

A Flexible Framework for Metacognitive Modelling and Development

Prof Liz Bacon, Prof Lachlan MacKinnon

e.bacon@gre.ac.uk

l.mackinnon@gre.ac.uk

Abstract: Research in eLearning and technology enhanced learning (TEL) has predominantly focused on the creation of learning materials in appropriate forms, such as learning objects, the assessment methods that can usefully be applied online, and the delivery mechanisms for these materials, particularly in virtual learning environments (VLEs). In more recent times, research has begun to focus on pedagogical issues, and in particular whether there is some specific model that applies explicitly to online learning situations. Through a number of projects over the last ten years the authors have considered issues of learning style, learning strategy, pedagogy, immersive environments, student engagement and motivation, games-based learning, adaptation and personalisation. Emerging from this work, and from extensive consideration of the existing research in this area, this paper argues a need to move not only to a different pedagogic model, but also to change the existing structural approach to learning to support the rising demand for online distance learning provision worldwide. Fundamental to this argument is a need to support a heutagogic model of student learning, which requires that the students involved are sufficiently educationally mature to take control of their own learning experience. Whilst within traditional teaching models in higher education there is an explicit aspiration that students will emerge as educationally mature, metacognitive graduates, this is often seen as an outcome of the learning process itself, rather than as a skillset which can be taught and assessed. The paper describes an approach to metacognitive assessment that has already been used to determine the level and skills displayed by students in making selections of learning materials online. Based on this approach, a structural model for online learning support is proposed, using an assessment, feedback and training loop to ensure that students have the level of metacognitive skills necessary to take effective control of their own online learning experience.

Keywords: Metacognition, learning strategies, heutagogy, personalised learning, technology enhanced learning.

1. Introduction

In recent times, there has been a huge explosion in the demand for online higher education for several reasons:

- Higher education in many countries in the developing world far outstrips supply and although governments recognise the need to educate more of their population to help their countries move out of poverty, for most, their ability to deliver this in the near future is limited, however the education is needed now. Whilst many students from developing countries study abroad, the majority cannot afford it. In the short term at least, online distance education offers one solution to help address this issue.
- Online education is not only for those studying at a distance. Students now arrive at university immersed in technology and they expect that technology to support them through their education in the same way as does in their everyday lives. Many students take online courses as part of their on campus studies, as reported by Hachey et al. (2012), in the US in 2010, 30% of students took an online course at some point during their college career and the trend is increasing. However, online education is not just about studying an online course it is also about supporting face-to-face delivery to provide an enhanced, innovative, enjoyable, immersive and personalised educational experience.
- Internet bandwidth, worldwide, has increased by an order of magnitude over the past 10+ years, providing the capacity to offer video etc. to many parts of the world where it previously either wasn't available or where the bandwidth made it not viable. This additional bandwidth is now providing us with the capacity to completely revise our online educational models to support more effective, efficient and personalised online teaching.

All of the above is good news so exactly what is the problem? The success of online education is, in the majority of cases, considerably worse than a typical on campus educational classroom experience where students are co-located for their learning. They have been shown to be particularly poor for MOOCs (Massive Open Online Course), the success rate of which is often at less than 10%. There are many reasons for this and

the literature has identified many factors, for example: prior experience of online courses; age; gender; ethnicity; motivation; intrinsic interest in the subject; personal and financial issues; learning styles and learning strategies; social and cultural characteristics including the ability to make friends online; the provision of engaging and immersive environments; and the retention of some physical contact with staff and other students i.e. a more blended approach to learning than completely online [MacKinnon and Bacon 2014]. However there is one characteristic that is key to success, without which, a student is unlikely to achieve and will certainly not perform at their best, that is, metacognition. In this context we define metacognition as the knowledge someone has about how they personally learn and can include strategies about when and how to use particular learning techniques, and how to make selections between learning objects and materials, i.e. someone's "learning strategy". In face-to-face education metacognition is not something that is generally taught, it is somehow expected to emerge as students progress through their education and by the time they reach higher education, it is assumed that students are generally metacognitive however, many are not. Despite this fact, most students pass their degrees in a standard classroom setting. Whilst they might not perform at their best, a traditional classroom style, structured form of education is one they are familiar with and have experienced all their life so most have learned to cope by developing learning strategies to deal with the variety of teaching styles that they have experienced.

The world of online education is however, very different. Students are often confronted with a range of materials in a variety of forms such as text, graphics, animation, audio, video and games. Student educated in a traditional classroom setting can encounter several problems with this for example:

- They may have limited experience of using these types of materials for learning.
- They may be given a free choice of which materials to use which can be confusing.
- Because of the nature of the web, learning materials maybe presented in a nonlinear way i.e. there may be more than one sensible route through the learning materials from which they have to choose (Azevedo, Cromley and Seibert 2004; Mulwa et al. 2010). Having been used to a more traditional style of education where the lecturer provides the suggested sequence of materials in order to learn, students can become confused having to decide the order in which to tackle the learning materials.

The result of this type of online education is that it requires students to take more control over their learning, as it requires a more andragogic/ heutagogic, as opposed to pedagogic, model of learning and therefore works best for students who are self-directed, motivated, well-organised and strategic in their learning. To quote, Blaschke (2012) says "Learner autonomy is characteristic of and promoted in distance education learning environments, distance education inherently supports heutagogical practice". However, in an online environment, where students are faced with decisions about how to learn, weaker, less metacognitive students, are likely to flounder more than in a traditional face-to-face, organised teaching environment, as this type of learning can accentuate the problem when metacognitive skills, coupled with the ability to regulate themselves and their learning are required to succeed. That said, having these skills is not a guarantee of success (Schunk 2008). Good students will always generally succeed however they are taught but current educational practices are not developing metacognitive skills in the majority of students to the level required and we are therefore failing in our practice.

The rest of this paper first of all reviews the literature on metacognition and then discusses a framework for developing metacognitive learners which brings together the work of the authors and their PhD students in this area. Before concluding it reflects on the future of online learning given the potential for the development of digital monitoring environments which could revolutionise our educational models and approach to assessment.

2. Metacognition

As discussed above, the definition of metacognition in this context refers to the ability to understand how someone learns and this includes the ability to develop learning strategies to cope with different styles of teaching, understanding how to find a sensible route through a range of learning materials and know which types of learning materials work best, in what order to tackle them etc. As also identified above, this is something rarely taught in education, students go through the learning process, most having been taught through traditional face-to-face models where a teacher stands at the front of a classroom imparting their words of wisdom. This is then typically followed by some practical discussion or application of the learning. These traditional 19th century models have worked reasonably well in the past however they have not served

some students well at all who do not learn in that way, or who have been unable to develop learning strategies to progress. They also do not embrace the potential benefits that online learning could offer. Many people often think of online learning a poor second to face to face teaching, partly because in many cases the pedagogy from the classroom is simply translated badly to the online environment. An online environment can however provide learning experiences that are simply not possible to deliver in a classroom. For example, the use of simulations such as the ability to mix chemicals together and experiment safely as though in a chemistry lab or learning through computer games which can be an immersive, fun and engaging learning experience [Kazimoglu et al. 2012].

Much of the literature on metacognition does not directly address how to develop it in learners. This is however a complex area that can only be summarised here and it should be noted that being metacognitive alone does not offer a guarantee of success (Efklides 2011). Both Efklides (2011) and Boekaerts (1996) argue that metacognition, motivation, affect and volition are all part of self-regulated learning and the ability to undertake self-regulated learning is itself a form of metacognition. It also includes the ability to translate knowledge, skills and attitudes from one learning environment to another (Boekaerts, 1999). Efklides (2011) agrees with other authors that metacognition has many facets. There is however, no single agreed definition for these but by way of an example, metacognition could be categorised into the following:

- *Metacognitive knowledge* which is important for the control of cognition and comprises declarative, procedural and conditional knowledge, self-efficacy beliefs, theories, achievement goal orientations etc.
- *Metacognitive strategies or skills* which influence the control of cognition and involve activities such as planning, orienting, monitoring, checking, selecting, revising, evaluating, self-monitoring and self-evaluation. Their purpose being to ensure that a goal is met.
- *Metacognitive regulation* which regulates the use of metacognitive strategies.
- *Metacognitive experiences* which are current and past experiences such as feelings of difficulty.

According to Boekaerts & Niemivirta (2000) and Boekaerts (1996), self-regulated learning involves three layers: regulation of the self, which is about a person's choice of goals and resources, regulation of the learning process which is about using metacognitive knowledge, strategies and skills to direct the learning and regulation of processing modes i.e. metacognitive regulation in which cognitive strategies are selected. In addition, metacognition, self-regulation and self-regulated learning are all influenced by a multitude of other factors such as personal characteristics, physiological and emotional states etc.

The literature has shown a number of ways that metacognition can be developed and supported, more recent literature referring to the development of heutagogic learners who must possess many of the desired characteristics of metacognition, self-direction etc. if they are to be independent learners (Blaschke 2012). Below summaries a few key examples from the literature of how metacognition can be developed:

- Woolfolk and Margetts, (2007), as part of the educational psychology literature has also questioned whether individual metacognitive abilities are as a result of biological differences or different learning experiences, i.e. nature vs nurture. In terms of biological differences, the research on this is unclear however several researchers have demonstrated that metacognitive skills training and support for self-development can help (Wagster et al. 2007 and Gunter et al., 2003), in addition to the fact that students develop metacognitive abilities as part of their usual learning and observation experiences (McInerney and McInerney, 2006).
- Azevedo and Cromley, (2004) argue the importance of metacognition. Their research shows that not all students have the ability to regulate and manage their learning, and deploy relevant strategies at the right time, or monitor their own progress etc. The presence of a tutor in a technology enhanced environment has been shown to assist with the development of metacognition (Azevedo and Cromley 2004).
- Kirsh, (2005) argues the need for a well-designed learning environment with a good visual design that provides an appropriate structure, well-written easy to understand sentences which require less cognitive effort to comprehend, ensuring that support tools, such as chat tools, are easily visible to students and links to learning materials and are not missed, can all make a significant difference to the effectiveness of metacognitive development.

3. A Flexible Framework for Metacognitive Development and Modelling

In this section we describe the development of a framework for metacognitive modelling which brings together successful research from a number of projects. These research projects and their results are summarised below and the section concludes with a description of the framework explaining how the research is brought together to assess and develop metacognitive skills in students.

3.1 Use of tagging to support the authoring of personalisable learning content

This section describes a research project which focussed on the personalisation of eLearning platforms. Whilst many learning platforms provide some means of personalisation, analysis of platform features revealed that most of these were fairly superficial e.g. changing the colour of the user interface. Nine of the most commonly used learning platforms were evaluated against a number of personalisation criteria and none of them were considered to offer a truly personalised experience. The analysis included an assessment of the instructor's ability to monitor learners, manage and sequence course material, a learner's ability to search for learning objects, whether the system can structure learning materials according to need, and the ability of the system to adapt the user interface, and adapt to a learner's goals, behaviours and learning styles etc. A conclusion from the analysis and background literature was a solution based on a tagging system, utilising concepts from adaptive hypermedia systems was required. A system was developed to allow authors of material to tag learning objects according to their subject, topic, learning style, level, object file type and object resource type. This ensured that multiple representations of learning objects were kept consistent, supported their reuse and provided a mechanism to aid personalised learning (Peter et al. 2010). The focus of the system as developed was for use by authors only, future developments will carry this concept further to enable student tagging for their own use as well as other students. In this research, the discriminatory model used was that of learning styles based on the VARK (Visual, Aural, Reading, and Kinesthetic Learning) [Fleming 2001] learning style. Whilst the research demonstrated, through expert and author evaluation, that learning styles could indeed be used successfully as a discriminatory type, it was acknowledged that this might not be the best discriminator however, there weren't any serious alternatives to use in order to discriminate between different types of learning materials. The methodology and tags devised are however flexible and could be applied to any discriminatory concept considered appropriate. This research supports the use of discriminatory tagging in the learning repository as part of the framework.

3.2 Categorisation of learning materials by learning style and their support for metacognitive development

This section describes two research projects that have both used learning materials, categorised by a specific learning style model, in different ways to explore the metacognitive skills of students. In the first research project students were asked to answer a questionnaire to determine their learning style. In this case the Felder and Silverman Learning Style Model (FSLSM) (Felder and Silverman 1988) was used. Students were then provided with the learning materials for all of the categories of FSLSM learning styles. Immediately after their learning was complete, they were asked to take a recall test and then two weeks later they were asked to undertake a retention test. The students were then divided into two cohorts, those who chose materials consistent with their learning style (the matched group) and those who chose materials inconsistent with their learning style (the mismatched group). In order to determine which group performed better, an analysis of some external factors that might have affected the learning, such as prior knowledge of the subject, were assessed and taken on board in drawing conclusions from this study. Key findings from the experiment were that statistically significant achievements in learning were demonstrated by both the matched and mismatched groups in different areas. The research showed that the matched group understood their learning style and were therefore able to demonstrate metacognitive skills however, where the mismatched group were also successful in some areas and despite choosing materials inconsistent with their learning style, they had clearly developed appropriate learning strategies to deal with this inconsistency in order to be successful. Analysis of these learning strategies and learning behaviours could prove helpful to other students and can provide support for the unsuccessful students identified in the framework. [Cemal Nat et al. 2011]

The second project researched the impact of learner control on learning in adaptable and personalised eLearning environments. Adaptable systems that allow the user to change certain system parameters and adapt their behaviour accordingly, are called 'adaptable' Santally (2005). There are many definitions of personalised learning systems however, they should be capable of adapting automatically to changes in an individual's learning characteristics as the learning experience progresses (Karagiannikis and Sampson 2004). In this research project (Mustafa, 2011), learning materials were developed based on the VARK [Fleming 2001]

learning style. Two cohorts of MSc students were divided into two groups randomly during the module registration process. One group was assigned to an adaptable eLearning environment and the other to a personalised eLearning environment. A switchboard model was then developed and used to manage the process of providing relevant materials to students, depending on different aspects of their learning style and whether they were in the adaptable or personalised group. The assessment questions were categorised into three types: Recall, Competency and Understanding. The results showed that a personalised eLearning system performed better in supporting learning that required students to recall and understand what they learned, whereas in the adaptable eLearning system, students showed a marked improvement in the assessment based on competency. Thus key findings from the analysis of the resulting data demonstrated that certain types of learning environment are better suited to certain type of learning behaviour. The outcomes from this research could provide a basis for the future design of eLearning systems, utilising different models of learner control, based on underpinning educational philosophies, in combination with learning preferences, to structure and present learning content according to type. In the context of the framework, this research provides guidance on how to help students choose the most relevant materials for them based on their learning style.

3.3 Use of Games-Based learning to support Metacognitive Development

Games are inherently fun, immersive, challenging, engaging etc. and have been used for educational purposes for a long time. This section describes a research project that was used to develop computational thinking skills in the game players with the aim of helping them learn how to program computers. Wing (2011) discusses the concept of computational thinking as including conceptualising, developing abstractions, building algorithms and designing systems etc. The game is called *Program Your Robot* (<http://www.programyourrobot.com/>) (Kazimoglu et al. 2012) is a puzzle game, the aim of which is to help a robot to escape from a grid platform by reaching the teleport square which will take players to the next level in the game. To do this, a player has to work out the algorithm to get the Robot from the start to the end square, negotiating various obstacles. An example screen shot of the game is shown in Fig 1.

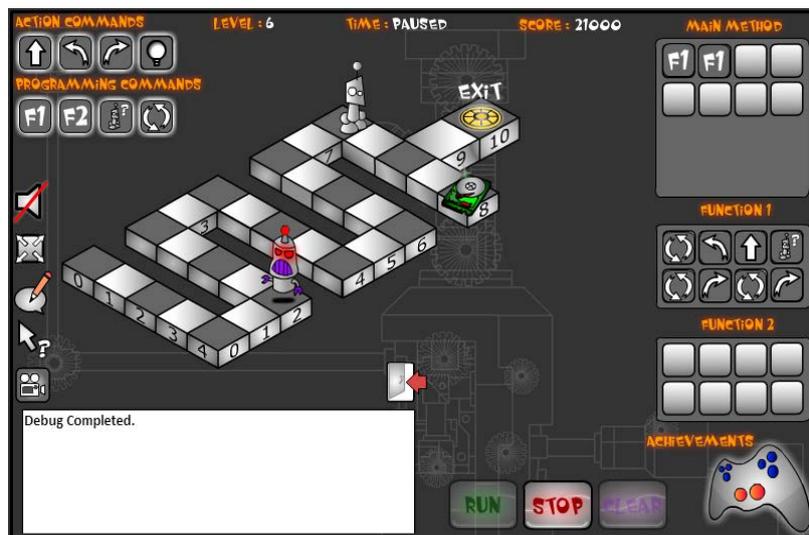


Figure 1: Program Your Robot game

The game was designed for use by higher education computing students and the results from considerable quantitative and qualitative analysis were extremely positive. Computational skills are a form of abstraction and so help to build metacognitive skills.

3.4 The Framework

Figure 2 presents an overview of the framework which outlines the concepts and structures within a system that could be used to test for metacognitive ability. Each stage of the process is briefly described below and shows how the research projects described above can be linked together to provide an approach to assessing an developing metacognitive skills in students:

Stage 1a: Students undergo an assessment based on one or more discriminatory learning models such as learning styles however they could also be categorised by other discriminatory models such as religious, cultural or accessibility needs.

Stage 1b: Learning objects are tagged based on all the discriminatory models used to assess the students and stored in a suitable learning environment. A learning object could be text, video, a game etc.

Stage 2: Students are given complete freedom to use any of the learning objects for their learning.

Stage 3: Having completed the learning they are given a recall test, typically within 48 hours of completion and then a retention test typically about two weeks later.

Stage 4a: For those students who do not demonstrate a threshold level of metacognition, the learning objects they used are compared to those they would have been expected to use as a result of the assessment in 1a and some guidance is provided. They can then repeat the learning process.

Stage 4b: Students who demonstrate a threshold level of metacognition are provided with a heutagogic environment in which to continue their learning.

Ideally the framework learning and assessment take place in a monitored digital environment and the reason for this will be explained in the following section.

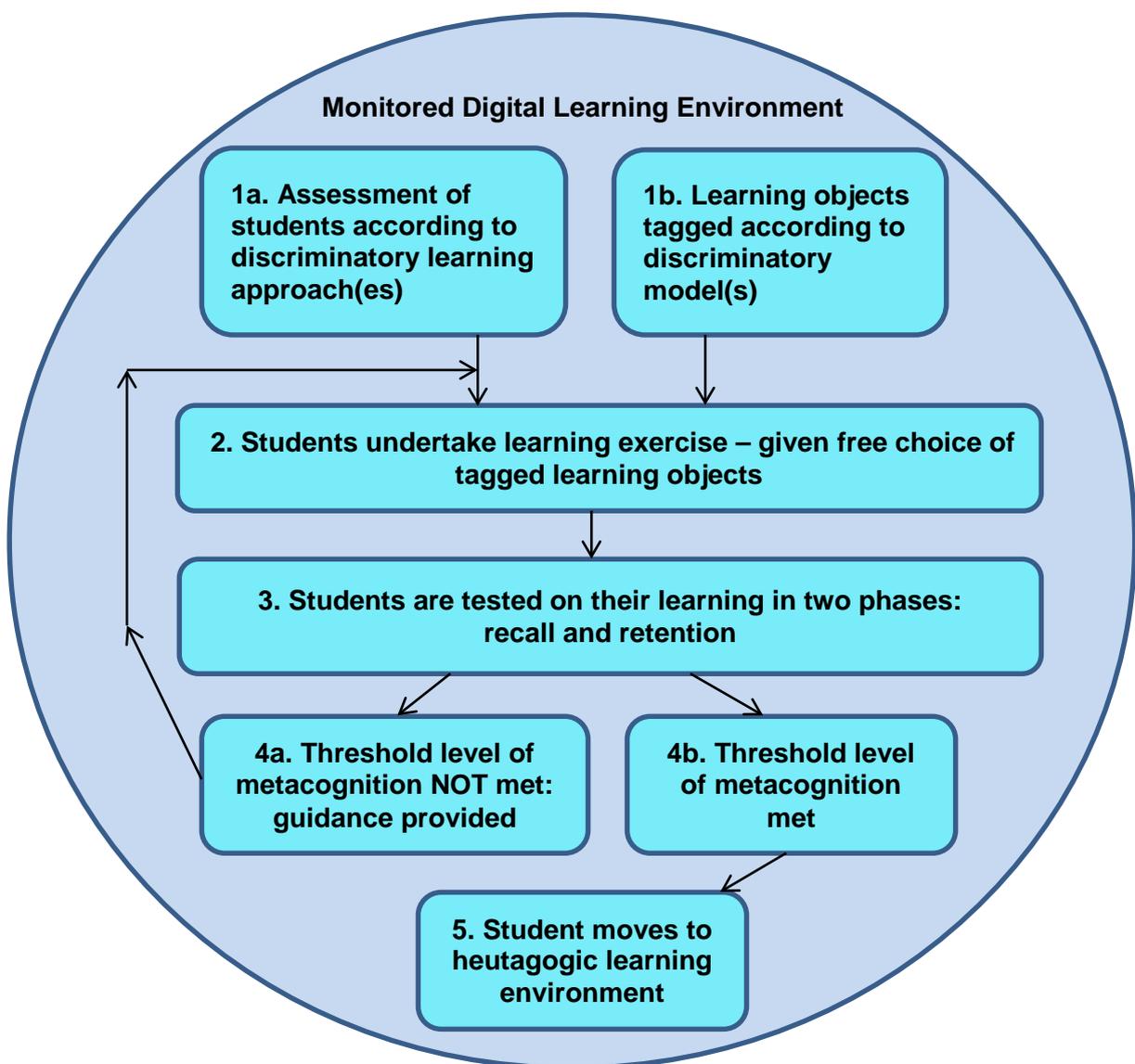


Figure 2: Framework lifecycle

4. Educational Models

As discussed earlier, if we really want to develop metacognitive, self-regulated learners then we need to revisit current approaches to online teaching, which tend to employ pedagogic as opposed to andragogic/heutagogic models of delivery that better support the development of truly independent learners (Blaschke 2012). Learning environments / platforms should be seen as a mechanism that frees the academic to develop new materials to support a different style of teaching on a far more individual basis as opposed to a convenient document repository which is their most common use today.

The proposed educational model for the framework is based on lessons learned from the games community where the focus is on providing a rich, engaging and immersive environment that allows a game player / learner, to progress at their own pace. In such a learning environment, learning objects are linked in to electronic assessment models and instruments regarded as appropriate for the subject area. Much of the feedback to students would be automated with students receiving near instantaneous feedback on their activities and assessments. Academics would therefore be free to concentrate on helping the students to develop their learning capabilities and subject knowledge by offering guidance on appropriate techniques, additional areas for self-guided study etc. Given that the educational model is intended to be andragogic/heutagogic, conversations between tutors and students could be focused much more on the professional advice given by the academic on how the student could improve or develop their performance to meet their own learning goals.

In this solution, the ability to monitor and capture the student learning experience in digital environments is vital and must then link in to a mechanism that will allow that experience to be quantitatively and qualitatively analysed. Taking this concept further, if we can properly authenticate a student and their experience in the fully monitored, digital environment then we could rethink our approach to assessment. Given the purpose of education is to enable a student to achieve some learning and people all learn at a different pace and in different ways, there is no reason to say that everyone has to be assessed in the same way and at the same time. If our digital environment is able to authenticate its use by a particular student then not only could the student submit themselves for assessment when they are ready but for certain skills where the digital environment is used for their development e.g. software development, we do not need to assess a student if we know that a particular skill has been successfully developed during the learning process, the digital environment can confirm that the student has achieved the desired learning outcomes. This approach would provide a more accurate reflection of a student's ability, particularly for students who have poor exam technique for example. This approach would also decrease incidents of cheating and plagiarism and reduce the assessment load for academic staff, freeing them up to provide other types of support to students. It could also provide employers with more accurate information about a student's abilities and finally, is very likely to be preferable and less stressful to the students.

5. Summary, Conclusion and Further Work

There is a massive requirement for higher education provision worldwide which cannot be met purely by trying to emulate traditional teaching models in an online environment. However, simply providing online materials, even of high quality, does not solve the problem. Being able to assess and develop the metacognitive skills of learners is an important step towards improving outcomes in online learning, because we cannot easily recreate the structured support online, that a traditional face-to-face learning experience provides. In order to be successful in online learning students need to be heutagogic learners and we therefore need a mechanism for testing and developing metacognitive skills. This work has brought together the outcomes of a number of research projects into a coherent framework for assessing and developing metacognitive skills in students. Whilst the individual components of the research have been rigorously tested, future work will focus on trials that test all the stages of the framework as a coherent process.

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