Learning analytics supported goal setting in online learning environments

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Abstract
The rapidly increasing role of technology in education has resulted in large amounts of data being collected about student learning and behavior, and as a result, has given rise to the field of Learning Analytics. Although much research in this field has focused on offering insights to educators, researchers have suggested learning analytics may be most effectively employed when they focus on insights which can be offered directly to students. Furthermore, researchers have called for more focus on research driven by educational theory and given the highly self-directed nature of higher education in general, and online learning environments specifically, self-regulated learning can be highlighted as an important theoretical framework to consider in future studies. Self-regulated learning (SRL) can be viewed as a cyclical process in which goal setting and monitoring play an integral role in driving behavior, and prior research has shown that SRL skills are positively related to academic performance. However, prior research on how learning analytics can support goal setting to enhance SRL is extremely scarce. The aim of this project is to explore the question of how learning analytics can support the goal setting process in online learning environments to improve SRL and performance? In this project several studies have been designed to (a) examine the effectiveness of a learning analytics supported goal setting and monitoring tool to improve academic performance, (b) consider the influence of individual student characteristics on the effectiveness of this learning analytics tool (c) consider whether personalizing learning analytics tools to support goal setting can increase the efficacy of the tools. Overall, the aim is to be able to offer guidelines for how learning analytics tools can be designed and personalized to increase the effectiveness of goal setting interventions to optimize SRL and performance in online learning environments.

Keywords 1
Goal setting, self-regulated learning, learning analytics, technology enhanced learning, personalized interventions

1. Introduction

The past few decades have seen some major changes within the field of higher education, and a fast-paced move towards digitalization has changed the way a lot of education is carried out. This shift has brought about changes on two fronts; firstly, technology enhanced learning (TEL) has become increasingly commonplace in traditional face-to-face education, and Information Communication Technology (ICT) is now a standard addition to the day-to-day learning activities of the average higher education student [1]. Secondly, there has been a rise in new forms of education, which are either partially online, called blended learning, or

fully online, like distance learning or massive open online courses (MOOCs). While these kinds of education have been on the rise for several decades, the past few years have seen them become more widely available and accessible to a larger audience. This shift has offered the opportunity to expand and grow both research and educational practice in many novel directions. However, this shift to partially or fully digital learning environments has also brought about some unique difficulties. It has become clear that the skills needed to thrive in these digital learning environments are not always the same as those needed in traditional face-to-face classrooms [2], [3]. This has been highlighted during the COVID-19 pandemic, where the sudden and widespread shift to digital education saw a lot of students struggling to effectively manage their own learning [4]. This struggle has highlighted the fact that some of the most important skills needed to thrive in TEL environments are self-regulated learning (SRL) skills. According to researchers, throughout their years in higher education "students are on a journey to become self-managing and self-directed learners." [5, p. 130]. While they may be important in any higher education program, SRL skills are even more important in TEL environments, which often involve high learner autonomy, less teacher oversight, and a non-linear program structure [6]. SRL is described as a process in which students are metacognitively and behaviorally active in their own learning process, and implement self-monitoring, learning, and reflection strategies to strive towards goal attainment [7]. As higher education continues its current trend towards digitalization, supporting students in their development of SRL skills is likely to become even more critical to ensure their success.

Understanding how to support learners SRL is a topic which has garnered much attention from researchers over the years [8]–[10]. Previous research has shown that high SRL skills are a predictor of effective learning processes, and better academic performance [11]. Furthermore, research has shown that many students lack effective SRL skills, and struggle to implement SRL strategies within their daily learning processes [12]. However, effectively supporting SRL, especially within online learning environments, has been shown to be a complex task [6], [13], [14]. Previous studies have demonstrated that student engagement with SRL support tools is often low [15], [16], and those students who are most in need of support are often the ones least likely to seek it out and make use of it [17], [18]. Furthermore, tools which are developed to support SRL differ widely in their approach and content, and as such, they are not all equally effective. Some SRL support tools are significantly more likely to result in behavioral change and have positive effects on academic outcomes than others [19]. Moreover, not all students interact with SRL support tools in the same manner, and what is effective for one group of students might not be as effective for other groups [20], [21]. Thus, it is important to fully explore how to effectively design and implement SRL support tools within TEL environments, as well as how to tailor them to the needs of individual students and increase the likelihood of students engaging with them.

1.1. Self-regulated learning and goal setting

SRL is a broad framework which describes several motivational, cognitive, and behavioral processes which contribute to an autonomous learning process [7]. These processes have been extensively studied, and as a result, there are many different models which have been proposed to describe them (for a review see [22]). The most commonly used model of SRL is that by Zimmerman [23]. Zimmerman described SRL as the process of transforming mental and physical abilities into task-related skills [7]. Zimmerman's model describes the process as cyclical, with three separate stages: 1) the forethought stage, 2) the performance stage, 3) and the self-reflection stage. Students start in the forethought stage by setting goals and creating plans to achieve them. In the performance stage they use regulatory strategies to guide their study activities and monitor their progress towards their goals. And finally in the self-reflection stage they reflect on their performance, and how well they have achieved their goals and adjust their plans for future learning accordingly. While it is important to support students throughout the whole SRL process, the first stage, goal setting, is especially critical as it drives the rest of the cycle and forms the basis for motivated behavioral change [24]. A goal is defined as "something an individual is trying to

accomplish" [25, p. 126] and goal setting is the act of consciously deciding upon goals to strive for. Without effective goal setting, students are not able to effectively carry out the second and third phases of the SRL cycle. This highlights the importance of understanding the underlying processes of the SRL cycle in order to support it. Self-determination theory (SDT) describes the elements which drive motivated behavior [26]. According to SDT the three crucial elements for motivation are autonomy, competence, and relatedness [26]. The importance of allowing students autonomy within education has been demonstrated [27], and the importance of autonomy within SRL has also been established [28]. Prior studies show that while TEL tools may try offer students autonomy in how they use them, the decisions students make may not always be the most effective for learning or performance [14]. It therefore becomes clear that in order to design an effective goal setting intervention, the goal setting process should be guided sufficiently for students to set effective goals, while still allowing students to feel autonomous and motivated in the process.

Goal setting as a means of improving performance has been studied for many decades, starting with Edwin Locke who developed the Goal Setting Theory [29]. Locke's original theory focused on how goal specificity and goal difficulty moderated the relationship between goal setting and task performance [29]. Goal setting has remained a popular research topic, and research over the years has suggested many other goal characteristics which may affect effective goal setting. However, despite a broad base of literature on the topic, there is very little consensus on what the characteristics of an effective goal setting tool are. Prior research does show that there is a delicate balance that needs to be struck between guiding students to set effective goals and giving them autonomy to create their own goals. Studies show that students are generally ineffective goal setters when allowed to set their own goals [30], [31]. However, merely having a goal in mind is not enough, the kinds of goals which are set as well as the act of creating plans to achieve them are also important [32], and therefore providing guidance is crucial.

Furthermore, although some studies in recent years have started to carry out goal setting activities in online learning environments, there has been very little research on the potential to enhance and support these tools when they are delivered digitally. To support the process of SRL in TEL environments, tools can focus on helping students set effective and meaningful goals, and then offer additional support to guide them through the remainder of the SRL cycle. However, SRL interventions can be resource heavy, especially given the fact that they are often most effective when they can be adjusted to the needs of individual students. TEL environments can offer personalized and adaptive interventions by making use of data collected about student performance and behavior, which is known as learning analytics. Therefore, offering support tools in TEL environments have a unique advantage in using learning analytics over traditional face-to-face classrooms.

1.2. Learning analytics

Learning analytics is still a new area of study, which arose as TEL became more common in day-to-day educational settings. The definition of learning analytics still differs across the literature, but The Society for Learning Analytics Research defines it as "the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments" [33]. This definition covers a broad range of data and analysis opportunities which have arisen within education. Learning analytics relies on data which is generated when students interact with digital learning environments, and this is called trace data [34]. Trace data are interpreted as observable indicators of students' underlying learning processes [35]. Thus, the aim of learning analytics studies is often to draw conclusions about learning processes based on how students behave in online learning environments. While researchers have previously theorized that learning analytics offer a powerful and efficient means of supporting SRL [36]–[38], few studies have implemented learning analytics as a means of enhancing and personalizing goal setting tools [9]. Furthermore, while prior research has shown that student engagement in online learning environments can be a challenge, learning analytics and technology in general

offer means of combating this problem. SRL tools in online environments can combat low engagement by offering personalized experiences using learning analytics data. Personalization in education, and within the field of TEL tools is a popular topic, but it's important to understand in what ways personalizing tools using learning analytics can be beneficial. There are many different characteristics which affect the way in which students interact with TEL environments, such as personality traits [39], [40]. In the context of learning analytics, personalization can include identifying groups of students on the basis of their individual characteristics, examining what their patterns of use reveal about their interaction with the tool, and their individual needs, and creating a tool which is adaptive in nature can be personalized in response. While this kind of personalization can take many forms, the aim is to create a tool which moves away from the one-size-fits-all approach of educational tools, and to take advantage of the affordances offered by TEL tools.

Another powerful means of leveraging technology and data to support goal setting is using conversational agents. Prior studies have shown that goal setting guidance is significantly more effective when delivered by an experimenter, as opposed to via a worksheet [41]. Furthermore, it has been suggested that conversational agents could significantly improve the effectiveness, and scalability, of goal setting based interventions [42]. Existing studies have shown that conversational agents can have a positive effect on student engagement with the tools, as well as increasing their effectiveness [43]. However, there is little experimental work on the effect of delivering goal setting interventions via conversational agents. This demonstrates the power of leveraging learning analytics and TEL environments to enhance SRL tools to increase their effectiveness, but also the gap in the literature about effective means of doing so. These methods of creating adaptive and personalized interventions are especially important given that current literature suggests that not all students interact with learning analytics tools in the same manner, and it is therefore important to offer individuals personalized experiences to maximize their benefits [44], [45]. Given the literature which suggests that that individual student characteristics affect the way in which students

interact with these tools, and it is therefore important to take this into consideration and create adaptive tools which can adjust to the needs of individuals [9], [46].

Therefore, during this project we aim to address the importance of SRL in TEL environments, by investigating how to best design and implement goal setting support tools, enhanced by learning analytics, to improve student SRL skills and academic performance. We aim to use learning analytics to not only offer personalized goal setting, monitoring and reflection tools, but also to create a tool which adapts based on a student's prior performance, and personal characteristics.

2. Proposed approach

With this project, we aim to apply a multidisciplinary approach by combining insights from the fields of psychology, educational sciences, learning analytics, and educational data mining. Figure 1 below shows an overview of the studies planned for this project. Overall, with this project we aim to understand how best to implement goal setting and monitoring tools in online learning environments, and to explore how learning analytics can be used to enhance and personalize them, to offer students support that is tailored to their individual needs. The main research question of this project is "How can learning analytics support goal setting in online learning environments to improve learning and performance?" We will attempt to address this question using a design-based research approach, in which we develop a learning analytics supported goal setting tool, which is then implemented, tested, and refined in an iterative process. During each study carried out in this project, the developed tool will be tested in real-life educational settings and refined and improved based on the findings during that study. Each study will build upon the findings of the previous study in an iterative process aimed at improving the effectiveness of the tool and expanding its functionality with each study. During studies 2-4 the learning analytics supported goal setting tool will be embedded in a learning management system (LMS), used by students carrying out their bachelor's degree within a large Dutch higher education institution. Students will be able to interact with the directly from their browser while using their

LMS. Student performance will be measured using course grades, and trace data about student performance and behavior will be drawn from the LMS, as well as the learning analytics tool directly.
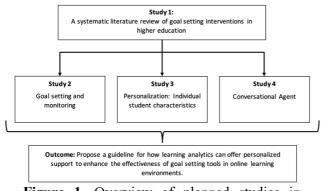

Figure 1. Overview of planned studies in project

2.1. Study 1: literature review

The first study will be a literature review, which will give an overview of the field and existing relevant literature. This will culminate in the development of a goal setting tool, which will be used in later studies. The research questions for this study are as follows:

1. How have guided goal setting interventions been carried out in previous studies in higher educational institutions?
   1.1. What kinds of goals are students guided to set?
   1.2. How are the interventions designed and implemented?
2. What is the effect of the guided goal setting intervention on academic performance and SRL skills?
3. How has technology, and learning analytics been used to support goal setting in prior studies?

This study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement to carry out a systematic search of the relevant literature [47].

2.2. Study 2: goal setting and monitoring

Study 2 focuses on developing and implementing the goal setting tool, alongside learning analytics support in the form of goal monitoring and reflection elements and testing what effect the tool has on SRL skills and academic performance. The research questions for this study are as follows:

1. What is the effect of goal setting interventions on self-efficacy, self-regulated learning, and student performance in an online learning environment?
2. How can real time goal monitoring supported by learning analytics enhance the effect of goal setting interventions on student performance and engagement in an online learning environment?

This tool will be designed based on findings from the literature review carried out in study 1, as well as on theory from the relevant fields. Study 2 will be a randomized controlled trial (RCT) with two types of goal setting interventions and a control group. Analyses of Variance (ANOVAs) will be used to test whether the experimental groups differ in performance after the intervention tool has been used for a semester, and repeated measured ANOVA will test whether there is a difference in pre- and post-intervention self-efficacy, engagement, and SRL. Throughout this project Zimmerman and Pintrich's models of SRL will be used to evaluate the interventions and SRL skills [22]. Trace data will be examined to identify patterns of behavior in the learning environment and when using the tool, to inform the design of future iterations of the tool. This step is more exploratory in nature and will be used to inform decisions made during Study 3.

2.3. Study 3: personalizing SRL tools

Study 3 focuses on individual student characteristics, and how the goal setting tool can be personalized using learning analytics, to increase its effectiveness. The research questions for this study are as follows:

1. To what extent are the effects of goal setting and monitoring interventions

moderated by individual student characteristics?

2. How can personalizing learning analytics tools based on student characteristics improve their effectiveness?

This study takes place in two parts. The first part will follow a similar design to study 2, but with a focus on testing the effectiveness of the tool, and students' interaction with the tool based on their individual characteristics. The second part aims to personalize elements of the intervention and examine whether this personalization improves the tools effectiveness. This personalization will be based on the exploration of groups of students and their patterns of behavior from Study 2, as well as existing theory and literature, and will focus on characteristics like personality traits, maladaptive study behaviors (like perfectionism or procrastination) and prior performance. The effectiveness of the tool will be tested in an RCT using an ANOVA to compare experimental groups.

2.4. Study 4: SRL supporting conversational agent

Finally, study 4 focuses on how to increase student engagement with the tool, by testing its implementation in the form of a conversational agent. The research questions for this study are as follows:

1. How does delivering the learning analytics supported goal setting tool via conversational agent affect engagement, self-efficacy, and student performance?

This study will follow a similar layout to Study 2 and 3 and will test the effectiveness of the tool when it is integrated with and delivered by a conversational agent. We will then examine whether this improves the effectiveness of the tool by examining differences student performance in a RCT. Patterns of student engagement with the tool will also be examined.

3. Current results

Currently, study 1 has been carried out. This is a systematic literature review of goal setting interventions in higher education settings. In this study, a systematic literature review was carried out following the PRISMA guidelines, and we aimed to examine all papers published after 2010, which had an active academic goal setting tool that was implemented amongst higher education students. The final sample included 37 papers. The final sample of papers were then examined, and the goal setting tools presented in them were broken down into various characteristics covering two main areas: 1) the intervention implementation and design, 2) the characteristics of the goal setting activity.

Regarding the intervention implementation and design, the results showed that less than half of the papers ($n = 16$; 43%), were experimental designs which tested the effectiveness of the intervention. This means most of the papers were implementing goal setting activities without testing whether they were having the intended effect on student behavior or academic performance. This result may seem surprising given previous studies showing that not all goal setting activities are effective at bringing about behavioral change [48], [49], however prior work has noted the gap between educational theory and what researchers want to measure, and the implementation of TEL tools [50].

Furthermore, the results showed that while the interventions were delivered digitally in almost half of the papers ($n = 17$; 46%) of, for the most part, these interventions had no form of technology support or enhancement and were neither personalized nor adaptive. Instead, most digitally delivered goal setting interventions were merely computer-based versions of a static pen and paper type intervention. This made it clear that while there is a definite shift in SRL interventions towards digitalization, at the current time most tools do not make use of the full potential of technology to improve or support their interventions.

Regarding the characteristics of the goal setting activities, several elements were examined including goal type, goal context, goal depth, and goal distance. Overall, what could be seen from this examination was that in general, goal setting interventions offered very little guidance as to the kinds of goals students should be setting. It was observed that students were asked to set goals, but not given any specific characteristics or content that their goals should contain in most studies. While this

allows for a lot of student autonomy, it is troubling in the face of prior research which shows that when unguided, students generally don't set very effective or meaningful goals, and that some types of goals are more effective at bringing about behavioral change than others [51].

The focus on unguided forms of goal setting, and non-experimental designs in the studies reviewed makes it hard to draw conclusions regarding the most effective way of scaffolding goal setting. However, the results did suggest that delivering interventions digitally, combining goal setting with support for other stages of the SRL cycle, and requiring that students set more detailed, specific goals were all associated with goal setting having a positive effect. From these results, it is clear that more studies are needed to actively examine the characteristics of effective goal setting interventions.

Taken together this suggests several things for the future of this project; 1) there is a disconnect between the existing literature on how to set effective academic goals, and the development of many of the goal setting tools implemented in previous literature. And 2) while these kinds of interventions tend to be delivered digitally, there is a lot of room for improvement in how technology and learning analytics can be used to support and enhance these tools.

4. Contribution to TEL domain

While the TEL domain has been around for several decades, the last decade has seen a massive increase in its popularity in the average higher education classroom. As such, it is more important than ever to address how to best support students while learning in TEL environments. This project contributes to the understanding of how learning analytics can be efficiently implemented to support student SRL in online learning environments. It focuses on bridging the current gap in the scientific literature between learning analytics implementation and educational sciences theories. This project will also build on the literature available about the SRL cycle in academic environments and offer insight into how this process motivates behavioral change, and how this can be further supported in online learning environments. It will go on to explore

how learning analytics and conversational agents can be used to enhance goal setting interventions in TEL environments in order to make them more engaging and better tailored to the individual needs of students. With the results from this project, we aim to advance the understanding of how to best implement goal setting support tools within online environments, to help enhance students' SRL skills that are needed to succeed in an increasingly digital educational landscape.

While this project has wide-reaching scientific significance, it also has important practical significance. It will focus on using education sciences theories to shape learning analytics tools and offer insight into the role of individual student characteristics in shaping the way students interact with learning analytics tools. These insights can be used to form the basis of future research into, and development of, learning analytics tools. The rise of technology enhanced learning has highlighted the need to create tools which can support students learning in online environments in a personalized manner. The studies in this project aim to understand how learning analytics tools can best offer this support, and to create guidelines for the development of these tools in the future.

While several studies have examined the use of learning analytics to support performance, very few have focused on the use of learning analytics tools to support goal setting and goal monitoring. Furthermore, there is currently very limited research on how individual student characteristics like perfectionism or self-efficacy affect the way students interact with learning analytics tools, and to what extent these tools are effective for students who differ on these characteristics. This project aims to develop tools which can be used to offer personalized learning analytics supported SRL tools.

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