiated, without necessarily ending it.
suppl_started	Frequency of complementary activities initiated with the learners, but not completed.
suppl_completed	Frequency of complementary activities that the learners initiates and completes.
suppl_interacted	Frequency of complementary activities initiated by the learners, but not completed.
Engagement with NMP	
Indicators	**Description**
time_vis_interaction	Related to Monitoring Strategy, it collects the frequency of interaction of the learners with the visualizations corresponding to the time invested.
goal_interaction	Related to Goal Setting Strategy, captures the total number of goals recorded by the learners
note_interaction	Related to Organization, it captures the frequency of interaction with the functionality of notes: edit, delete, search, download or create.
s_c_interaction	Related to Self-evaluation Strategy, it gathers the frequency of interaction of the learners with the functionality that allows them to compare their performance with that of other learners.
nmp_interaction	Related to Self-evaluation, it collects the frequency of interaction of the learners with the vision of the general dashboard.
effect_interaction	Related to Self-evaluation, it gathers the frequency of interaction of the learners with the NMP dashboard.

- For the **Self-evaluation** strategy, we defined three indicators. The *s_c_interaction* indicator measures the number of times learners use the *social comparison* functionality that allows them to compare their activity in the course with other learners. The *effect_interaction* indicator, which counts the number of learners' interaction with the visualizations corresponding to efficiency in the *effectiveness self-reflection panel*. That is the time spent to make progress in each of the activities of the course. The *nmp_interaction* indicator captures the frequency of access to the learners' general dashboard of the activity with the MOOC.

SRL Profile and Performance measures. We classified Learners into different groups depending on (a) their SRL profile, and (b) whether they pass or not the course. To classify learners according to their SRL profile, we clustered them based on their scores obtained through self-reported SRL questionnaire in order to observe how learners are distributed across the different clusters. We used the elbow curve technique to determine the optimal number of cuts in the cluster qualitatively and we used k-means and silhouette score to validate the number of cuts quantitatively. As a result, the learners were classified with high and low SRL. To classify them as those who passed or did not pass, the threshold for passing each of the MOOCs was used as criteria (60% for MOOC one, and 70% for MOOC two). The final grades obtained were normalized in order to compare them.

Final Dataset used for Analysis. The final dataset used in this study combines different data sources and measures. The final dataset contains information regarding: (1) User ID, (2) indicators of engagement with the MOOC resources (frequencies of interaction with video-lectures, assessments and supplementary resources defined in Table 4-3), (3) indicators of engagement with NMP (frequencies of interaction with NMP defined in Table 4-3), (4) Coursera learners' grades (normalized), and, (5) SRL profile (High 1, Low 0).

4.3.4. Analytical methods

To answer the main research question, we conducted an analysis in four phases. In the *first phase,* we analyzed the **effect of NMP on learners' engagement**. For that, we analyzed the difference in terms of engagement between those learners using NMP (NMP Group) and those not using them (NoNMP Group). Specifically, we run a statistical analysis using the T-Test for comparing the average of interactions with the course content between the two groups. Firstly, we compared the two groups in general. Second, we compared only those in each group who passed the course. And third, we compared those in each group who did not passed the course.

In the second phase, we analyzed the learners' engagement in relation with their SRL profile. That is, we calculated if there **is any difference in learners' engagement with the MOOC and NMP functionalities between learners with High and Low SRL profiles.** For this, a T-test of independent means was also used. The average grade obtained for each of the groups was also added as information.

In the third phase, we analyzed whether **there is any difference in the learners' engagement patterns.** For that, we run two steps of analysis. Firstly, we calculated the interaction effect of the SRL, NMP condition and the course grade on the engagement patterns. Secondly, we run a random forest prediction to predict the learners' grades using the engagement patterns, individual NMP interactions and the individual SRL components. For the prediction, we divided the whole dataset into training (90%) and testing (10%) data sets. We used a 10-fold cross validation to remove any sampling bias in the training set.

In the fourth phase, we analyzed the EFLA Questionnaire **to evaluate the learners' perception of NMP**. To calculate the NMP's EFLA score, we followed the procedure recommended by Scheffel (Scheffel, 2017). First, we calculated the average value per item. Second, we calculated the average value for each dimension base on the average of its items. Third, we calculated the dimensional scores by rounding the result of ((x-1)/9) *100 where x is the average value of a dimension. Finally, we calculated the overall EFLA score by taking the average of the three-dimensional scores. The open-ended question was analyzed qualitatively by two researchers. Each comment was tagged to a particular SRL strategy of those supported in NMP.

4.4. Results

This section reports the results obtained from the analysis to address the main research question. First, we present the results obtained from comparing the engagement of those learners who used NMP (NMP Group) and those who did not (NoNMP Group). Second, we present the results of analyzing the engagement with the course and NMP of the learners with different SRL profile.

4.4.1. Effect of NMP on Learners' Engagement

Table 4-4 presents the results of comparing the engagement of learners who used the NMP tool (NMP Group) with those who did not use it (NoNMP Group). The table shows the learners' interaction average for each of the previously defined indicators, together with their standard deviation. A statistically significant difference (95% and 99% confidence levels) is shown in the engagement of learners who used NMP and those who did not use it. Learners who used NMP interacted more with the assessments and lectures, completed and initiated more lectures, and initiated more supplemental activities. There is also a statistically significant difference (95% confidence level) in the performance of the learners who used NMP (they obtained a better grade on average) compared to those who did not use it.

Table 4-4: Learners' engagement NMP Group and NoNMP Group

	NMP Group		NoNMP Group			
Indicators	**mean**	**sd**	**mean**	**sd**	**t**	**p**
exams_interacted	**3.054**	1.688	**2.375**	1.877	2.986	**0.003****
lectures_started	**9.197**	6.451	**7.075**	6.026	2.598	**0.01****
lectures_completed	**10.417**	6.338	**7.589**	6.586	3.398	**0.001*****
lectures_interacted	**19.615**	11.189	**14.664**	11.525	3.381	**0.001*****
suppl_started	**0.505**	1.205	**0.115**	0.492	2.958	**0.003****
suppl_completed	0.703	1.433	0.595	1.638	0.552	0.580
suppl_interacted	1.208	2.307	0.710	1.882	1.774	0.078
# Learners	91 (100 %)		173 (100 %)			
Passed	26 (28.5 %)		30 (17.4 %)			
Did not pass	65 (71.5 %)		143 (82.6 %)			
Grade	**0.495**	0.331	**0.358**	0.323	3.217	**0.002****

Note. *p < 0.1; **p < 0.05; ***p < 0.001.

Finally, and to reach a better understanding of the learners who used NMP, Table 4-5 shows the results of the behavior of learners' engagement with their performance in the course (passed and did not pass). Learners who used NMP and passed the course showed greater engagement with assessments, lectures, and supplemental activities than their counterparts. However, the most interesting result between these two groups is the use they made of the functionalities of NMP related to goal setting and self-evaluation strategies in relation to the activity of others. The results show that learners who used NMP and passed the course on average interacted more with the goal setting functionality (1.807 times) and social comparison (0.923 times) than those who used NMP and did not pass. These differences are statistically significant (confidence level of at least 90%).

Table 4-5: Learners' engagement NMP Group

	PASSED		DID NOT PASS			
Indicators	**mean**	**sd**	**mean**	**sd**	**t**	**p**
exams_interacted	**4.692**	0.970	**2.400**	1.455	8.738	**0.0001*** **
lectures_started	**13.653**	6.254	**7.415**	5.653	4.415	**0.0001*** **
lectures_completed	**16.000**	4.882	**8.184**	5.428	6.676	**0.0001*** **
lectures_interacted	**29.653**	8.606	**15.600**	9.476	6.832	**0.0001*** **
suppl_started	**1.153**	1.804	**0.246**	0.729	2.485	**0.02** **
suppl_completed	1.115	1.773	0.538	1.250	1.514	0.13
suppl_interacted	**2.269**	3.231	**0.784**	1.662	2.227	**0.03** **
effect_interaction	0.961	4.902	0.061	0.348	0.935	0.358
s_c_interaction	**0.923**	2.544	**0.030**	0.248	1.784	**0.086***
note_interaction	3.692	7.341	2.584	6.043	0.682	0.499
goal_interaction	**1.807**	2.154	**0.984**	1.397	1.802	**0.080***
time_vis_interaction	0.923	4.316	0.307	1.951	0.698	0.490
nmp_interaction	20.730	39.536	8.338	14.274	1.558	0.130
# Learners	26		65			
Grade	**0.929**	0.056	**0.322**	0.215	21.002	**0.0001*** **

Note. *p < 0.1; **p < 0.05; ***p < 0.001.

4.4.2. Learners' engagement in relation with their SRL profile

We found no statistical differences in the level of engagement with NMP or their performance between learners with high and low SRL profile in the NMP Group. However, when comparing the behavior of learners with a low SRL profile in the NMP group with those in the NoNMP group, there are observable statistical differences in relation to their engagement with the course and their grade (Table 4-6). Learners who used NMP engaged more with lecture assessment and supplemental activities and initiated and completed more lectures. Finally, the learners in the NMP group obtained, on average, a better grade than their counterparts.

Table 4-6: Engagement of Learners with Low SRL

	NMP Group		NoNMP Group			
Indicators	**mean**	**sd**	**mean**	**sd**	**t**	**p**
exams_interacted	**3.090**	1.654	**2.397**	1.816	2.195	**0.03****
lectures_started	**10.113**	6.868	**7.306**	5.983	2.308	**0.02****
lectures_completed	**10.272**	5.812	**7.886**	6.410	2.147	**0.03****
lectures_interacted	**20.386**	10.912	**15.193**	11.184	2.556	**0.01****
suppl_started	**0.590**	1.299	**0.113**	0.512	2.346	**0.02****
suppl_completed	0.954	1.627	0.636	1.620	1.060	0.29
suppl_interacted	**1.545**	2.415	**0.750**	1.858	1.918	**0.059***
Grade	**0.498**	0.310	**0.359**	0.317	2.237	**0.02****

Note. *p < 0.1; **p < 0.05; ***p < 0.001.

Performing the same analysis but for the group of learners with High SRL profile, we observed that there are also statistical differences in the engagement of the NMP group compared to the NoNMP group (Table 4-7). Specifically, learners who used NMP engaged more with the course assessment activities, completed more lectures and more supplemental activities, and on average got better grades than those learners with a high SRL who did not use NMP tool.

Table 4-7: Engagement of learners with high SRL

	NMP Group		NoNMP Group			
Indicators	**mean**	**sd**	**mean**	**sd**	**t**	**p**
exams_interacted	**3.021**	1.738	**2.352**	1.950	2.024	**0.04****
lectures_started	8.340	5.982	6.835	6.096	1.374	0.17
lectures_completed	**10.553**	6.855	**7.282**	6.788	2.634	**0.01****
lectures_interacted	**18.893**	11.512	**14.117**	11.909	2.254	**0.02****
suppl_started	**0.425**	1.117	**0.117**	0.473	1.800	**0.07***
suppl_completed	0.468	1.195	0.552	1.665	0.338	0.73
suppl_interacted	0.893	2.179	0.670	1.917	0.587	0.55
Grade	**0.501**	0.353	**0.357**	0.331	2.29	**0.02****

Note. *p < 0.1; **p < 0.05; ***p < 0.001.

4.4.3. Engagement patterns using the SRL, NMP, and grades

Table 4-8 shows the interaction effect of the SRL, NMP condition and the course grade on the engagement patterns. It also shows the interaction effect of the SRL and grades on the interaction with the NMP tool. One can observe that grade has a direct effect on all the engagement patterns. All the engagement patterns are positively correlated with the grade (exams_interacted 0.91, lectures_started 0.72, lectures_completed 0.81, lectures_interacted 0.85, suppl_completed 0.28, suppl_interacted 0.32, all correlations are significant with $p < 0.01$). Grade also has a direct effect (positive correlation) on the number of times learners interacted with the note taking (0.15, $p = 0.02$), goal setting (0.27, $p = 0.001$) and social comparison functionalities (0.18, $p = 0.003$). We also observed a direct effect of NMP condition on the engagement patterns.

Table 4-8: Engagement patterns modelled using the SRL, NMP, and Grades

Indicators	SRL	NMP	Grade	SRL/ NMP	SRL/ Grade	NMP/ Grade	ALL
exams_interacted		***	***			**	
lectures_started		***	***			*	
lectures_completed		***	***				
lectures_interacted	*	***	***			*	
suppl_started			*				
suppl_completed			***			*	
suppl_interacted		*	***				
effect_interaction		NA		NA	*	NA	NA
s_c_interaction		NA	**	NA		**NA**	**NA**
note_interaction		NA	*	NA		NA	NA
goal_interaction		NA	***	NA		NA	**NA**
time_vis_interaction		NA		NA		NA	NA
nmp_interaction		NA	***	NA		NA	**NA**

Note. *p < 0.1; **p < 0.05; ***p < 0.001.

Also, we observed that there are certain interaction effects on the engagement patterns of NMP condition and grades (in all the panels of Figure 4-1 with color: red/orange = no NMP and blue = NMP). The correlation between the grades and the exams interacted, between the grades and the lectures interacted, between the grades and the lectures started, and the grades and supplemental material interacted is lower for the NMP group than that for the NoNMP group. These results suggest an effect on learners' grades in the

NMP condition is weaker than the effect on learners' grades in NoNMP condition on the number of interactions with the course content.

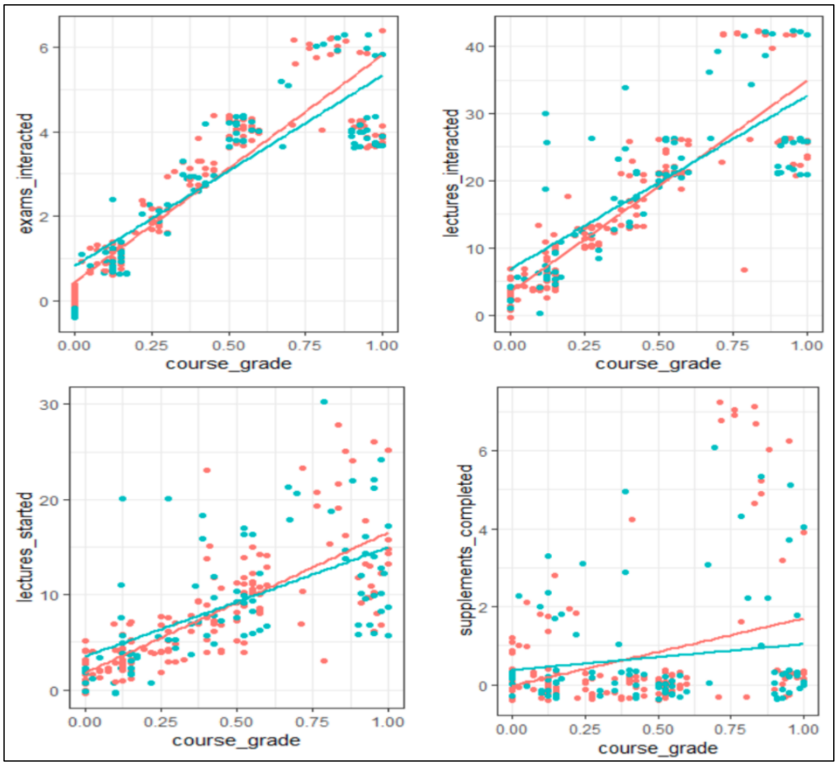

Figure 4-1: Interaction effects on engagement patterns of NMP and course grade.

Red points/line: no NMP; blue points/lines: NMP group

Further, the Root Mean Squared Error (RMSE) for predicting learners grade using engagement patterns, individual NMP interactions and SRL components was 12.4% (Std Dev = 2.7%) and the R^2 for the predictive model was 0.86. Figure 4-2 shows the feature importance from the final model. We can observe that the exams and lectures interacted are the two most important features while the supplements started is the least important. We also observe that goal setting, social comparison and note taking functionalities (NMP terms) are scored higher on the feature importance scale than all the individual SRL terms. On the other hand, visualizations on effectiveness and time management (time_vis_interaction) (NMP terms) are scored lower than most of the individual SRL terms. These results suggest that supporting SRL strategies such as goal setting and providing learners with references regarding their performance (social comparison) might have a positive impact on learners' final grades.

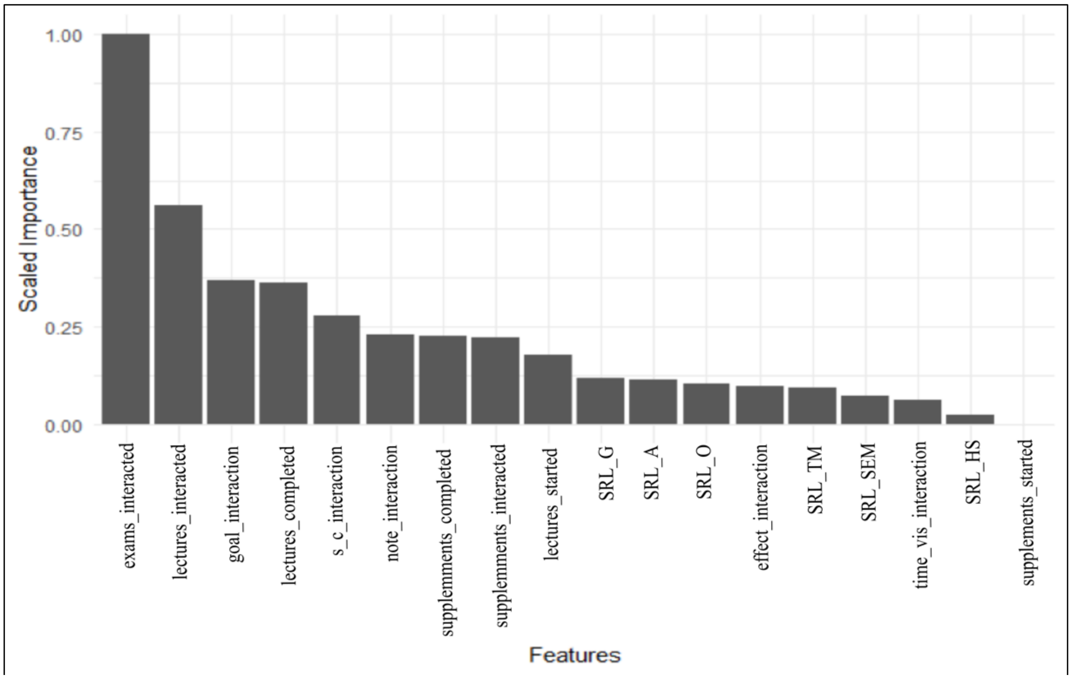

Figure 4-2: Variable importance to predict the learner grade using the individual engagement, SRL and NMP items.

4.4.4. Learners' evaluation of NMP

Table 4-9 shows the results of the EFLA questionnaire about NMP perception from 57 learners. The results show that the learners consider the NMP equilibrated in all dimensions, giving an average value of over 6.6 at each item. The items with the highest value correspond to "Q7: This LA tool stimulates me to study more efficiently" and "Q8: This LA tool stimulates me to study more effectively, which relate with the "Awareness and Reflection dimension." The second highest dimension is "Impact" with a score of 67.822. These two dimensions are highly correlated with the evaluation of the tool in terms of awareness, reflection, efficiency, and effectivity.

Analyzing the comments to the open question "What uses have you given it, or what has this tool been useful for you?", we observe that learners value NMP for time management, goal setting and strategic planning, organizing their study and self-evaluating their advance on the course. For example, some learners comment related to *time management* that NMP was useful to know the time they devoted in the course, their procrastination time over a study session, and when they were more efficient: "This tool has useful to me to quantify the time in the course versus the time in other activities." Regarding to *goal setting and strategic planning strategies,* learners commented that NMP was useful to schedule plan and organize activities, as well as to reflect on their study habits to re-plan their working sessions. One learner commented on this regard: "This tool has helped me to identify my leisure time during the study session, and to create plans to improve the use of time". Other learners valued the note-taking functionality as support *organizing* their work: "This tool has been useful to me to make summary cards of the advanced topics." Finally, some leaners commented that NMP was useful as a *self-evaluation*, to follow up on their performance, control their progress in the course, and get feedback about their own activities. For example, one of the learners' stated: "NMP is a great thermometer to assess whether progress is correct and to take steps to ensure timely compliance," while another commented: "It (NMP) has allowed me to focus and be more effective in my study."

Table 4-9: NMP'S evaluation from learners

Dimension	**ITEM (Q)**	**Average Item Value**	**Dimensional score (0 -100)**
Data	Q1: For this LA tools it is clear what data is being collected	6.638	65.367
	Q2: For this LA tool it is clear why the data is being collected	7.128	
Awareness & Reflection	Q3: This La tool makes me aware of my current learning situation	7.745	68.533
	Q4: This LA tool makes me forecast my possible future learning situation given my (un)changed behavior	6.681	
	Q5: This LA tool stimulates me to reflect on my past learning behavior	7.289	
	Q6: This LA tool stimulates me to adapt my learning behavior if necessary	6.958	
Impact	Q7: This LA tool stimulates me to study more efficiently	7.630	67.822
	Q8: This LA tool stimulates me to study more effectively	7.577	

4.5. Discussion

4.5.1. Summary of results

In this study, we analyzed the relationship between learners' SRL strategies and engagement with the MOOC resources. We presented the results of an observational case study conducted with 263 learners from two MOOCs complemented with the NoteMyProgress (NMP), designed as a complement to the MOOC platforms to support learners' self-regulation strategies (Pérez-Alvarez et al., 2018). Each of the functionalities in NMP is associated with one SRL strategy defined in the SRL model by Pintrich (P. Pintrich, 1999, 2000): goal setting and strategic planning, organization, self-evaluation, and time management. Data from different nature and sources were collected, from MOOC and NMP logfiles to surveys on learners' self-perception of their self-regulatory abilities and on the NMP tool. The main objective was to understand whether the use of NMP as a complement of a MOOC has an impact on learners' engagement and their performance.

The results show that learners using NMP: (1) were more engaged with assessments and lectures; (2) completed more lectures and initiated more supplemental activities; and (3) obtained higher grades. Also, our results show that learners' self-reported level of SRL is not related with their engagement level. In addition, an analysis of the engagement patterns considering SRL, NMP condition, and the course grades show that there is a positive correlation between learners' final grade with NMP functionalities supporting goal setting, organizational (note taking) and self-reflection (social comparison) SRL strategies. Further, models for predicting learners' grades using engagement pattern, SRL profile, and individual NMP interactions shows that, after learners' interactions with exams and lectures, interactions with these functionalities were the most important predictive features. Finally, the results of the EFLA questionnaire shows that learners have a good perception of the NMP tool and value it as good support for planning and organizing their study, as well as a self-awareness tool to reflect about their advance on the course.

4.5.2. Discussions

The results of this study have implications for theory and practice around SRL in digital environments. Here we discuss the two main findings in relation to prior work.

First, scaffolding goal setting, strategic planning and organization SRL strategies had a direct effect on learners' engagement patterns with the MOOC content and their final grades. The results of analyzing the relation between SRL, NMP condition and grades, indicate that learners who used NMP were more efficient in completing lectures with which they interacted and obtained a better grade. Similar results were obtained in prior work, which showed that intervening with a SRL scaffold for supporting goal setting in a MOOC increased learners' engagement with lectures and assessments (Davis et al., 2018). Previous studies also found (Milikic et al., 2018) a positive effect supporting learning with social comparison functionality. In this study, the social comparison functionality is initially disabled, and learners had enabled it functionality to compare their performance, which suggest that learner consider useful this option and had a positive impact on learner' engagement. Although we did not find a positive effect of *time monitoring panel* functionality, we observed that that time use related visualizations are the visualizations most used by learners. We hypothesize, take into account learners' perception results, that learners' interaction with those visualizations was useful to become aware of the use of the other functionalities, for instance, goal setting. These results suggest that the interaction with NMP's functionalities that support goal setting and strategic planning, organization, and self-evaluation strategies had a positive effect on learners' engagement with MOOC's learning activities, as suggested in prior work (Davis et al., 2017, 2018; Stovall, 2003). We also found a positive relationship between the use of NMP and final grades, confirming the findings in prior works in which learners with a SRL scaffold performed better (Davis et al., 2018; Sunar et al., 2016).

Second, learners perceive NMP as a good support for organizing, planning and self-evaluating their SRL strategies and performance in the course. According to the results collected through the EFLA instrument, learners agreed that NMP was effective to analyze their time efficiency on the course and study sessions, which helped them organize and plan their study goals. Participants also found that the information displayed through interactive visualization was useful have an overview of their performance and reflect about their learning strategies. These results contrast with those obtained by Milikic et al. (Milikic et al., 2018), who did not find any relationship between the number of interactions with a self-awareness functionality showing their progress on the course, and the goal setting strategy. So, more experiments comparing the two approaches should be conducted. Furthermore, the results of learners' perception showed that learners valued those functionalities related with time management (time spent on course activities vs time spent on other activities) and activity progress for better planning their study in the course. These results support the quantitative results obtained from the logfile analysis, which indicated that learners who used NMP had a better engagement with course activities than learners who did not use NMP.

Even if our study was conducted with a group of participants non-randomly assigned and, consequently, we cannot demonstrate causality, the data collected from the SRL questionnaires and EFLA surveys, together with the analysis conducted allowed us to reduce the self-selection bias. On the one hand, the predictive analysis showed that, for the NMP group, the correlation between grades and exams, lectures and supplementary material is lower than in the NoNMP group. This suggests that intervening a MOOC with SRL scaffolds had an impact on how learners address the course content, increasing their engagement with the course and their performance. On the other hand, and despite prior work have found differences in learners' engagement depending on their SRL profile (Kizilcec et al., 2017; Littlejohn et al., 2016; Maldonado-Mahauad et al., 2018), we found no relationship between learners' self-reported SRL profiles and engagement. Moreover, no significant differences were found neither between learners with high and low SRL profiles in the NMP group. This is an interesting result, since prior work suggests that SRL scaffolds might support learners with difficulties in self-regulating their learning (WINNE, 2010; Winne & Hadwin, 2013). In part, these results could be explained because of the level of education of the participants (88% having a higher education degree), and now difference were observed. Or it could also be a natural effect when intervening a higher educated population which, according to prior research, might benefit more from this type of interventions (Davis et al., 2017).

4.5.3. Limitations of the study

This study has two major limitations that concern external validity that, although common in learning analytics works in MOOCs, need to be considered when drawing conclusions from the findings. The first limitation is the characteristics of the participants' data sample. For methodological purposes, in this study, we only considered as participants sample those learners who completed the SRL survey. This reduced the data sample from the 19,052 learners enrolled in the courses to 263. Moreover, the study sample comes from 2 MOOCs deployed in the Coursera platform for Latin America. Therefore, our sample comes from Spanish speaking countries and, especially, from in Latin America. This limitation might be considered, when running similar experiments in different countries, since prior work has already shown that socio-cultural context has consequences for how learners perceive and engage with a course (Guo & Reinecke, 2014; Kizilcec & Schneider, 2015; Ogan et al., 2015).

The second limitation concerns the self-selection bias of the data sample. As in many other studies running interventions in MOOCs, in this study the participants sample was not randomly selected. Therefore, no generalizable conclusions can be drawn from the findings of this study. However, we combined different sources of data and carefully selected the analytical methods in order to isolate at maximum this self-selection bias. On the one hand, we used the SRL questionnaire as a control instrument to compare participants under a similar parameter. On the other hand, we conducted a predictive analysis to identify the features that better predict grades and better distinguish the effect of the intervention from other aspects. And finally, we also conducted a questionnaire asking for learners' perception of the tool to complement quantitative results with qualitative data that helped us understand the effect of the intervention.

4.6. Conclusions

This study contributes to lying the groundwork on the study of SRL scaffolds and engagement in digital environments. Until recently, most studies analyzing SRL scaffolds in MOOCs felt short on providing empirical evidence relating learners' behavior with SRL strategies and performance. In this study, we followed the third wave of SRL measure (Panadero et al., 2016) to propose a solution to complements MOOCs for both, SRL scaffolding and measuring. Combining data sources and methodologies, this study provides new empirical accounts on the relationship between SRL scaffolds and engagement. This study also proposes a set of indicators in which behavioral and self-reported data are combined based on theoretical frameworks. The way in which these indicators were defined and combined for the analysis is also an example of how empirical work can be effectively connected to theory, one of the main challenges in the context of data-driven research on SRL (Gašević, Dawson, & Siemens, 2015; Winne, 2014). The resulting correlational findings, showing the importance of scaffolding goal setting, strategic planning and organization strategies, permit refinement on theory and can inform new experimental research on SRL scaffolding and subsequent analysis connecting empirical results with theory.

Chapter 5

Conclusions

This chapter presents the main conclusions of this thesis to the scientific community. In particular, the activities undertaken and results generated by the thesis contribute towards efforts to overcome the challenges associated with the design and evaluation of tools that aim to support SRL strategies in MOOCs. This chapter is divided into three sections. Section 5.1 presents a summary of the main contributions. Section 5.2 reviews the lessons learned about the characteristics and evaluation of tools designed to support SRL strategies in MOOCs. Finally, section 5.3 details the new research avenues derived from the thesis. As an end note, it should be explained that this chapter corresponds to the *evaluation of broader impact phase* of the interactive learning design (ILD) framework.

5. CONCLUSIONS

5.1. Summary of contributions

The primary motivation of this thesis was to explore the opportunities of deploying learning analytics tools to support learner SRL strategies in MOOCs while, simultaneously, collecting data to enhance understanding of how learners use these types of tools. Specifically, two research questions were addressed by this thesis: ***RQ1***. What **characteristics** should be considered in the **design of an educational tool** that **supports** effective **self-regulation strategies** for learning in **MOOCs**? And ***RQ2***. What effect would the educational tool have on the self-regulation strategies of learners and their achievements?

To guide the research process, this thesis followed the design-based research methodology (DBR) (Reimann, 2011). Concretely, the DBR methodology was applied using the interactive learning design (ILD) framework (Bannan-Ritland, 2003) and the research process was organized by following the four phases proposed by this framework: *informed exploration phase, enactment phase, evaluation of local impact phase,* and *evaluation of broader impact phase*. First, in the *informed exploration phase*, three systematic literature reviews were conducted to analyze the current state of tools designed to support SRL in online environments. Second, in the *enactment phase*, the NoteMyProgress (NMP) tool, a web application that supports learner SRL strategies in MOOCs, was designed and implemented. Third, in the *evaluation of local impact phase*, three case studies were conducted to iterate the tool design and evaluate the usability, adoption and impact of the NMP. Finally, in the *evaluation of broader impact phase,* the main findings and contributions of the research project were presented.

Therefore, the contributions of this thesis can be organized into three main blocks:

5.1.1. Analysis of existing tools that support SRL in online learning

This thesis contributes to the broader field by providing a detailed overview of the current state of development of tools designed between 2008 and 2018 to support SRL in online environments. Specifically, three systematic literature reviews were conducted in this thesis, which provided a progressive analysis of the main functionalities, SRL models, SRL strategies, visualizations and indicators used by tools to support SRL in online environments. Although the thesis focused on the design of a tool to support SRL in MOOCs, the systematic literature reviews were extended to general online environments in order to gain a greater understanding of the design processes and evaluation methods used by researchers.

The first systematic literature review analyzed 21 tools designed between 2008 and 2016 (Pérez-Álvarez et al., 2016). It focused on analyzing the functionalities of the tools, the SRL strategies supported and the evaluation methods used. This review provided a general overview of tools and an outline of a first approach with regard to how such tools supported SRL. Moreover, it detailed a list of tools designed to support SRL and documented the main characteristics identified in the description of these tools. The results of this literature review were used to design the first beta version of the NMP.

The second systematic literature review analyzed 23 tools designed between 2008 and 2018 (Pérez-Álvarez et al., 2018). It expanded on the first review and focused on providing a more in-depth insight into the relationship between the design of the tools and how their functionalities relate to the self-regulated strategies of learners on the course. This review organized tool functionalities according to the classification proposed by Bodily & Verbert (2017). Furthermore, it analyzed indicator types used by tools to provide learners with feedback. The indicators were organized using the classification proposed by Schwendimann et al. (2017).

The third systematic literature review analyzed 23 tools designed between 2008 and 2018 (reference). It focused on examining how the concept of self-regulation is adopted in the design of the tool. Specifically, it looked into the association between tool functionalities and the self-regulation strategies that support that functionality. Moreover, this review analyzed the indicators used to measure the impact of the tool on learner self-regulation. The indicators were organized according to the classifications proposed by Jivet et al. (2018).

The most noteworthy contribution of this block is the broad overview it provides of how the theoretical SRL models can be linked to and implemented in the design process of the tools. It also shows how the activities performed by learners with the tool can contribute to measuring the impact of the tool on learner SRL. In addition, the three reviews analyzed the most effective SRL strategies for learners in MOOCs.

5.1.2. NoteMyProgress to support learners SRL strategies in MOOC

By means of NoteMyProgress (Pérez-Alvarez et al., 2018; Pérez-Álvarez, Maldonado-Mahauad, et al., 2017), this thesis contributes a tool that was designed based on the lessons learned from three systematic literature reviews and an iterative design process. The NMP tool works as a complement to MOOC platforms and consists of two components: first, a Google Chrome plugin which collects information about the learning activities of learners in the MOOC platform; and second, a dashboard which analyzes the collected data and creates interactive visualizations that help learners to follow their respective learning process. The NMP tool is an original contribution since, to date, only four tools have been registered as providing support to SRL strategies in MOOCs.

Furthermore, this thesis contributes with a systematic process for designing and evaluating the NMP. This process provides a useful scenario for researches on the way in which to associate tool functionalities with SRL strategies. It also presents an approach of how to measure the impact of the tool on SRL strategies. The design process explains SRL model selection for defining tool functionalities and describes the way in which each functionality can be linked with a specific SRL strategy defined in the theoretical SRL model selected. Significantly, the association between functionalities and SRL strategies can facilitate analysis of the impact of tools on learner SRL.

A further contribution of this thesis is that the NMP has been used in the Learning Analytics to Improve Higher Education in Latin America (LALA) project as a part of a set of tools developed by Latin American universities. Specifically, this project ensures valuable experience and lessons have been learned by the Pontificia Universidad Católica de Chile with regard to the NMP, which can, in turn, be used to enhance the development and implementation of learning analytics tools in other higher educational institutions in Latin America. In addition, this project promotes the use of the NMP in other institutions. For example, the NMP has been used to support SRL in four MOOCs offered by the Universidad de Chile.

5.1.3. Novel educational experiment to measure the impact of tools on learners' SRL strategies, engagement and performance in MOOCs

The third contribution of this thesis is that of a novel experiment conducted to evaluate the way in which the NMP affects learner engagement with course learning activities and SRL strategies. The literature reviews undertaken by this study show that current tools fail to measure their own impact on SRL (Jivet et al., 2018; Pérez-Álvarez et al., 2018, 2016). However, this particular contribution provides empirical results and evidence on the relationship between engagement and SRL scaffolding. It compared the level of engagement with course content (lectures, assessments and supplementary materials) of learners who used the NMP with those who did not use the tool. Engagement was analyzed in a holistic manner by considering the frequency of interactions with both course content and the functionalities of the NMP that support the SRL strategies: goal setting and strategic planning, self-evaluation, time management and organization.

The most noteworthy contribution of this block is the set of indicators proposed to measure the impact of the tools on learner engagement with SRL strategies (tools functionalities), their engagement with course activities, and their achievements. These indicators are the result of cross-analyzing data from different sources, not only from the course and tool log files that register learner interactions with the course and the NMP, as in previous works, but also by considering the findings from self-reported data about learner SRL profiles and their perceptions about the tool.

Furthermore, this is the first research to have analyzed the relationship between SRL scaffold and engagement in MOOCs deployed in the Coursera platform. The only similar research to have been undertaken was found to relate to the edX platform (Davis et al., 2018). Since Coursera is a closed system, it is difficult to conduct interventions beyond introducing questionnaires or providing written guidelines to learners perform (Kizilcec et al., 2016). Accordingly, this experiment proposes to use the NMP as a complementary tool to the Coursera platform for SRL scaffolding.

Finally, no changes were conducted to the instructional design of the courses in this study in order to scaffold learner SRL strategies. The use of the NMP (SRL scaffolding) was entirely voluntary and no changes were applied to course activities to condition learner behavior. This approach enabled the NMP experiment to be conducted in 18 MOOCs on the Coursera platform.

Therefore, this contribution offers a new perspective on how the impact of tools designed to support SRL strategies in MOOCs can be measured, while simultaneously providing evidence of the functionalities that offer improved support to SRL learners.

5.2. Lessons learned

The first main research question addressed in this thesis was: w*hat characteristics should be considered in the design of an educational tool that supports effective self-regulation strategies for learning in MOOCs?* The results of the three systematic literature reviews raise four main considerations for the design of tools to support SRL strategies.

1. ***Define the SRL model prior to defining tool functionalities***. Tool functionalities should be aligned with the SRL definition offered by the selected model. Thus, each functionality can be designed to support a specific SRL strategy or phase and the interaction of learners with the different functionalities can serve as a proxy to identify what self-regulated learning strategies leaners' use. In this thesis, the SRL Pintrich model (P. Pintrich, 1999) was selected to guide the design process of the NoteMyProgress tool. Each functionality of the NMP was associated with a specific SRL strategy defined in the Pintrich model. This association was used to define a set of events which were used as indicators to track and measure the impact of the NMP on learner SRL strategies.
2. ***Select which set of SRL strategies to support.*** Once the SRL model has been defined, the next step is to select which of the strategies to support. In selecting the SRL strategies to support, researchers should be aware that learning context plays an essential role in how learners self-regulate (Maldonado-Mahauad et al., 2018). Research shows that *goal setting*, *strategic planning*, *time management*, *self-evaluation* and *note-taking* are effective SRL strategies for learners in MOOCs (Kizilcec et al., 2017; Milligan & Littlejohn, 2016; Veletsianos et al., 2016).

Significantly, the NMP was designed to support these specific SRL strategies. Wong et al (2019) recommend supporting more than one strategy, to the extent that these strategies are related to supporting learners throughout the entire self-regulation process. For instance, if the tool provides support to *goal setting*, designers should also consider providing support to the *monitoring* and *self-evaluation* learning processes and ensure that a new plan is created in order for learners to achieve their goals.

3. ***Provide interactivity***. SRL is an active undertaking in which learners are able to take control of their learning process (P. Pintrich, 1999). Beyond interaction with tool functionalities, designers should consider providing learners with feedback through interactive visualizations that allow them to analyze their learning process from different perspectives. The use of tools that provide learners with interactive visualizations has been observed to have a positive effect on learner achievements (Pérez-Álvarez et al., 2018, 2016). Interactivity enables learners to monitor their learning process in accordance with their specific goals and needs as well as to make decisions and improve behavior. The design of the NMP involved adding a set of interactive visualizations that allow learners to filter information shown in those visualizations. For example, learners can filter information by intervals (the last seven days, last month), per specific week, per learning category (lectures, assessments) and per effectiveness (activities started or completed). Interactivity not only allows learners to play an active role, but it also enables them to follow up such interaction with visualizations. The NMP tracks learning interaction with visualizations in order to analyze the visualization(s) that proved most useful for learners during the case study. It also analyzes the deployment of learner SRL strategies associated with the visualizations.
4. ***Offer different comparison criteria for the learning process analysis.*** According to Pintrich (1999), an appropriate approach to self-monitoring and control by learners with regard to their learning process is for them to set goals or standards with which they are able to compare their performance, assess whether their learning process should remain the same, or whether a certain change may be required (P. Pintrich, 1999). Three different criteria have been used by tools to support learner SRL: **(1)**

goal-setting by teachers, whereby tools usually allow learners to compare their performance against goals defined by the teacher in the course design; **(2)** ***goal-setting by learners***, whereby if tools provide support to a goal-setting strategy, they usually allow learners to compare their performance against goals they have defined themselves; and **(3)** ***social comparison***, whereby certain tools allow learners to compare their performance against the performance of other learners. The NMP includes the three comparison criteria and provides learners with functionalities to self-evaluate their performance in relation to their goals or goals defined by the teachers. Furthermore, it allows learners to compare their performance in relation to the performance of learners in previous editions of the course. The results of the NMP evaluation show that social comparison has a positive effect on learner achievement. In order to provide learners with additional alternatives with which to monitor and control their learning process, designers should consider integrating different comparison values.

The second main research question addressed in this thesis was: what effect would the educational tool have on the self-regulation strategies of learners and their achievements? With regard to this question, three lessons were learned:

1. **The most recent studies fail to evaluate the impact of tools on learner SRL strategies**. Although research has measured the impact of tools on learner' achievements, it has not measured the impact of tools on learner SRL. The lack of both a model to guide the design process and an association between SRL strategies and tool functionalities significantly impedes efforts to conduct evaluations in order to measure the impact of tools on SRL.
2. **Define indicators associated with SRL strategies.** To measure the impact of tools on SRL, different approaches to linking theoretical SRL models and tool functionalities are required. By establishing a clear relationship between SRL models and functionalities it is possible to define indicators in order to measure the SRL activities that learners perform with any given tool. This thesis has presented empirical evidence on how to relate learners' SRL events with NMP functionalities.

Indeed, Chapter 4 outlined a useful set of indicators that were used to measure the impact of the NMP tool on learner SRL strategies.

3. **The NMP had a positive effect on learner SRL strategies**. The impact of tools designed to support SRL strategies in a MOOC can be measured by means of the analysis of learner engagement with tool functionalities. The third case study conducted in this thesis shows that learners who used the NMP functionalities, specifically those of *goal setting and planning*, *note taking* and *social comparison*, were more engaged with MOOC learning activities than learners who did not use the NMP. Moreover, learners perceived a positive impact of the NMP on their SRL strategies.

5.3. Limitations

This thesis has three major limitations. The first limitation is that the studies carried out in this thesis were conducted only on the Coursera platform; it is required to reproduce the studies on other platforms such as edX to make a comparison of the results obtained. The second limitation is that in this research project, it was not possible to explore which type of visualization or which type of interactivity is the most appropriate to support student self-regulation. An observational study was conducted on the main characteristics that should be considered in the design of the tool; however, the different types of visualizations were not analyzed to determine whether a bar chart, a table, or a pie chart are the most appropriate to provide feedback to students. The third limitation concerns the self-selection bias of the data sample. In this study, the participants sample was not randomly selected. Therefore, no generalizable conclusions can be drawn from the findings of this study.

5.4. Future perspectives

In addition to the aforementioned contributions and conclusions, this thesis opens up a number of new research lines.

- This thesis provides a new outlook on how to measure and analyze learner engagement with regard to learning interaction with the platform in question, which raises the opportunity to ***expand this analysis using new techniques such as process mining***. This future work will delve beyond the study of learner interactions with a platform for measuring engagement to encompass patterns of interconnected activities that show the learning paths performed by learners when undertaking a MOOC that is complemented with an SRL scaffold (Maldonado-Mahauad et al., 2018).

- This thesis has conducted experiments only in MOOC environments. As such, this opens up possible new lines of research to explore how NoteMyProgress ***supports SRL in a blended learning environment.*** Currently, there is a Master's research project being conducted at the Pontificia Universidad Católica de Chile exploring the effect of the NMP on learner SRL when a MOOC is used to support the learning activities of a face-to-face class. Moreover, the experiment presented in this thesis is being extended to support learners in another platform: the LALA project (https://www.lalaproject.org/), in which a new version of the NoteMyProgress tool is being developed to provide support in the Moodle platform.
- A further line of research that this thesis has opened up is the study of how to provide ***support to teachers with regard to learner SRL activities***. The NMP collected large quantities of data about learning activities both inside and beyond the MOOC platform. Consequently, this data may prove useful for providing feedback to teachers about how learners self-regulated their learning processes in order to achieve learning activities. For example, the type of feedback that could be available to teachers includes information related to learning activities performance and time spent in each learning category (see Figure 5-1).

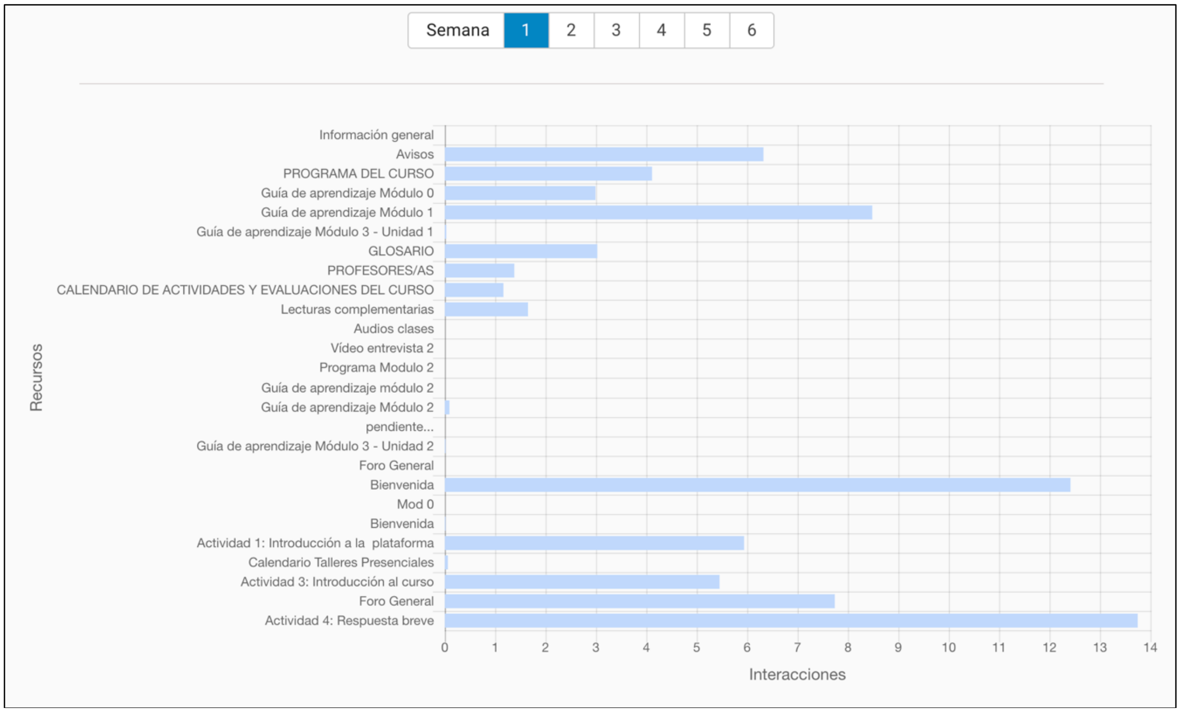

Figure 5-1: Mock-up example of feedback for teachers on learning activities for learners

- The NMP collects data about learner activities undertaken both inside and beyond the learning platform. This thesis conducted two initial analyses to understand what type of activities learners perform beyond the MOOC and how these activities are related to their academic performance (Pérez-Sanagustín, Sharma, Pérez-Álvarez, Maldonado-Mahauad, & Broisin, 2019; Sapunar-Opazo, Pérez-Álvarez, Maldonado-Mahauad, Alario-Hoyos, & Pérez-Sanagustín, 2018). Although results are preliminary and could be expanded, this initial overview successfully broadens available knowledge on the type of activities and content that learners use to enrich their learning experiences. Moreover, the results of this work may have implications on MOOC design and the tools that are implemented to support learning. For example, one future line of research would be to ***conduct an analysis of the most frequently consulted sites to support teachers,*** so as to engage learners in critical discussions about course content. In addition, the results of the predictive models could serve to identify the moment at which learners begin to struggle and, in response, to suggest resources to them through which they could seek help.

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APPENDICES

APPENDIX A: RESOURCES OF NMP

Resource	URL	Description
User's manual	https://drive.google.com/file/d/1f3FWB3Suk20yuSNea3eBwVohH5At8Aki/view?usp=sharing	In this link, you can download the NMP user manual.
Source code	https://git.cti.espol.edu.ec/LALA-Project/PUC	In this link, you can download the source code of the plugin and the NMP dashboard.
Plugin in chrome web store	https://chrome.google.com/webstore/detail/notemyprogress/aghbcfhpjnmgkgafdbcaljgegcimcmng?authuser=2	In this link, you can install the NMP plugin in your google chrome browser.
Demo video	https://www.youtube.com/watch?v=pTjffF0LuaQ&feature=youtu.be	In this link, you can watch the NMP demo video.

APPENDIX B: PUBLICATION BY THE AUTHOR

A. Publication 1.

Pérez-Alvarez, R., Maldonado-Mahauad, J. J., & Perez-Sanagustin, M. (2018). Design of a tool to support self-regulated learning strategies in MOOCs. Journal of Universal Computer Science, 24(8), 1090–1109.

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Design of a Tool to Support Self-Regulated Learning Strategies in MOOCs

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Abstract: The massive and open nature of MOOCs contribute to attracting a great diversity of learners. However, the learners who enroll in these types of courses have trouble achieving their course objectives. One reason for this is that they do not adequately self-regulate their learning. In this context, there are few tools to support these strategies in online learning environment. Also, the lack of metrics to evaluate the impact of the proposed tools makes it difficult to identify the key features of this type of tools. In this paper, we present the process for designing *NoteMyProgress*, a web application that complements a MOOC platform and supports self-regulated learning strategies. For designing *NoteMyProgress* we followed the Design Based Research methodology. For the evaluation of the tool, we conducted two case studies using a beta version of *NoteMyProgress* over three MOOCs offered in Coursera. The findings of these two case studies are presented as a set of lessons learned that inform about: (1) a list of requirements to inform the design of a second version of the tool; (2) a list of requirements that could serve as a reference for other developers to design new tools that support self-regulated learning in MOOCs.

Keywords: Self-Regulated Learning, SRL, Massive Open Online Courses, MOOC, Tool, Learning Analytics, Dashboard.
Categories: K.3.1, K.3.2

1 Introduction

One of the most relevant characteristics of MOOCs is their massive number of learners. This massiveness makes it difficult for teachers to monitor learners' performance and support them in achieving their goals. In this context, one of the keys for learners to reach their goals is their capacity for self-regulated learning (SRL). Self-regulation is defined as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, intentions and behavior, guided and constrained by their goals and the

B. Publication 2.

Pérez-Alvarez, R., Maldonado-Mahauad, J. J., Kshitij Sharma, Diego Sapunar-Opaso, & Perez-Sanagustin, M. (2018). Characterizing Learners' Engagement in MOOCs: An observational case study using NoteMyProgress tool for supporting self-regulation. Journal of IEEE Transactional on Learning Technologies, under review.

Characterizing Learners' Engagement in MOOCs: An observational case study using NoteMyProgress tool for supporting self-regulation

Ronald Pérez-Álvarez, Jorge Maldonado-Mahauad, Kshitij Sharma, Diego Sapunar-Opaso, Mar Pérez-Sanagustín

***Abstract*— Recent research finds that learners able to self-regulate their learning show greater engagement with the MOOC content. As an approach to better support learners' in their self-regulatory processes, technological solutions have been proposed to transform recorded MOOC data into meaningful and actionable knowledge. However, studies providing empirical evidence on how these solutions impact learners' engagement with the course and their self-regulatory behavior are still scarce. In this study, we present the results of an observational case study in which NoteMyProgress (NMP), a web-based tool designed to support learners' self-regulation in MOOCs, is applied as an intervention into two MOOCs of Coursera. The main aim of this study is to provide insights about how supporting learners' SRL strategies has an effect on engagement with the MOOC resources. The evaluation was conducted with a sample of 263 learners. Different data sources, from log files to SRL self-reported questionnaires capturing learners' profile, are used to propose indicators of learners' engagement with the course and NMP. The results suggest that supporting learners' SRL profile had an effect on their engagement with the course content. Specifically, learners who used NMP: (1) were more committed to assessments and lectures; (2) completed more lectures and initiated more supplemental activities; and (3) obtained higher grades. Also, we found no significant behavioral differences in how learners with low SRL and high SRL profiles engage with the course or NMP. We discuss how these results relate to prior work and implications for future technological solutions for promoting engagement in MOOCs.**

***Index Terms*— Dashboard, Data Capture, Engagement, Learning Engagement, Massive Open Online Courses, MOOC, Self-Regulated Learning.**

I. Introduction

STUDYING the reasons of learner's engagement and disengagement with Massive Open Online Courses (MOOCs) has been one of the main lines of research in the past years [1]–[4]. Engagement in MOOCs is defined in the literature as the learners' involvement with the course content and with the tools available within the learning environment [5], [6]. Taking this definition as a basis, there are several researchers who have studied learners' reasons of greater engagement and disengagement in MOOCs. The results of this prior works showed that, while learners' personal intrinsic motivation [1], and prior knowledge [2] has been related to greater learners' engagement, the lack of self-regulatory skills is one of the most attributed reasons for disengagement [4]. In a context such as MOOCs, where there is little to none guidance from teachers, learners have difficulties in completing their learning goals and planning their tasks to achieve their learning objectives. In fact, according to recent studies, learners capable of self-regulate their learning have greater engagement with the activities of the course [7], [8] and a greater chance of success in achieving their learning goals [9]–[11].

Based on the evidence relating learners' Self-Regulated Learning (SRL) with engagement in MOOCs, researchers have started to design tools and conduct interventions to support learners' SRL strategies in these environments [12], [13]. But, only a few of these works actually evaluate and measure how learners' SRL strategies relate with engagement [14]–[16]. All these works follow a novel approach for studying SRL that Panadero [17] calls "the third wave of SRL measure" that consists on studying SRL taking advantage of computational systems that serve for both, scaffolding learners' SRL strategies and capturing data for measuring their self-regulatory process. Studies following this approach propose different measures for studying the relationship between engagement and SRL. Authors such as Davis et al. [14], [15] propose high-level measures; that is, studying the relationship between engagement and SRL from an overall perspective by measuring the relationship between the number of learners' interactions with course activities and their interactions with the tool proposed for supporting SRL strategies. More recently, authors such as Milikić et al. [16], inspired by the approach proposed by Siadaty et al. [18], went further and proposed micro-level measures; that is, an analysis of learners' interactions with the

C. Publication 3.

Pérez-Álvarez, R., Maldonado-Mahauad, J., & Pérez-Sanagustín, M. (2018). Tools to Support Self-Regulated Learning in Online Environments: Literature Review. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 11082 LNCS, pp. 16–30). Springer, Cham. https://doi.org/10.1007/978-3-319-98572-5_2

Tools to Support Self-Regulated Learning in Online Environments: Literature Review

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Abstract. Self-regulated learning (SRL) skills are especially important in Massive Open Online Courses (MOOCs), where teacher guidance is scarce, and learners must engage in their learning process trying to succeed and achieve their learning goals. However, developing SRL strategies is difficult for learners given the autonomy that is required in this kind of courses. In order to support learners on this process, researchers have proposed a variety of tools designed to support certain aspects of self-regulation in online learning environments. Nevertheless, there is a lack of study to understand what the commonalities and differences in terms of design are, what the results in terms of the effect on learners' self-regulation are and which of them could be applied in MOOCs. Those are the questions that should be further explored. In this paper we present a systematic literature review where 22 tools designed to support SRL in online environments were analyzed. Our findings indicate that: (1) most of the studies do not evaluate the effect on learners' SRL strategies; (2) the use of interactive visualizations has a positive effect on learners' motivation; (3) the use of the social comparison component has a positive effect on engagement and time management; and (4) there is a lack of models to match learners' activity with the tools with SRL strategies. Finally, we present the lessons learned for guiding the community in the implementation of tools to support SRL strategies in MOOCs.

Keywords: Self-Regulated Learning · Tools · System · Online MOOC · Literature review · Massive Open Online Courses · Dashboard Learning analytics

D. Publication 4.

Pérez-Sanagustín, M., Sharma, K., Pérez-Álvarez, R., Maldonado-Mahauad, J., & Broisin, J. (2019). Analyzing Learners' Behavior Beyond the MOOC: An Exploratory Study (pp. 40–54). Springer, Cham. https://doi.org/10.1007/978-3-030-29736-7_4

Analyzing Learners' Behavior Beyond the MOOC: An Exploratory Study

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Abstract. Most of literature on massive open online courses (MOOCs) have focused on describing and predicting learner's behavior with course trace data. However, little is known on the external resources beyond the MOOC they use to shape their learning experience, and how these interactions relate with their success in the course. This paper presents the results of an exploratory study that analyzes data from 572 learners in 4 MOOCs to understand (1) what the learners' activities beyond the MOOC are, and (2) how they relate with their course performance. We analyzed frequencies of the students' individual activities in and beyond the MOOC, and the transitions between these activities. Then, we analyzed the time spent on outside the MOOC content as well as the nature of this content. Finally, we predict which transitions better predict final learners' grades. The results show that we can predict accurately students' grades of the course using only internal-course fine-grained data of student's interactions with video-lectures and exams combined with trace data of interactions with content outside the MOOCs. Also, data shows that learners spent 75% of their time on the MOOC, but go frequently to other content, mainly social networking sites, mail boxes and search engines.

Keywords: MOOCs · Massive Open Online Courses · Learning Analytics · Exploratory study

E. Publication 5.

Pérez-Álvarez, R., Pérez-Sanagustín, M., & Maldonado-Mahauad, J. J. (2017). NoteMyProgress: Supporting learners' self-regulated strategies in MOOCs. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 10474 LNCS, pp. 517–520). Springer, Cham. https://doi.org/10.1007/978-3-319-66610-5_53

NoteMyProgress: Supporting Learners' Self-regulated Strategies in MOOCs

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Abstract. NoteMyProgress is a web tool for supporting learners' self-regulation strategies in MOOC environments. NoteMyProgress lets learner take notes, define objectives and goals for their learning, strategically plan their learning activities, and track how they spend their time in the course. This demonstration presents the first prototype of NoteMyProgress, a Google Chrome plugin and web app that includes features for taking notes and managing the time learners spend on the course. Specifically, the article presents: (1) How NoteMyProgress is integrated with the Coursera learning platform to collect information on student learning activities; and (2) how learners can visualize their learning processes on the NoteMyProgress dashboard. This demonstration aims to show how NoteMyProgress, through interactive displays, lets learners monitor how they have spent their time in the course and how to take notes during their study sessions.

Keywords: NoteMyProgress · Self-regulated learning · Massive Open Online Course · Tool · MOOC · SRL

F. Publication 6.

Pérez-Álvarez, R., Maldonado-Mahauad, J. J., Sapunar-Opazo, D., & Pérez-Sanagustín, M. (2017). NoteMyProgress: A tool to support learners' self-regulated learning strategies in MOOC environments. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 10474 LNCS, pp. 460–466). Springer, Cham. https://doi.org/10.1007/978-3-319-66610-5_43

NoteMyProgress: A Tool to Support Learners' Self-Regulated Learning Strategies in MOOC Environments

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Abstract. The lack of self-regulation is one of the main reasons why students find it difficult to complete a MOOC. However, existing learning platforms do not have tools that support student self-regulation strategies and only few have been developed for MOOCs. This study presents NoteMyProgress, a tool designed to support self-regulation in MOOCs. We present the beta version of the tool as "proof of concept" in order to assess its usability and adoption with experts and learners in a MOOC. The results indicate that usability is well evaluated by experts, and students consider the included features to be useful in managing their time and organizing their learning process.

Keywords: Self-Regulated learning · Massive open online courses · Tools

G. Publication 7.

Pérez-Álvarez, R., Pérez-Sanagustín, M., & Maldonado-Mahauad, J. (2016). How to design tools for supporting self-regulated learning in MOOCs? Lessons learned from a literature review from 2008 to 2016. In *Proceedings of the 2016 42nd Latin American Computing Conference, CLEI 2016* (pp. 1–12). https://doi.org/10.1109/CLEI.2016.7833361

How to design tools for supporting self-regulated learning in MOOCs?

Lessons learned from a literature review from 2008 to 2016

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***Abstract*— This paper presents a systematic literature review that examines and analyzes the articles from 2008 to 2016 that have addressed the development of tools to support Self-Regulated Learning (SRL) in online and MOOC environments. The findings denote that: (1) there is a lack of tools to support SRL in MOOC environments; (2) the evaluation of the existing tools are not aligned whit the objectives of the research; (3) current research presents proposal of tools but very few achieve the stage of implementation; and (4) current existing tools tend to support many SRL strategies at the same time. We end up with a set of lessons learned for guiding the implementation of tools to support SRL strategies in MOOCs environments.**

***Keywords*— Self-Regulated Learning, Tools, System, Technologies, Online, MOOC, Literature review.**

I. Introduction

Los cursos masivos abiertos en línea o MOOCs (Massive Open Online Course) han demostrado ser una alternativa de aprendizaje en la educación superior. Más allá de los cursos tradicionales online, los MOOCs ofrecen oportunidades de aprendizaje a miles de estudiantes alrededor del mundo [1], [2], [3] tanto a nivel formal, ofrecido como parte de un programa académico para obtener un grado [4], [5]; como a nivel informal para desarrollo profesional [6]. Hoy en día, ya son miles los alumnos registrados en las plataformas que albergan estos cursos, tales como, Coursera, edX, Open edX y MiríadaX. Sin embargo, y a pesar de la alta demanda en la matrícula de los MOOCs, estudios recientes revelan que son pocos los estudiantes que logran terminar los MOOCs [7].

Una de las causas atribuidas a este problema es la falta de autorregulación de los estudiantes en este tipo de entornos [8]. Los MOOCs son entornos abiertos que ofrecen pocas directrices y guía a los estudiantes para avanzar de forma exitosa en su curso.

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El estudiante debe ser capaz de auto-dirigir su aprendizaje, gestionando bien su tiempo, regulando sus esfuerzos y monitorizando sus avances, entre otras estrategias de autorregulación. En situaciones con una alta demanda cognitiva el estudiante debería trabajar en mejorar sus habilidades de aprendizaje, pero desafortunadamente, los estudiantes tienen una alta probabilidad de fracasar en esta tarea [9].

En el momento que los estudiantes buscan aprender de fuentes de información en Internet, la autorregulación del aprendizaje debería sobresalir productivamente. De hecho, estudios realizados demuestran que los estudiantes capaces de autorregular su aprendizaje tienen mayor éxito en alcanzar sus metas de aprendizaje y completar los cursos [10], [11], [12] .

Actualmente, las plataformas MOOC cuentan con muy pocos mecanismos para apoyar la autorregulación de sus estudiantes. Coursera, por ejemplo, ofrece una visión de los materiales donde se muestran los tiempos de cada video-lección, para facilitar la gestión del tiempo. Además, cuenta con un calendario de entregas que, complementado con avisos por correo electrónico, ayuda a mantener un ritmo de aprendizaje medido. Sin embargo, estos mecanismos no resultan ser suficientes [13] y se hace visible la necesidad de desarrollar una nueva generación de herramientas capaces de apoyar la autorregulación del aprendizaje para administrar el conocimiento clásico y plataformas de aprendizaje en línea [14], [15]. Por este motivo, varias investigaciones se han enfocado, en el último año, en el estudio de la autorregulación en MOOCs con el fin de entender cómo mejorarla [16], [17], [18], [11] .

En el aprendizaje tradicional en línea, son varios los trabajos que se han centrado en el estudio de herramientas para el apoyo de la autorregulación del aprendizaje [6], [19], [20], [9]. Sin embargo, actualmente existen muy pocos estudios dirigidos a facilitar la autorregulación en MOOCs [11], [21], entornos más complejos por su masividad y el seguimiento de los alumnos. Muchas de estas propuestas son solamente ideas y prototipos que necesitan testearse en contextos reales para entender cuál es el impacto en la autorregulación de los estudiantes en este tipo de cursos. Las herramientas existentes, principalmente dirigidas a aprendizaje

H. Publication 8.

Pérez-Álvarez, R., Maldonado-Mahauad, J., & Pérez-Sanagustín, M. (2018). How to map learning activities through URLs? The case of Coursera platform. In *II International Conference MOOC-Maker* (pp. 25–34).

¿How to map learning activities through URLs?: The case of Coursera platform

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Abstract. The increased use of online learning environments such as MOOCs creates an ideal setting for data collection and the application of learning analytics techniques to better understand how we learn. However, access to data from today's MOOC platforms is limited, and it is often difficult to collect and clean up data to obtain information that will help to better understand how learning occurs in these contexts. In this study we analyze how to track the learning traces of the students' activities on the MOOC Coursera platform to understand their behavior. The study analyzed the URL patterns of 13 MOOCs offered by the Pontificia Universidad Católica de Chile on this platform. As a result, 5 categories of activities were identified in the URLs: 1) the actions of the students on the platform; 2) the content involuted in the learning process; 3) the context in which the learning took place, and 4) the social interaction with other students. These results aim to provide guidance to other researchers in analyzing the behavior of students at MOOCs de Coursera and applying learning analytic techniques.

Keywords: Tools, learning analytics, Massive Open Online Courses, MOOC, Coursera, learning activities, MOOC platforms.

1 Introducción

El incremento en el uso de ambientes de aprendizaje online, como el caso de los MOOCs (Massive Open Online Courses), ha creado un escenario ideal para la recolección de datos y la incorporación de técnicas de analítica del aprendizaje [1]. Sin embargo, el acceso a los datos de las actividades de los estudiantes en la plataforma MOOC es limitado. Algunas plataformas como Coursera, edX, Future Learn proveen un paquete de datos con los logfiles de las actividades. No obstante, este paquete de datos se genera de forma periódica, con tiempos que varían entre un 1 a 15 días. Por ejemplo, el paquete de datos de Coursera se actualiza cada 24 horas, es decir las actividades de las últimas 24 horas no se encuentran en el paquete de datos. Kulkarni et al. [2] encuentran que los estudiantes que reciben retroalimentación en un rango menor a las 24 horas después de haber realizado sus actividades obtienen mejores salidas de aprendizaje.

I. Publication 9.

Sapunar-Opazo, D., Pérez-Álvarez, R., Maldonado-Mahauad, J., Alario-Hoyos, C., & Pérez-Sanagustín, M. (2018). Analyzing learners' activity beyond the MOOC. In *1st Latin American Workshop on Learning Analytics* (pp. 120–127).

Analyzing learners' activity beyond the MOOC

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Abstract. Research on help seeking in MOOCs has mainly focused on analyzing learners' traces within the course forum, or in external social tools which are directly associated to the course. However, little research has been done on the external supplementary websites and digital resources that learners consult outside the MOOC as a way of help seeking. In this working paper, we present the results of an exploratory study with 61 learners from 3 MOOCs in which we analyzed what type of information learners visit outside the MOOC during their study sessions. The results show that learners spent 2% of the time in their study sessions outside the MOOC, being social networking sites, search engines and sites related to the course content the most visited.

Keywords: Learning Analytic, Massive Open Online Courses, MOOCs, Exploratory study.

1 Introducción

De acuerdo con la bibliografía de autorregulación de los últimos 30 años, saber buscar ayuda cuando lo necesitas es una de las estrategias más importantes para lograr sus objetivos de aprendizaje [6] [11]. Esta ayuda puede provenir tanto de otras personas, como también de fuentes de información (búsqueda de información). Debido a la falta de guía por parte de un profesor en los Cursos Masivos en Línea (del inglés *Massive Open Online Courses*), la habilidad de buscar ayuda por parte del estudiante para enfrentar dificultades y lograr los objetivos de aprendizaje es crítica [8].

Investigadores han estudiado la búsqueda de ayuda por parte de los alumnos de MOOCs mediante dos perspectivas: (1) búsqueda de ayuda desde otras personas, y (2) búsqueda de ayuda desde fuentes de información. Respecto a la primera perspectiva, hay estudios que se centran en analizar las interacciones entre los distintos estudiantes dentro del MOOC, generalmente mediante el foro de discusión del curso. Por ejemplo, los autores en [5], proponen diferentes métodos para investigar el intercambio de conocimiento que ocurre en los foros de discusión de un MOOC de Coursera, con el objetivo de ver cómo la estructura de comunicación va cambiando con el transcurso del tiempo. Los autores en [14], analizaron quiénes son los estudiantes más influyentes en los foros