Chapter 1
Influencing Metacognition in a Traditional Classroom Environment Through Learning Analytics

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Abstract Metacognition plays an important role in the learning process as it allows learners to become better aware of their level of understanding and comprehension. Knowledge of learners' metacognition level allows teachers to provide feedback to learners to enable correction of learning strategies. However, measuring metacognition based upon learner activities outside a computer-based learning environment is a challenging task. This paper explores this challenge in adult learners for the purpose of developing a learning analytics model that can be used to influence the use of metacognitive strategies to improve learning and comprehension. As a solution, a novel learning analytics model is presented. This model is based upon data captured from a traditional physical classroom environment and can be used to build a working learning analytics model designed to provide feedback to the learner. Such feedback can provide insights of learners' use of metacognitive strategies with a view to improving their comprehension of a given topic and thus to improve their understanding of that topic and ultimately to improve their academic success.

Keywords Metacognition · Self-directed learning · Learning analytics · E-learning · Learning and comprehension · Learning awareness

1.1 Introduction

One of the many challenges facing both college and university faculty alike is assisting learners in becoming more aware of their level of comprehension of course content and to use this awareness in real time to alter their study strategies to

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improve their academic success. The purpose of this research is to develop a learning analytics model that can be leveraged by future researchers to explore how data captured in the context of a traditional physical classroom environment can be used to influence metacognition in the adult learner. The model presented can potentially be used to influence the use of metacognitive strategies by adult learners, resulting in improved understanding of a given topic and potentially achieving higher grades. Although young children can be taught memory and cognitive strategies, they are unlikely to use these strategies spontaneously as this is a complex metacognitive act which is developed over time through experience, practice and support [7]. Consequently, the focus of this research is on adult learners as they have developed the ability to make conscious use of metacognitive strategies.

Capturing data within the context of a traditional physical classroom is an atypical approach to learning analytics in today's online learning and mobile computing environment. Much research has been conducted in building learning analytics models from data captured within the context of a computer-based learning environment (CBLE). A CBLE lends itself to the collection of data relative to learner activity as long as all learner activities take place within the CBLE. However, the purpose of this paper is to explore the practicality of capturing learner activity from a traditional physical classroom environment and in turn use these data to provide feedback to the learner for the purpose of influencing the use of metacognitive strategies to improve learning and academic success.

Monitoring learning behaviors has the potential to contribute to academic success for post-secondary learners [8]. The overall goal of this paper is to inform future research in the area of metacognitive processes in the context of the traditional physical classroom environment, thus enabling adult learners to more effectively practice metacognitive strategies to improve their overall understanding of a given subject and potentially improving grades.

The main research problem explored in this paper is as follows:

What parameters should be used to build a learning analytics model for a traditional physical classroom environment that could be used to influence the use of metacognitive strategies by adult learners?

The desired result of using metacognitive strategies is to enable adult learners to become more aware of their degree of comprehension of a given topic so they will take the necessary action to adequately prepare themselves for future assessments and thus improving their overall academic success.

Mytkowicz [8] has shown that many new college learners struggle because their past academic experiences do not sufficiently prepare them to handle the demands of college because their available learning strategies, and indeed their ability to select and apply the appropriate strategies, are poor.

Given its importance to post-secondary success, it is clear that metacognition should be taught explicitly to college and university learners [8]. The focus of this essay is inspired by a scenario that we witness often as post-secondary educators. The scenario to which we are referring is that ever-recurring situation in which a learner fails to comprehend their lack of understanding of a particular concept and proceeds to enter into a testing situation convinced of their superior grasp of the topic—only to receive a failing grade. After receiving the grade, the learner is surprised—even dumbfounded, and draws every conclusion as to the source of their failure, except that they truly do not understand the topic. The authors have observed that students with an advanced awareness of their own level of comprehension will take corrective action while studying to reference alternate sources of information to get a better understanding of a topic they are struggling with. So the question this scenario raises is as follows: Why is it that some learners are more aware of their own lack of comprehension then others?

1.2 Literature Survey

There is little evidence in the literature for building a learning analytics model from data captured from a traditional physical classroom environment. At the same time, much work has been done to capture data through direct interaction with the learner in an effort to gain a deeper understanding of metacognition and the use of metacognitive strategies. Common off-line techniques currently being used to capture these data are self-report questionnaires, interviews, and teacher ratings [9]. A common method for gaining insights into the process of task execution is the use of think-aloud techniques [10]. Researchers have been using these techniques for quite some time to better understand learners' metacognitive activities by asking the learners to 'think aloud' as they study or solve a particular problem. This technique is typically (if not always) conducted in a face-to-face context and serves to provide insights specifically into metacognition relative to the task a learner has been working through.

Self-report questionnaires on the other hand are developed with the aim of assessing metacognition using Likert scale questions. Generally, two types of questionnaires are used in metacognition research: general and domain specific. General metacognitive questionnaires are designed to assess metacognition independent of any specific learning domain or activity. Domain-specific questionnaires are designed to assess metacognitive activities in the context of a single domain or learning activity [10].

Another off-line technique to assess metacognition is simply interviewing the learners either shortly after a learning activity or in general. Mainly, there are three varieties of interviews used in metacognitive research. One interview approach is to simply ask the learners to describe their typical learning behavior or activities as they reflect upon past learning experiences. Alternatively, individuals are asked to describe their metacognitive behaviors after completing a specific task. In more advanced interview protocols, hypothetical learning situations are presented and learners are asked what strategies they could use in those particular situations [10].

Teacher ratings are another off-line technique of assessing the use of metacognitive strategies of learners. Teachers are requested to evaluate their learners' use of metacognitive strategies using an appropriate rating scale [9].

All of the above-mentioned techniques are focused on capturing data directly from learners using a human operator. Indeed the traditional approach to measuring learners' SRL-oriented thinking has been through self-report questionnaires. The questions are designed to assess various aspects of the learners' self-regulated learning strategies.

Online learning is the ideal scenario where this type of data can be captured, especially if learners are provided with an online learning environment within which all of their course work is completed. To improve learning from instruction, researchers, instructors, and learners alike need data that will give insights to the effectiveness of how a course is designed.

Winnie et al. [12] provides a good overview of software that is currently available to capture and analyze data from a learning environment. Software developed by the learning kit project is one example of the use of technology and computer-based learning environments to analyze and interpret data from an online learning environment. The learning kit provides scaffolds for learners to develop expertise in study tactics and learning strategies that align with aspects of instructional design theory. With trace data, the learning kit can reconstruct a complete time-referenced description of the learners' learning actions which give indication of how the learner studied. gStudy is another software solution that provides learning tools that learners can use to engage with multimedia information through indexing, annotating, analyzing, classifying, organizing, evaluating, cross-referencing, and searching learning content. Such tools for studying multimedia information are designed based upon research into ways to positively influence solo and collaborative learning and problem solving.

As described by [11], a more recent approach to learning analytics and the need to capture data from disparate inputs is the Tin Can API. This API is an emerging specification for learning technology that makes it possible to collect online and off-line learner experience data. Data are collected in a consistent format via assorted technologies and stored in a learning record store (LRS). Learner experiences are recorded in the form of secure 'noun, verb, object' statements (e.g., Bill attended lecture three on Pythagorean theorem) that are sent to the LRS. Once stored, these statements can be shared with other LRSs, LMSs, and reporting and analytic tools. Essentially, Tin Can allows the user to fashion a complete picture of an individual's learning journey based upon their experiences along the way. Most importantly, Tin Can is designed to record learning events in a personal data locker that becomes the property of the learner versus the University, the employer or the LMS. The aggregation of these learning experiences can assist researchers to identify the training paths that lead to the most successful outcomes as well as the least successful outcomes resulting in an overall measure of the effectiveness of a given training program.

Although not all learners successfully self-regulate, it is something that can be developed and learned over time [5]. Metacognition, a facet of self-regulated learning, is a complex, multifaceted structure that cannot be accurately assessed using a single technique or tool [9]. Both off-line and online techniques are required to provide accurate insight into metacognitive processes. Studies show that there is compliance between the teachers' opinions and the learners' opinions of themselves relative to their comprehension of a given subject [9].

1.3 Methodology

A literature review was conducted based upon peer-reviewed papers that were primarily published since 2010. The identification of appropriate papers was based upon a search for topics, including but not limited to, metacognition, learning analytics, self-regulated learning, metacognitive strategies, metacognitive awareness inventory (MAI), and online learning technologies. Papers were selected that described specific theories, research results, and background information relative to using learning analytics data to influence metacognition. Fifty-three papers and conference proceedings published primarily between 2010 and 2014, and relevant Web-based material, were selected and reviewed for this paper. Each paper was carefully reviewed to identify relevant material that would inform this study and the resulting proposed learning analytics model.

1.4 Issues, Challenges, and Trends

Research into theories of education seeks to identify causes of learning performance and the lack thereof. By discovering and understanding such causes, we are able to design appropriate interventions to improve learner comprehension and thus academic performance. However, research in this area is challenging due to the difficulty in measuring unobtrusively the metacognitive strategies employed by the learner [1]. Secondly, the literature provides little guidance on how to capture and interpret data about learner context in researching self-regulated learning [5].

Additionally, current self-report protocols reveal very little about how learners select and utilize specific learning tactics to form an efficient metacognitive strategy [5]. There is a need for greater insight into self-regulated learning by capturing more granular data that accurately reflects the learning journey and the learners' environmental variables, such as motivations and distractions.

When it comes to self-report surveys and interviews, results may not accurately reflect the learners' actions, as these tools capture results after the fact which may be subject to memory decay [5]. From a technical point of view, the accuracy of data collected from any of the above-mentioned tools remains the biggest challenge for data analytics. In this context, data collected is assumed to be free of bias from context and therefore should provide a true representation of the learning activities recorded [4]. However, in most learning settings, learners introduce contaminants into the dataset, usually unknowingly; indeed, this is a reflection of the complexity of metacognition. However, it is clear that if learners receive feedback on their performance, they may modify their self-assessments to be a more accurate reflection of their actual knowledge levels; thereby, the correlation between self-assessments and actual performance will increase [10].

With regard to the use of self-reports, reliability may be an issue, as participants may not always provide truthful responses or may provide responses that they feel the researcher is anticipating [6]. Alternatively, if the learners lack an appropriate level of self-awareness, they may report information which they feel is truly a reflection of their learning approach or level of comprehension yet is not at all accurate. This of course is a circular argument, as the very purpose of employing self-report methodologies is to ascertain the learners' metacognitive strategies which include self-awareness!

The MAI is a frequently used tool for data collection. Despite being used in several studies, the models and results generated from MAI scores are not conclusive [6]. Additionally, evidence suggests that the use of metacognitive skills is related in some way to the learners' intellectual ability; for example, strategies differ between average learners and gifted learners.

1.5 The Learning Analytics Model

The proposed learning analytics model (Fig. 1.1) is based upon the capture of data within the context of a traditional physical classroom environment (vs. a computer-based learning environment) and feeding the results of this data to the learners to provide them with insight into their use of metacognitive strategies and in particular their ability to predict their own learning outcomes by monitoring their own level of comprehension. The overall goal of the model is to provide the learners with the appropriate level of feedback so that they will take necessary actions to improve their level of comprehension, thus improving their academic success. The biggest challenge of the model is to understand how best to intervene to assist learners based on sound models of causal relationships [1].

One of the main goals of integrating traditional teaching methods with learning analytics is to improve teaching and learning quality [2]. Ultimately, what we wish to solve is the problem of learners walking into an assessment convinced that their degree of understanding of the subject matter is at an acceptable level, only to find out from the assessment results that they indeed have a very limited understanding of the subject matter. Hence, we are trying to equip learners with knowledge of their comprehension so that they can make better decisions regarding study strategies by improving their ability to monitor their own comprehension. To learn intentionally, learners must consciously understand and be able to identify their strengths and weaknesses, their unique learning strategies, the techniques they use to evaluate the way they execute learning tasks, how they monitor their own learning, and whether they are creating new ways to learn intentionally [6].

The question now becomes what data do we capture, how do we capture these data, and how do we present these data to the learners to motivate them to take affirmative action to better understand the subject matter and to improve their overall

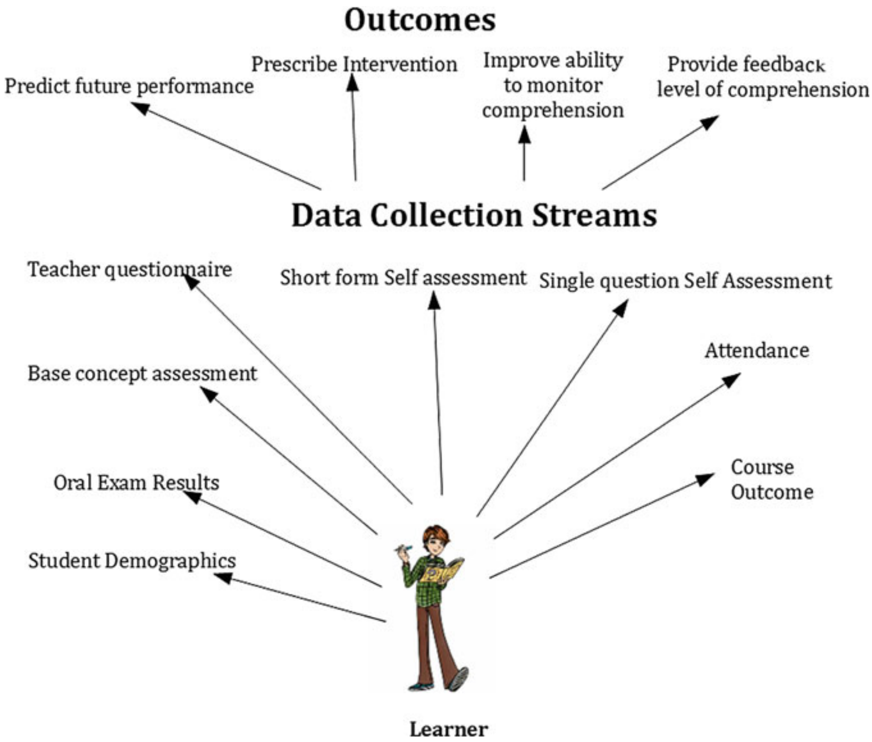

Fig. 1.1 Data analytics model

ability to monitor their own comprehension. Essentially, we are trying to develop or equip learners to become intentional learners. This development of intentionality requires educators to create learning opportunities to cognitively challenge their learners as well as to present the learners with tasks which will cause them to reflect upon their own learning process [6]. Integration of multiple and diverse data sources, both off-line and online, may lead to more pedagogically meaningful learning indicators because a more holistic picture of the learner is provided by the data [2].

The data capture streams proposed by this solution are as follows:

- teacher questionnaires;
- short three-question self-assessments at the beginning of each formal assessment;
- short one-question assessment at the beginning of each topic;
- multiple-choice questions on fundamental concepts that are grouped by concept;
- course outcomes measured against learner achievement;
- attendance; and
- oral exam results.

Teacher Questionnaire: The purpose of the teacher questionnaire is for teachers to provide their views about learners' ability to use metacognitive strategies and in particular provide commentary on the learners' ability to monitor their own comprehension of specific subject matter.

Short three-question self-assessment at the beginning of each formal assessment: This assessment is a direct 'measure' of the learners' views about their own overall comprehension of the material being presented in the assessment. Three simple questions placed at the beginning of each formal assessment ask the learners to rate their overall comprehension of the material and the strategies they used to prepare for the assessment.

Short one-question assessment at the beginning of each assessment topic: This assessment is a direct and more granular 'measure' of the learners' views about their comprehension of the specific topic being evaluated; this, for example, may be one question on an exam.

Multiple-choice questions on fundamental concepts that are grouped by concept: This is an assessment written specifically to evaluate the understanding of base concepts that when put together make up the pieces required to solve problems a given situation. There would be several multiple-choice questions on each concept that would be grouped together. From this evaluation, the learner would be able to quickly identify fundamental concepts that they do not understand and therefore may be impeding them in their ability to solve high-level problems based upon these fundamental concepts.

Course outcomes measured against learner achievement: This feedback would be based upon progress against published course outcomes as evaluated by standard assessment tools.

Attendance: Attendance is typically a fair predictor of a learner's probability of being successful in a course. These data would represent attendance in both lectures and laboratories where applicable.

Oral exam results: The instructor would draft a set of questions to probe the learners' understanding of base concepts of the course through an oral exam. Prior to the oral exam, the learners would be asked to rate their comprehension of each of the topics in which they will be questioned.

1.6 Learner Feedback

Once the data are collected and analyzed, it would be used to provide feedback to the learners to increase their level of awareness of their true comprehension of specific topics, provide a prediction of future performance, prescribe possible strategies that the learners can implement to improve their performance, and ideally help the learners to improve their ability to monitor their own comprehension.

Feedback is an important aspect of self-regulated learning in that it allows learners to compare their own views about their comprehension of a topic to their level of comprehension as evaluated by the feedback provided [3]. The reduction or elimination of this overconfidence will allow the learners to arrive at a more realistic judgment of their level of comprehension. The model presented utilizes three data streams to provide the learners feedback on their comprehension as measured by the model. These three data streams are as follows: short three-question assessment at the beginning of each formal assessment, short one-question assessment at the beginning of each assessment topic, and course outcomes measured against learner achievement. A formal review of the data from these three sources by the course instructor will provide the learners with valuable feedback that will provide insights to their own view of their comprehension of the material that is the subject of the review.

Consistent feedback sessions as described above will assist learners to improve their ability to monitor their own comprehension over time by becoming more intentional about their own learning. Intentional learners tend to understand their own self-capacity, their own learning processes, and examine the way they evaluate, monitor, and execute their own learning processes and comprehension [6].

Primarily, the teacher questionnaire data combined with the multiple-choice questions on fundamental concepts that are grouped by concept will equip the course instructors to prescribe to the learners study strategies that will assist them in becoming more self-directed and intentional learners. In particular, the multiple-choice questions on fundamental concepts that are grouped by concept will allow the instructors to pinpoint exactly what basic concepts the learners are struggling with relative to the assessment topic as a whole. This will allow the instructors to prescribe remedial work that builds the learners' understanding of these fundamental concepts so they are better equipped to tackle more advanced topics that are built upon these fundamental concepts. The other data streams (short three-question assessments, one-question assessments, course outcomes) will also provide insights into the learners' ability to monitor their own comprehension and thus discover strategies to provide feedback prior to a formal assessment.

Finally, the attendance data stream along with the course outcomes will allow the instructors to predict the future performance of the learners by identifying an academic success pattern that will continue unless evasive action is taken by the learner. The other data streams (short three-question assessments, one-question assessments) will also inform this discussion as a learners' ability to monitor their own comprehension will significantly inform their academic success.

From the above discussion, it can be seen that the course instructors play a significant role in helping the learners interpret the feedback provided by the model and to apply that feedback to alter their study strategies. The overall goal of the model is to train learners to interpret their own feedback so they can, without guidance, alter their study strategies when necessary.

Research suggests that self-assessments are strongly related to actual knowledge levels when learners are given opportunity to self-assess and receive feedback on their self-assessments [10]. However, Efklides [3] argues that judgments of learning can be flawed if the learners rely upon the inference that a certain topic may be more important than another because it is processed more fluently, or faster, yet in reality it is already well understood. In this case, the learner may be focusing their attention on material they have already mastered versus material they still do not understand. Additionally, basic psychological research suggests that the correlation between self-assessed knowledge and test performance may be low because some learners may simply be inaccurate in their self-assessments [10]. However, metacognitive judgments can be improved and monitoring can become more accurate if:

- the learners have prior knowledge that allows for evaluation of the correctness of their judgments;
- the learners are given corrective feedback; and
- the learners have understanding of how memory works and the factors that influence memory [3].

Recognition of prior learning strategy posits that learners monitor their improvement in learning as they study and therefore are able to conclude when they no longer need to study a topic they have mastered or stop studying altogether because learning abates when little progress is being made [3]. However, unintentional learners are influenced by external factors such as prior knowledge, types of tasks, and facilitation and thus will change their learning process accordingly [6].

This model may be most suited for those learners who struggle with math or other science concepts. Equipping learners to monitor their own comprehension is a significant step toward course success. Course instructors could design the questions for each assessment as well as the oral exam to gain insights into the learners' level of comprehension and use of metacognitive strategies. An exam on TCP protocol, for example, could be broken down into several fundamental concepts to build the multiple-choice questions that are grouped by concept; which will provide both the instructors and the learners insights of what fundamental concepts are not clearly understood. Technology courses in particular are conducive to this model. Feedback from the model can equip instructors to give learners feedback of what specific concepts the learners are struggling with and what resources and strategies the learners could use to improve their understanding of the course material.

1.7 Conclusion and Future Research

Learning analytics is still in its infancy and is seen by many as one of the technological advances that will bring learning to the next level [6]. However, there is still much work to be done to replace the insights gained by a human instructor when it comes to evaluating learner motivation and distractions. One of the challenges of learning analytics is its current reliance on computer-based learning environments. With this focus, there is a risk that the traditional classroom learning paradigm will not benefit from the research that is being carried out in the area of learning analytics. Interestingly, Lee [6] argues that there is a dark side to learning analytics. This view sees learning analytics as a mechanism for higher education institutions, governments, and private companies to use these data to manipulate the learners to paths they may not have chosen on their own [6]. Therefore, it is important that learning analytic models be designed from the learners' perspective to ensure that the interests of the learners are the primary motivator for design decisions and data usage [4]. Future studies should explore the relationships between intentional knowing and abilities such as problem solving and critical thinking which are important attributes of today's learners [6]. Additionally, further research should be conducted on the role of self-assessments and the potential benefits of administering self-assessments throughout a course with a view to understanding how quickly these improve in accuracy and how they influence learning processes [10].

There are indeed limitations to the work presented in this paper. Limited research has been conducted in the area of building learning analytics models based upon a traditional classroom environment; hence, the model presented here is based primarily on anecdotal evidence. Secondly, this model is written based upon a technical curriculum; therefore, the model may not be as effective if applied to non-technical courses.

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