Personalized Education Using Adaptive Learning Technology: One Size doesn’t have to fit all

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Abstract

The goal of this project was to investigate how adaptive learning can enhance student learning by tailoring the educational experience to each individual. Adaptive learning technology allows students to navigate their own personal learning path, typically not possible through traditional lecturing. This study has explored the degree to which this approach improves inclusive and personalised teaching, by allowing learners to self-select the mode or format of teaching materials offered to them using the CogBooks adaptive learning software. The principal aim was to improve the learning environment and student experience in the area of technology-enhanced learning. There is evidence from this pilot study in BSc(Hons)/FdSc degree chemistry teaching within the faculty of Science and Engineering at Manchester Metropolitan University (MMU) that this student-centred teaching method can lead to significant educational gains.

Keywords: Adaptive learning, CogBooks, technology-enhanced learning, e-learning, VLEs, flipped classroom, inclusive teaching, personal teaching.

Introduction

Adaptive learning is a term that applies to a range of technologies and techniques involving the use of software that monitors student performance and engagement with learning materials, often in conjunction with a virtual learning environment (VLE), and tailors the environment experienced by each student based on those observations (Waters 2014, Kostolányová 2012, Scalise et al. 2007). The purpose of adaptive learning systems is to offer different content choices to learners based on formative assessment, summative assessment, engagement, and student responses solicited during engagement. The process provides immediate metrics for each student that an instructor can act upon (Hattie 2009), while aiming to
optimise progression of individual students towards the learning objectives (Clark 2014, Bain et al. 2010). The mechanism for monitoring progression is based on predictive machine learning analysis of student engagement and performance data, while the outcomes of the analysis are designed by the instructor (Hattie 2009).

This approach provides several advantages to the use of passive e-learning materials alone, including

- Allowing students to skip redundant material for topics they are competent in,
- Providing extra material for topics a student is struggling with,
- Providing a detailed record of achievement and engagement for each student,
- Providing a sustained environment of engagement, allowing learners to work at their own pace to a level of detail typically not possible in traditional lecturing.

In recent years, there have been great advancements in the use of VLEs in e-learning provision. However, most systems exhibit a linear delivery of learning materials or a hierarchy of statically linked resources, offering the same content and experience to each student (Thompson 2013).

This approach has a number of drawbacks, including

- If the student is already competent in an aspect of the material, they still have to work through every step, which can decrease engagement,
- If the student has problems at any point, there is no immediate help and they have to hunt for support materials, which can again decrease engagement,
- Learning experiences tend to be self-contained, not built upon or reinforced in the future.

Because learning occurs in different modalities, traditional flat or linear presentation of material may not be ideal for every student in every context. The idea for this is derived from cognition theory; because the brain does not store memories in a linear fashion,
alphabetically or hierarchically, information is absorbed in a highly personalised fashion based on our individual network of knowledge, experiences and on the type of information, being absorbed (Clark 2014, Bain et al. 2010). An adaptive, personalized approach places students at its heart and is inclusive; giving all an equal opportunity to succeed and this technology provides a mechanism to deliver a genuinely innovative and flexible curriculum (Thompson 2013). The differences between the traditional and adaptive learning pathways are illustrated in Figure 1, where the traditional linear presentation forms a predetermined sequence of materials; however, adaptive learning presents a network of materials for the student to navigate a personal learning journey governed by their own individual needs.

![Traditional Learning vs Adaptive Learning](image)

*Figure 1. The differences between traditional and adaptive learning pathways.*

Adaptive learning technologies provide a method to promote inclusive teaching practice and personalized instruction on a large scale in a way that would otherwise be resource-limited and practically impossible. CogBooks is a cloud-based online learning system, which uses machine-learning software to drive its active learning system (Clark 2013) in a micro-adaptive approach, which advances the adaptive concept by continually tailoring delivery to the user based on real-time interaction. The data science underlying this
system is similar to algorithms used by Google and Amazon; however, instead of recommending purchases, the software predicts learning resources that are best to use to meet the learning objectives.

**Adaptive Technology in Learning and Teaching**

The primary objective of this project was a student-orientated one, to improve the learning experience using adaptive learning and it was noted that such technology could potentially have the following positive impacts:

1) **Students progress faster and higher.** Data collected about engagement and formative assessment progress based on student interaction with a VLE outside of the classroom informed teacher-student interactions inside classroom. The adaptive learning system tailored the educational environment to cater to the broadest possible range of background experiences of learners.

2) **Curricula is optimised to student experience.** Inclusive teaching may be defined as instruction that provides an environment for learners of all abilities and knowledge to achieve learning outcomes, yet this is challenging to achieve in the traditional classroom. Adaptive learning promises inclusive teaching by identifying gaps in learner knowledge and providing immediate support in the form of information in multiple modes (limited only by the unit design) and formative assessment. This feedback is instant and simultaneous to all students.

3) **Improve lecturer management of progression and curricula.** While lecturing in a traditional format, it is difficult for instructors to know whether their students understand the material (‘Do they ‘get it’?’). During the adaptive learning approach, detailed information is available to instructors continuously about each student in their progress towards learning objectives based on materials tailored to their individual progress.

4) **Enhance student engagement.** One of the strengths of adaptive learning is to challenge all students at a level appropriate to their needs. Thus, if one student is strong in one learning outcome, less time is spent providing material and assessing that topic (preventing boredom), while a student weak in another area is presented with
additional material on that subject before moving on (preventing frustration).

5) **Allow students to progress at different paces.** One of the strengths of VLE instruction is that material is available for students at any time outside of the classroom. With adaptive learning, this advantage extends to progression towards outcomes. Learners can progress towards outcomes at different rates as an integral design feature of the programme.

6) **Extra time for one-to-one instruction.** Because significant formative assessment and information is available outside of class time when individualized performance data is collected, there is more time to act on this information by the instructor during class contact time.

In general, adaptive learning systems have long-term potential for teaching, learner attainment and course retention. This has recently been confirmed by results presented at the Educause Learning Initiative (Johnson et al. 2016) from a pilot study in a biology course at Arizona State University, which showed a higher student success rate with 18% more students passing and a lower dropout rate, from 15% to 1.5%. This was built as a flipped course using adaptive content on the CogBooks platform where students completed tasks using the adaptive learning content before attending class and completed applied exercises in small groups during class. A survey conducted among these students showed very high satisfaction, where 84% agreed that the adaptive learning system had helped with a deeper understanding of the subject. In addition, 81% of the students surveyed would like to have this system for other modules they studied.

**The Learning and Teaching Design**

The first step in constructing the adaptive leaning content in CogBooks is to define the learning outcomes of the course. Outcome based education is a methodology used to develop curriculum driven by existing learning outcomes that the students should display at the end of their learning (Spady 1994, 1998). This forms the foundation for a learning map, which is developed from the top down, initially
identifying the programme outcome followed by sub-outcomes and subject outcomes, see Figure 2.

![Diagram of a learning map based on Programme, Sub- and Subject outcomes.](image)

**Figure 2. Development of a learning map based on Programme, Sub- and Subject outcomes.**

The programme outcome, outlined in red in Figure 2, is the highest-level outcome that would span across the all of the course. The sub-outcomes, outlined in orange in Figure 2, are the objectives a learner must achieve in order to fulfil the programme outcome and the subject-outcomes define what needs to be achieved by the learners to understand a subject. The subject-outcomes, outlined in yellow in Figure 2, may be considered as the offspring of the sub-outcomes and extra vertical subject-outcomes provide additional layers of depth to the learning resources available to the students. By starting the development process with the identification of these key outcomes allows the content creation to focus on what the learner already knows, what they need to know and what will help them understand what they need to know. This content is mapped directly to the specific subject outcomes in the form of concept pages, tests and exercises, forming the learning activities (LA) outlined in blue in Figure 2. Hence, the learning map provides an illustration of the relationship between learning objectives and desired outcomes. Based on this map, the instructor defines the default learning path when building the course that forms the starting point for all students.
and as they work through the materials, the path will personalise to each student based on their individual needs. The nature and extent of the adaptation within the system is governed by the depth of learning activities mapped to the subject outcomes during the construction of the map.

In addition, CogBooks provides automated feedback and direction for individual students, while tracking resource use and achievement, within a framework of content and assessment provided in the learning map. The adaptive learning tool continuously captures click track data relating to students’ use of text, graphical and animated content, whereby learning resources are offered to match student progression. Regular diagnostic tests within the adaptive learning materials provide the students with an opportunity to master the subject content, gain confidence and receive automated feedback. The results of these tests provide a mechanism for the software to direct students towards the most appropriate next step in their personal learning path, where the system may recommended further underpinning content or guide students to the next stage.

Within the system, a dashboard of usage and students’ progress through the online materials is available to both staff and students so that students can monitor their own activity, see Figure 3 below.
Figure 3. An example dashboard providing the instructor with comprehensive progress information for each student and each learning activity.

The reports available in CogBooks provide detailed information of a student's learning journey in real time and the staff can gain valuable insights into the progress of their students and provide individually tailored support. Hence, the instructor does not have to wait for mid or end of term results to know how their students are performing and can provide guidance online or modify their face-to-face teaching as they move along. In addition, the system allows students to communicate with tutors online, and to receive feedback.
Implementation of Adaptive Learning for Level 5 Chemistry Undergraduates

The plan for this pilot project was to implement adaptive learning using the CogBooks software (Clark 2013, Thompson 2013) in the delivery of two established level 5 chemistry units from the School of Science and Environment programme within the Faculty of Science and Engineering at MMU. CogBooks uses algorithmic machine intelligence to drive its systems to record student interaction and is therefore highly capable in terms of system response and subtlety. Examples have been reported of adaptive online learning systems used to deliver undergraduate level organic chemistry courses in the US (Koseler et al. 2016). However, at present, there are no examples of CogBooks used in the delivery of chemistry courses at UK universities and this pilot represents a new development for e-learning in the UK HE sector. Of the adaptive learning commercial suppliers in the market, CogBooks was selected since it has been identified as a leader in this field (Gates Foundation 2014) that can be easily dovetailed within an existing learning management system, such as Moodle and has a UK base in Edinburgh, which is able to provide face-to-face support and training.

The level 5 core chemistry 30-credit unit Organic and Inorganic Synthesis (Chemical Concepts 1) was chosen since it contained the largest full-time cohort with 113 students (71 male and 42 female) and has a significant theory component bridging between a number of disciplines. In addition, this unit provides valuable underpinning for important topics at level 6, so it is vital that students obtain a clear understanding of the key principles at this stage. The class met once a week for two 60-minute lectures and once a week for a 60-minute tutorial. Three instructors taught this unit; two taught the organic chemistry section, whilst, one tutor taught the inorganic chemistry section. This described the chemistry of transition metals, and it was this later section of the unit that was taught using the CogBooks software. CogBooks was integrated into the existing unit Moodle area to compliment the face-to-face teaching during lectures and tutorials. This unit has previously employed a flipped classroom approach (Mazur, 1997; Crouch et al. 2001; Slater et al., 2006) and there was already a variety of electronic resources along with a bank of formative assessment materials available to initially populate the adaptive leaning content (Smith 2015). The adaptive learning resources were made available seven days prior to the lecture via a
link on the VLE. The aim was to use these materials to deliver the initial knowledge and skills to the students, so they could come to class able to engage in problem solving activities and interact one-to-one, in an effort to promote peer assisted learning. In addition, Cogbooks was used to build upon the learning during class by delivering post-lecture activities such as formative quizzes where the adaptive nature of the system could guide students along the appropriate path for their individual needs and provide feedback as required. A similar format was used to build the varied learning activities, which were attached to the subject outcomes on the learning map. Each of the content pages showed the text, equations, diagrams and tables to illustrate the subject along with an accompanying screencast that provided a short audio-visual explanation of the topic followed by a quiz containing up to five multiple-choice questions. A variety of additional materials were linked to these learning activities on the learning map, which provided resources for those students who needed extra support. The development of regular pre-lecture exercises provided a mechanism to integrate the Moodle content with the in-class work, with the goal of using CogBooks to add value to the VLE space and increase the routine usage of the e-resources by the students.

Further work included developing adaptive learning content for the 30-credit unit Chemical Concepts 2 as part of the FdSc Chemical Science course. FdSc Chemical Science is an online distance-learning course for part-time students working in the chemical industry, which contained 23 students (11 male and 12 female) who came from a wide variety of educational backgrounds, some with recent training close to the subject whilst some were encountering the subject for the first time. Unlike the Chemical Concepts 1 unit, these students did not have regular timetable face-to-face contact with the tutors and the unit Moodle VLE area provided the primary mechanism for delivering the course materials. This unit contained three study elements; organic chemistry, thermodynamics, and chemistry of transition metals; and again it was this later section of the unit that was taught using the CogBooks software. Hence, the data from both these units provided a useful comparison between two different cohorts of students with contrasting modes of study and backgrounds.
The timeline for the project included initial training at the start of September 2015 followed by content creation within a four-month period during the first term, and the pilot study was launched for Chemical Concepts 1 in the second term with adaptive learning materials released to the students in January 2016. The impact of adaptive learning upon student behaviour, satisfaction and learning outcomes was evaluated during this period, and feedback from the students was obtained from questionnaires, the internal student survey and focus groups. Furthermore, this analysis highlighted the impact that adaptive learning technology had on these students, which informed a review of the CogBooks materials and minor modifications were made for the launch of the Chemical Concepts 2 unit in May 2016. For both these units, the adaptive learning content provided the means of ongoing formative assessment throughout the delivery of the units and these topics were part of the summative assessment for the end of unit exams during May and August 2016 for the Chemical Concepts 1 and 2 units respectively.

**Results and Discussion**

Student feedback from the pilot study was obtained from a questionnaire, which contained the ten questions shown in Figure 4. Students were invited to respond to each question with either Yes, Ambivalent or No and were invited to add any further comments. 65 out of the total 136 students enrolled on the two units, which used CogBooks, participated in the feedback showing a response rate of 48%, and the percentage of the class that circled each response is illustrated in Figure 4 below.
In addition, a selection of comments obtained from the questionnaire, the internal student survey and a focus group are highlighted below:

'I am very good at retaining information but understanding the theory is different, this helped me to learn things I found difficult.'

'I liked that the CogBooks gave you your individual learning path based on what questions were answered incorrectly.'

'The CogBooks have a short compressed lecture with rich questions, so as to focus learning more precisely.'

'If you didn’t get a perfect score on the quizzes, you were shown a screencast on that topic area, which was really helpful.'

'I found the organized bite-sized chunks really useful to understand individual concepts at my own pace and it felt intuitive.'

'The way it broke down topics helped make sure you got the background you needed to answer harder questions and it definitely built the topics slowly and clearly.'
'The short screencasts after every topic helped to tie up my understanding of the subject matter.'

'The quizzes were very useful to test if you had retained the knowledge from the lectures.'

'The materials were laid out in a logical order building on knowledge previously covered and explanations were clear with difficult points explained in the right amount of detail at the right speed.'

The above results from this pilot study highlight some clear messages in terms of the positive impact of the CogBooks adaptive learning technology upon enhancing the student learning experience and satisfaction. A majority of students, 72%, indicated that they found it easy to explore subject materials using CogBooks and encouragingly 82% thought the system had directed them to useful content. Only a small minority of students (8%) found the adaptive learning content difficult to follow or confusing. 87% found that it had helped them obtain a deeper understanding and a similar number (85%) indicated that CogBooks content had helped with concepts and difficult topics. From the above comments, it was clear that the screencasts and quizzes were valued by the students and these proved to be useful tools in their learning pathway. The majority of students (87%) accessed CogBooks during revision for their exams, further emphasizing their perceived effectiveness of these resources.

The feedback showed that the students appreciated the fundamentals of adaptive delivery, where they commented on the value of the structured content presentation, which enabled self-paced learning; 86% of students indicated that they would have like to CogBooks for other units they were studying. The content mapping received particular praise, specifically how key topics were compartmentalized, breaking the content into bite-sized chunks, allowing students to quickly find what they wanted when they wanted it. This demonstrates the benefits of the learning map and highlights the value of constructing the course from the top down by initially defining the key learning outcomes and focusing attention on what it is the students need to know/understand at various stages in their learning. This pedagogical approach is an illustration of Biggs’s theory of constructive alignment, where the teacher makes a
deliberate connection between the planned learning activities and the intended learning outcomes (Biggs 1996). This represents a conscious effort to provide the learner with a clearly specified goal, a well-designed learning activity and assessment criteria for giving feedback. Most students appeared uninterested in uploading content themselves, 32% of respondents indicated that they would be happy to do so while a slightly greater proportion (37%) were ambivalent to this suggestion. This might point to some limitations in students’ readiness to contribute to learning material in the spirit of co-creation and collaborative learning, and perhaps expecting their tutor to be the sole supplier of content. The majority of the students surveyed (87%) indicated that they had accessed the adaptive learning resources during their revision for the exams. Nearly half the students (48%) indicated they would have liked additional content in CogBooks and a common suggestion was that more examples of working thorough exam-type questions would have been helpful, which could be an area for future development to maximize the effectiveness of the materials during the preparation for exams.

A comparison of the average exam marks relevant to the topics delivered using adaptive learning are summarized in Figure 5 below, where results show an increase of between 3-25% during 2015/16 compared to the previous academic year.

![Figure 5. A comparison of the average end of unit exam marks for the CogBooks content of the part-time FdSc and full-time BSc units during the 2013/14, 2014/5 and 2015/16 academic years.](image-url)
The CogBooks topics were assessed in two sections of the exam paper, which comprised of a series of short question worth 4 marks or long questions worth 20 marks and students were required to answer three short questions and one long question. From a comparison of the 2015/16 results with the previous year, the highest average exam marks were exhibited by the results from short answer questions for both the BSc and FdSc papers, which showed an increase of 25% and 15% respectively. The increase in marks recorded for the long answer questions on the same exam papers was more modest in comparison, showing increases of 3% and 6% amongst the full-time BSc and part-time FdSc students respectively. Notably, the exam results from the full-time BSc students were slightly higher than for the equivalent part-time FdSc cohort, where the short and long answer questions showed an increase of 3% and 5% respectively. This suggests that the full-time students may have benefitted from the synergy between human face-to-face teaching and modern technology, where CogBooks offered an accessible and convenient mechanism to promote pre- and post-class engagement with e-learning resources to complement the timetable classes. From the part-time FdSc course five students, 22% of the cohort, did not fully engage with the adaptive learning materials and on average they obtained exam marks 4% lower than the rest of the group. The benefits of adaptive learning are less clear from a comparison with the 2013/14 results, which displayed higher average exam marks for the long answer questions in both the FdSc and BSc exam papers of 9% and 2% respectively when compared to the equivalent 2015/16 papers. Nevertheless, the 2015/16 results showed an increase in the average marks for the short answer question of 3% (FdSc) and 22% (BSc) when compared to the equivalent 2013/14 exam papers. However, the results for the FdSc 2013/14 cohort only included four students’ responses to the questions, which is not enough data to give a meaningful statistical representation.

It is difficult to draw too many conclusion from this data since there are a number of other factors that can influence these results. For example, each group of students has its’ own relative strengths and weaknesses, and more data from future years is required for a better-informed view about the potential influence of this technology on assessment marks.
Conclusions
The early use of VLEs largely involved ‘shovel-ware’ where course materials were uploaded in bulk for students to access. This approach can overload students with too much information, since it requires skill to sift through the content to find the relevant materials, which can result in a largely non-interactive learning space and the Moodle experience has been described as ‘death by scroll’.

However, this study has shown that adaptive learning systems, such as the CogBooks tool used in this study, provide an opportunity for innovative blended learning that can add value to the VLE space. Ultimately, this was not an easy option for both staff and students for two reasons. The development of the resources was time-consuming, which can feel like a bold commitment, and this mode of delivery represents a cultural shift in the way students approach their academic development. This model did not involve any reduction in contact hours for the full-time students but the primary focus was on how this time was used. I currently plan to continue to introduce more adaptive learning methods into my teaching practices, but at present, I am not in the position to completely phase out traditional modes of delivery. Fundamentally, student reaction has been very encouraging and the integration of adaptive learning in this way can lead to significant educational gains, which give rise to valuable outputs that can enhance the student learning experience.

Finally, I would be happy to hear from any colleagues who might be interested in collaborating to further explore the use of adaptive learning technology and potentially establish cross faculty links within this field.

References


