Example of a micro-adaptive instruction methodology for the improvement of flipped-classrooms and adaptive-learning based on advanced blended-learning tools

K.E. Kakosimos*

Department of Chemical Engineering and Mary Kay O’Connor Process Safety Center Qatar, Texas A&M University at Qatar, Qatar

ARTICLE INFO

Article history:
Received 16 July 2014
Received in revised form 1 June 2015
Accepted 8 June 2015
Available online 20 June 2015

Keywords:
Blended learning
Flipped classroom
Multimedia
Articulate storyline

ABSTRACT

Despite the wide spread of modern teaching techniques such as the flipped classroom, adaptive e-learning, and active learning, still most of them provide limited and delayed feedback from the student to the instructor. Something, which could lower their efficiency and limit their applicability. This paper presents a teaching methodology and the development of the related tools. A key aspect, of this methodology, is the collection of students’ feedback prior to lecture and additional detailed information on their learning progress. This information is then used to adapt course's content. The methodology has been tested and demonstrated on a module of a Chemical Engineering Fluid Operations course. Three evaluation tools were implemented between modules of the same course and an equivalent control group. The qualitative evaluation showed an improvement on the students’ perception, a significant engagement and motivation. The quantitative evaluation showed no clear change between modules of the same course (with and without the proposed approach). On the other hand, an overall improvement was observed against the control group. Finally, significant effort was necessary to upgrade the existing teaching material to the level of the new tools. Something, which might discourage more instructors to adapt fully the proposed tools. Nevertheless, the findings related to the methodology are promising, and the tools development can take place gradually or even be directly adopted by the educational publishers.

© 2015 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.

1. Introduction

In principle, adaptive instruction is about addressing the needs of individuals. It is linked with the success of education itself and is practiced by teachers since ancient times (Corno and Snow, 1986). In the ongoing course of instruction and in response to particular students practicing teachers make micro-adaptations all the time (Corno, 2008). There is a number of mechanisms used by teachers to adapt their teaching to the pace of the class. Angelo and Cross (1993) outlined many of these concepts such as the “Background Knowledge Probe”, the “Minute Paper” and the “Muddiest Point”. Later Mezeske, B.A. and Mezeske, R.J (2007) compiled some modern ideas on creative assessment e.g. “Exams as Learning Experiences”. Although, the implementation of these mechanisms is rewarding, there is always the challenge of managing the finite classroom time (Felder, 1992), the limited number of face-to-face meetings (Hannafin et al., 1997), and student’s resistance (Felder, 2011).

Flipped classroom models have attempted to address these challenges with successful outcome most of the times even for quite different topics and audience composition (Danchak

* Correspondence to: 271 Texas A&M Engineering Building, Education City, P.O. Box 23874, Doha, Qatar. Tel.: +974 442 306 78.
E-mail address: k.kakosimos@qatar.tamu.edu
http://dx.doi.org/10.1016/j.ece.2015.06.001
1749-7728/© 2015 The Institution of Chemical Engineers. Published by Elsevier B.V. All rights reserved.
and Huguet, 2004; Kim et al., 2014). Through this approach, students can prepare at their pace, level of understanding and schedule for the lectures (Davies et al., 2013). Instructors in turn, commit more in-class time to provide adaptive and instant feedback to individual or group of students (Fulton, 2012). However, one of the most critical disadvantages of flipped-classrooms is that the instructor must also develop and include activities to ensure that students are prepared for the class (Day and Foley, 2006; Kellogg, 2009; Mason et al., 2013). It became clear that regardless of the advantages of flipped classrooms this is not enough (Lam et al., 2013; Ronchetti, 2010). More advanced tools need to be employed in order to track students’ out-of-class behavior and utilize it to adapt the content of the course (Chen et al., 2014). Lian (2003) observed the difficulty to implement adaptive learning without actual feedback from the students. Therefore, he proposed a methodology to monitor continuously students’ performance during and after a lecture. Hughes (2007) presented an online tracking system to monitor students’ access to the material as a tool to identify and proactively help “at risk” learners. A step further, Fraij (2010) developed a computer-aided instruction system where students could provide feedback on blended learning material. Then the system provides instructors with the knowledge about learners’ challenging topics.

Indeed, the current state of information technology provides a major opportunity in education and especially in engineering education and training. Beyond the simple exchange of lectures and homework, the use of learning technologies such as multimedia provide new tools for instructors and new opportunities for students (Lage et al., 2000). Maximizing the best advantages of face-to-face learning and multiple technologies to deliver learning is called blended learning (Bonk and Graham, 2006). There are examples in the literature where blended learning tools like multimedia and web-platforms have been used to improve and enhance teaching and learning experience. Assael and Kakosimos (2010) developed an interactive course platform on consequences modeling (fires, explosions, and dispersions) based on Macromedia Authorware®. They demonstrated its efficiency in teaching the principles of safety to undergraduate engineering students. Violante and Vezzetti (2013) described the effectiveness of an interactive web-based learning application using a 3D virtual environment for biomedical engineering students. Marepalli et al. (2010) developed a tool called SugarAid to help students monitor their learning progress by providing e-homework to prepare them for in-class examination. Kalinic et al. (2011) designed an application to offer the blended learning material not only to browsers but specifically to mobile devices. Analysis of quantitative data for blended learning indicates improved performance of students in typical courses (Swartz et al., 2013). As well as, in more particular case studies such as vocational training (Pohl et al., 2008) and distance learning (So and Brush, 2008).

In blended learning, computer-based technologies have a central role. It spans from enhancing classroom teaching and learning activities to access control and tracking of individuals records and performance (Bonk and Graham, 2006; Wu et al., 2010). However, more recent studies (Fraj et al., 2012; Kakosimos and Mihailidi, 2010) note that similar platforms are extremely rare in the academic environment though highly praised by both students and instructors. Furthermore, even in the cases where such platforms are employed, they are merely used as passive tools. In other words, they only support the one-way transfer of knowledge; from the instructor to the students.

This study demonstrates a micro-adaptive instruction (mAI) methodology for the improvement of flipped-classrooms and adaptive-learning. mAI focuses on the collection of information and student’s feedback prior to lecture and off class-time. Then the instructor can use this information on designing the flipped-classroom or simply adapting the content of the next lecture. mAI is based on the development and deployment of advanced blended learning tools. The present study also illustrates the methodology to develop such tools and how to design the context of the course. In brief, the blended learning material of the course is provided through a multimedia platform, which students are using for reading and practice prior to the lectures. The platform tracks detailed information on students’ “behavior” such as time spent on each slide and section, answers and attempts of quizzes, individual comments, access date and time, and self-assessment/evaluation. Thus, transfer of feedback takes place both directions – student to instructor and vice versa. The instructor can carry out the flipped classroom more efficiently because (s)he is aware of the specific topics that need to be addressed and clarified. In other words, mAI deploys some of the known classroom assessment techniques (minute paper, muddiest point, etc.) during the off-class time to use the in-class time more efficiently e.g. for active learning. Therefore, next section presents a brief background and more details on the concept of the proposed methodology.

2. Development and tools

2.1. Background

“Education as Usual” (EaU) is a well-established process that involves two parties the students, and the instructor. The latter party formulates the syllabus of the course and the content of each lecture; primarily based on the context and experience. An experience that is mainly personal, through teaching the same context multiple times. Fig. 1 illustrates the most common teaching approach where the instructor just prepares printed or electronic material (e.g. videos, notes) and distributes it to the students. Depending on the style of the classroom (normal or flipped), during the in-class time the instructor interacts with the students to explain concepts, describe examples and, in general, convey knowledge. In other words, EaU develops and supports a one-way feedback. The instructor can only collect this scattered feedback, solely based on his/her limited “multi-tasking” abilities; according to extensive studies (Watson and Strayer, 2010) most of us are not real “multi-taskers”. There are techniques to develop and enhance the feedback from the student to the instructor. For example, the online-homework (Fraj et al., 2012), “clickers” (Caldwell, 2007) and others (Felder, 1992). Most of these refer to the time-scales during or after the lecture. So it seems that little are available to support a pre-lecture feedback, which could be the most critical factor (Corno, 2008) to implement real micro-adaptive instruction.

The author’s concept of micro-adaptive instruction (mAI) is illustrated in Fig. 2. Many things are of course similar to the EaU approach. Such as the sources for preparation of the
material (e.g. textbook, notes, slides) and the course assessment tools (e.g. homework, exams, minute paper). However, in mAi the instructor uses a new form and host for the tools and material, a platform which:

(a) the student can be introduced to the new topics without the instructors’ physical presence (e.g. narrative presentation, video, excerpts from the textbook, multimedia context, quiz, self-evaluation), and
(b) the instructor can track the student’s behavior and performance specifically on the provided material and collect this information before class-time.

Then, the instructor uses the collected information to adapt the context of the following lecture. Especially, in a flipped-classroom type lecture the instructor has available a tremendous amount of information to formulate the script of the lecture for the maximum efficiency properly. Academics do use similar platforms such as Smart Sparrow® ([http://www.smartsparrow.com](http://www.smartsparrow.com)) and Knewton® ([http://www.knewton.com](http://www.knewton.com)) to create and deploy adaptive eLearning courses. However, mAi is not about the platform itself but focuses on how to use such tools to improve the efficiency of in-class time. As Kolb (1984) observed, individuals learn in different ways. Therefore, it is not practical to follow one specific teaching pattern. On the other hand, each lecture could and should be adapted based on the pre-class feedback of the students and include activities that will appeal to each style of learning and organize these activities in a cycle.

Fig. 1 – A schematic representation of the most common teaching approach – “Education as Usual”.

Fig. 2 – The proposed concept of micro-adaptive instruction.


2.2. The course

To demonstrate mAI, the author selected the Fluid Operations course (CHEN 304) of the Chemical Engineering program (accredited by ABET) at Texas A&M University at Qatar. More specifically the module on “External Flows”. It is a third-year mandatory course in a 4-year bachelor program, and the topic above is discussed on week 11 of 14. CHEN 304 deals with the fundamentals of fluid mechanics and the applications to design and analysis of process equipment. The demonstration and data collection took place in the Fall terms of 2013 and 2014 where 18 and 20 students took the course respectively (20 students is the average of the equivalent courses). Class meets three times a week for 50 min. Seven tools assess students’ performance: four mid-term exams, one comprehensive final exam, homework (set of nine) and in-class participation. The selected module (External Flows) is the single topic of the fourth exam (tool E2, discussed at a later point).

Owe to the small number of students in CHEN 304, the author selected another course as a control group: the Transport Processes in Petroleum Engineering (PETE 314) of the Petroleum Engineering Program at the same campus. Although, the titles are different both CHEN 304 and PETE 314 syllabuses are 90% similar, and they share common primary and secondary textbooks. Also, the author taught both in Fall 2014. On the other hand, PETE 314 class meets twice a week for 70 min. Therefore, instead of four mid-term exams it has only two. Nevertheless, the examination style and context is equivalent. The selected module is the primary topic of the second exam (tool E2) of PETE 314.

Three groups of students have been formed, and Table 1 describes the general information of each. The same table presents the results of the selected examination tools E1 and E2. Exam E1 was selected for comparison because mAI is not implemented on the respective topics. E1 assess the students (of both courses) on an equivalent topic, compared to E2, and it has also a similar examination style. Note that E1 and E2 of PETE 314 include more material and are longer than E1 and E2 of CHEN 304. For this reason, only the corresponding questions, from each one, have been used in the present study and for the comparison between the CHEN and PETE groups.

2.3. Context design

Information technology tools are important for the implementation of the proposed methodology, mAI. At the same time, the context design of the course has to be comprehensive, clear, attractive and adaptable on such tools. Here, the main two tools are a multimedia platform (based on Storyline® by Articulate; for the educational material) and the host – eLearning Management System – of the platform (eCampus based on Microsoft® Learn). Fig. 3 outlines the tools that supported the current implementation of mAI. Next paragraphs describe the context design, principles, and later the developed tools.

The first step is to structure the topic material while breaking it down into three parts: concept, methods and application (examples). The first part presents all new concepts and definitions, again following a piecewise approach rather than throwing one after the other. In each case, audio and visual aids help the student comprehend the text descriptions. At the same time, these aids make the connection between the concept and real life. For example, sport cars, submarines, and airplanes reveal the significance of “drag force” while at the same time clarify what “external flow” is. Use of Storyline makes this part quite interesting and user-friendly. Checking of additional material (e.g. pictures, videos) is made easy.

---

**Table 1 – General information for the studied groups.**

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course</td>
<td>CHEN 304, 2013</td>
<td>CHEN 304, 2014</td>
<td>PETE 314, 2014</td>
</tr>
<tr>
<td>Students</td>
<td>18</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Tool</td>
<td>E1,E2</td>
<td>E1,E2</td>
<td>E1,E2</td>
</tr>
<tr>
<td>AVG</td>
<td>87.8</td>
<td>86.2</td>
<td>86.8</td>
</tr>
<tr>
<td>STD DEV</td>
<td>7.4, 7.8</td>
<td>8.1</td>
<td>8.1</td>
</tr>
</tbody>
</table>

* For Groups A and B the real titles of E1 and E2 are E2 and E4 correspondingly. The renaming deemed necessary to avoid confusing the reader.

---

**Fig. 3 – The whole process to develop the necessary information technology tools for the implementation of micro-adaptive instruction.**

All logos have been retrieved from http://www.iconarchive.com with the appropriate license to use.
by clicking on keywords and buttons, and pop-up windows (see Fig. 4a). There is no need to change page and lose control of the material flow. Something, which is irritating while checking material over the web or typical presentation slides. Similarly, formulas’ presentation and derivation follows the definitions but not on the same screen, to avoid confusion and intimidation of the students.

In a similar manner, the second part, “Methods”, initially states the problem(s) that link one or more of the concepts. Then, it guides the student through the steps to achieve a qualitative solution. From problem to problem, quantities exchange role between known and unknown, and primary and auxiliary. This part usually contains more information on the formulas, but still it does not emphasize on the numbers. For example, in Fig. 4b, the user can hover over the terms of an equation to get their meaning and the variables’ name. The emphasis on the numbers and the calculations, take place in the third part, “Examples”. There, short and extended problems assign values to each quantity and prompt for a final solution. Again, most problems guide the student through the solution, following a method from the second part and link the findings with the concepts.

The content is also adaptable and dynamic. For example if an answer to a question is wrong, more preparation material is provided before re-taking the question. A functionality similar to the Smart Sparrow® and Newton® platforms mentioned earlier. On other occasions, the student has to interact with the platform to move forward. For example, (s)he has to click on an object or hover over a specific part of the screen to get additional information.

A key aspect of the context presentation is the animated female character called “Meleti” (means “study” in Greek). The character introduces herself in the beginning and appears (see Fig. 5) frequently with instructions and feedback. It gives a more pleasant and personal feeling to the whole platform. It also helps the student to connect with the platform and anticipate the informative and sometimes funny responses and behavior. The character’s appearance and actions/reactions can originate from a Storyline® library or custom sketches. The author has a version of the platform where the character is a caricature of himself.

All of the above, they are the “frontend” and what the student sees and interacts with. In parallel and the “backend”, the platform, a more technical description follows, collects relevant information for the implementation of the methodology. There are three types of information collection tools: (a) quizzes and problems, (b) self-assessment questions and (c) user’s interaction with the platform (clicks, active time). The
results section discusses the aspect of each tool and how they were used for the evaluation of the methodology as well. However, their main role lies in the proposed methodology. The instructor can access this information prior to the actual lectures. A thorough study of the various outcomes reveals each student’s weak and strong points, and misconceptions. It is useful and unique information for both normal and flipped classrooms. Based on this, the instructor designs and adapts the following classes’ content. For example, when most students have spent more time on a page compared to another, this reflects the need for more focus and examples on this topic.

2.4. Tools development

A few more words about the multimedia development tool Storyline®, which offers a rich developing environment with a high-level user interface. One can directly import existing presentation slides or develop new multimedia material following only a small number of steps. The developing environment and options resemble a lot of Microsoft PowerPoint®, which makes the learning curve rather smooth. The content is grouped into scenes to keep it structured. In this implementation, a scene defines a module (chapter) of the course. An example view of the scene and the structure of the content and slides is presented in Fig. 6. Each thumbnail (in Fig. 6) represents a slide, and the arrows show the path from slide to slide. For example, slide “2.1 outline” is the introductory slide and the user will be lead to one of the “2.24”, “2.21”, “2.9” or “2.2” slides. Apart from the visible slide connections, with the arrows, a user action can lead to any other slide or even scene. These connections are not visualized directly, but there are tools to check and modify them. This representation also helps the developer to maintain a visual picture of the content’s structure. Through the same view, it is possible to add new slides, move them to a new scene and modify the main connections.

Furthermore, Storyline® seemingly integrates with eCAM-FUS – the eLearning Management System of Texas A&M University (based on Microsoft Blackboard Learn®). Students can access the platform via any web browser (desktop and mobile versions) that supports Adobe Flash® or even download a standalone player for Apple® iOS. Finally, eCampus logs very detailed information while the students read the content, answer the quizzes and solve the problems. The post-processing of this information is part of the proposed methodology and the study evaluation; therefore next paragraph discusses it in depth.

In any case, it is not within the scope of this study to compare and evaluate the available multimedia development tools, but other alternatives to Storyline® also exist. The developed platform is available as a supplementary material (Sup. Mat. 1) and also at the web address “http://www.aqert.net/TAMUQ.CHEN304.v05” (without the quotes).

2.5. Evaluation of the proposed methodology

Much effort accompanies the preparation of the multimedia platform, especially the first time. In addition, instructors are always skeptical for the adaptation of any new technique without careful evaluation and analysis from a number of perspectives. Unfortunately, the small size of classes in our campus limits the capacity for such an extensive evaluation, using multiple control groups and other techniques. Therefore, the author adapted the triangulation method for the evaluation as proposed by Patton (2002). Triangulation is a method of cross-checking data (O’Donoghue and Punch, 2003), in this case the evaluation outcome, by using multiple metrics (sources) to identify regularities. The tools selected for this study are similar to what Stuart (2014) proposed to evaluate a blended learning approach for safety training, these are:

2.5.1. Active time spent on the platform

Active time accounts for the time where the student is using the platform. This is monitored by periodic uses of the keyboard and mouse. It also means that when the platform is unattended for prolonged periods the timer pauses. The exact threshold is not known to the author nor customizable.

2.5.2. Student’s performance

The multimedia platform includes some quizzes and problems, which the students answer and solve before class. There is the option to repeat the assessment as many times the student wishes. The progress is monitored and logged. All material is available to them one week prior the specific module and is part of the homework assignments. The latter serves as the “accountability gate” (Swartz et al., 2013) of the pre-class assignment. Apparently, this gate is the most critical aspect of all similar techniques, like the flipped classroom (Lian, 2003) and the proposed mAI concept. Therefore, the students are asked to carry out pre-class assignments as part of the graded homework. The results of the quizzes and problems are also as part of mAI (described earlier) for the course adaptation.

Students’ performance on the presented topic is assessed via a mid-term exam, E2. Paired t-tests were performed to determine effectiveness compared to the control group (Group C – PETE 314) and between another exam for the same groups (E1).

2.5.3. Self-assessment and survey

The third evaluation tool consists of two questionnaires, before the specific lectures and after the grading of the related exam. Before the specific lectures and at dedicated locations of the platform, students self-assess their comprehension at each subtopic on a five-level scale (excellent, good, average, fair, and poor). For the module of “External Flows” these subtopics are drag coefficient, force balance, Stoke’s Law,
and form drag. Their answers are used to adapt classroom material, as proposed in mAI, and as a pre-assessment of students’ perception.

After the grading of the related exam (week 13 of 14), students fill in a ten questions survey. It is related to the whole module of the course and uses a five-point Likert scale (strongly agree, agree, undecided, disagree, strongly disagree). Four of these questions address a particular aspect of the mAI evaluation. Both the questions and the aspects are presented in Table 1. Unfortunately, this tool was used only in Groups A and B.

These three tools were deemed the most appropriate ones for the impact assessment and analysis of the proposed mAI and the developed tools. Next section describes the outcomes of each tool and discusses the findings.

3. Results and discussion

The whole study took place during the Fall terms of 2013 (only CHEN 304) and 2014 (both CHEN 304 and PETE 314). The corresponding groups appear in Table 1. To repeat, mAI was applied to Groups A and B while Group C was the control group. Following paragraphs present the results for each of the three evaluation tools.

3.1. Active time spent on the platform

On average Groups A and B spent correspondingly 34 and 39 active minutes on the platform while 25% spent more than 60 min, the full statistics are presented in Fig. 7. This active time corresponds to a period where the user interacts with the
platform. The total active time might not seem much for the preparation of a whole topic, including the quizzes and problems. Nevertheless, it is significantly more than the minimum necessary time, around 6–10 min, needed just to scroll through the material. The real time spent on the platform, based on the logged time for starting and finishing, was also calculated. The estimation shows that students spent on average three times more time on the platform, when compared with the active time. This real time could correspond to just reading the material, checking the textbook, solving the problems on paper, etc. Apparently, a student could also leave or forgot the platform running, so this is a crude estimation of real-time. Only one student, from each group, failed to visit the platform and to complete the homework. All students attempted the quizzes as many times as necessary (from 1 up to 3 times) to achieve a perfect mark.

3.2. Student’s performance

Table 1 presents all grades for each exam and group. Groups A and B received mAI and scored, in the corresponding exam (E2), an average of 86% ± 7.8% and 85% ± 8% correspondingly, which are very close to the exam (E1) without mAI, but on a different topic. In contrast, Group C, which received no mAI, scored a quite lower 78% ± 14% on the similar exam (here E2 is for all groups). At the same time, Group C scored similarly, 86% ± 9% on E1, which is also equivalent to E1 for Groups A and B.

Following the recommendations of Sullivan and Feinn (2012), and of many other researchers, the author performed multiple paired t-tests to calculate the two tail p-values and the effect size d in order to determine the effectiveness of mAI. Table 3 summarizes all results. Concerning groups A and B and the null hypothesis that Test-1 is better that Test 2, the conclusion is that students performed similarly well; in all cases p-value >0.05. The values of effect size d support this finding. In other words, there is no significant improvement when implementing mAI. On the other hand, there is a significant improvement if we compare E2 of Groups A and B against Group C (control group). The null hypothesis is rejected in both cases with two tail p-values equal to 0.0017 and 0.00154 correspondingly. Effect size d shows a medium improvement in the performance of Group A and B in E2 compared to Group C, with values 0.68 and 0.58 correspondingly. This is a valid comparison because Group C has performed similarly in E1 compared to Groups A and B; two tail p-values equal to 0.40 and 0.68 correspondingly and effect size d equal to 0.19 and 0.06. In other words, Groups A and B performed similarly with the control group on the examination of the material without mAI but significantly better when mAI was used.

In any case, the quantitative findings are indicative of a small improvement but cannot lead to a safe conclusion because:

(a) of the small size of the samples,
(b) groups of CHEN 304 (A & B) might not be entirely equivalent to the control group of PETE 314 (C) and

Fig. 7 – Histogram of the average (including min and max) active time students spent on the platform.

Fig. 8 – Results of the self-assessment before and after the classes and exam (N = 27).
(c) within the Groups (A & B) of the same course there was no obvious change with and without mAI.

3.3. Self-assessment and survey

This evaluation tool focused on how students perceived mAI and on how it affected their learning efficiency. Of course, it is a qualitative tool but commonly acceptable and often safer for small samples.

The self-assessment took place prior to class and examination (only for CHEN 304), while the students were following the material on the platform. On the five-level scale (excellent, good, average, fair, and poor) students self-assessed their level of comprehension. Some subtopics seemed to be already clear, like Stoke’s law and drag coefficient but others needed more effort, like force balance and form drag. The detailed results are presented in Fig. 8. Following the mAI approach, author used this information to adapt the content of the following classes. For example, the author spent more time on examples related to force balance rather than on Stoke’s law. In addition, this information was not anonymous, so author addressed specific questions to most of the students for an on-the-fly assessment of their individual understanding.

On the other hand, most instructors do use techniques to assess students’ level of comprehension and adapt their class. On the other side, in this case, students knew how this is going to happen and appreciated this particular effort, to adapt the teaching flow based on their individual concerns. Obviously, this will not be as easy with a lot more students. Next paragraphs include more details on students’ perception related to mAI.

Later, the same self-assessment was conducted again as part of the module’s survey, where the students’ self-assessed their level of understanding quite higher. This outcome is similar to the overall improvement observed at all the other modules of the course (TAMUQ-CHEN, 2014). Therefore, it can only be considered as an indication that mAI improves the perception of students at least equal to all other approaches implemented in this course. Unfortunately, the same assessment was not conducted for the control group, which might have helped to identify the specific impact of mAI.

After the end of the specific classes and the grading of the related exam, author conducted an additional anonymous survey. Fig. 9 presents the answers on the four, related to this study, questions (see Table 2). In general, students assessed the mAI approach and the developed tools very positively. Around 80% of them agreed that the collected information actually helped the instructor to adapt properly the lectures to their needs. While almost 90% believes that, the platform enhanced their understanding. When the students were asked whether “the development and employment of the platform it worthy the effort from both sides”, the vast majority agreed with that. Finally, an interesting conclusion came up from the question “if this kind of platform should be adapted to other courses”. More than 71% sees this positively but almost 16% do not like the idea. This argument was further discussed during sample interviews. The discussion revealed a major concern related to the time spent on home reading. According to the students, the instructor could misinterpret this information and low-grade students with lower times.

In other words, students’ level of endorsement highly depends on the instructor; probably as many other things. If this information is used for the course adaptation – mAI – almost everybody wants to see this progressing. On the other hand, this information might be used to grade directly students, something that students are not keen to see it happening.

Table 2 – The statements and the examined aspects of the Questionnaire metric (the results are presented at Fig. 8).

<table>
<thead>
<tr>
<th>Question</th>
<th>Aspect</th>
<th>Abbreviation at Fig. 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>The platform helped me understand the material better than just using the book/handouts</td>
<td>To assess the enhancement of understanding</td>
<td>Enhanced understanding</td>
</tr>
<tr>
<td>I am willing to spend more time preparing for the lectures if I can do it through such a platform</td>
<td>To explore whether the students feel rewarded for the effort</td>
<td>Worth the effort</td>
</tr>
<tr>
<td>All courses should have similar platforms</td>
<td>To explore the potential to adapt it in more courses</td>
<td>Adapt in more courses</td>
</tr>
<tr>
<td>The instructor seemed to know exactly which points/concepts I needed to be explained in more detail</td>
<td>To assess the impact on the instructor from the students point of view</td>
<td>Assisted the instructor</td>
</tr>
</tbody>
</table>

Table 3 – Two tail p-values (upper diagonal) and effect size d (lower diagonal) of paired t-tests (Sullivan and Feinn, 2012) between all combinations of Test 1 compared to Test 2 for Groups A, B and C and the corresponding exams. Groups are described in Table 1 and the exam details in Section 2.2.

<table>
<thead>
<tr>
<th>(Test 1)</th>
<th>A-E1</th>
<th>A-E2</th>
<th>B-E1</th>
<th>B-E2</th>
<th>C-E1</th>
<th>C-E2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-E1</td>
<td>0.397</td>
<td>0.571</td>
<td>0.190</td>
<td>0.401</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>A-E2</td>
<td>0.21</td>
<td>0.776</td>
<td>0.636</td>
<td>0.995</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>B-E1</td>
<td>0.14</td>
<td>0.07</td>
<td>0.950</td>
<td>0.682</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>B-E2</td>
<td>0.33</td>
<td>0.12</td>
<td>0.19</td>
<td>0.456</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>C-E1</td>
<td>0.19</td>
<td>0.001</td>
<td>0.06</td>
<td>0.11</td>
<td>0.710</td>
<td></td>
</tr>
<tr>
<td>C-E2</td>
<td>0.84</td>
<td>0.68</td>
<td>0.72</td>
<td>0.58</td>
<td>0.64</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Test 2)</th>
<th>p-Value</th>
<th>Effect size d*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-E1</td>
<td>0.397</td>
<td>0.571</td>
</tr>
<tr>
<td>A-E2</td>
<td>0.21</td>
<td>0.776</td>
</tr>
<tr>
<td>B-E1</td>
<td>0.14</td>
<td>0.07</td>
</tr>
<tr>
<td>B-E2</td>
<td>0.33</td>
<td>0.12</td>
</tr>
<tr>
<td>C-E1</td>
<td>0.19</td>
<td>0.001</td>
</tr>
<tr>
<td>C-E2</td>
<td>0.84</td>
<td>0.68</td>
</tr>
</tbody>
</table>

* p-Value <0.05 rejects the null hypothesis that Test 1 is not better than Test 2.

* Effect Size d shows a relative improvement of Test 1 vs Test 2 as such: small when >0.2, medium >0.5, large >0.8 and very large >1.3.
4. Conclusions

A teaching approach – the micro-adaptive instruction (mAI) – was presented in this paper. Through mAI the instructor adapt lectures’ content based on students’ feedback prior to lecture and additional detailed information on their learning progress. mAI employs a multimedia platform (designed in Storyline® by Articulate) that delivers the course material. Students reaches the platform at their personal time and carry over individual tasks prior to the class time. The platform logs their activities, “behavior”, answers and attempts of quizzes, individual comments, self-assessment/evaluation, access date, and time. Later the instructor can access and analyze all this information. The above are similar to well-known classroom assessment techniques (minute paper, muttiest point) which aim to transfer feedback in both directions. Thus, the instructor can carry out the lectures and flipped classes more efficiently because of the awareness of the individual student’s and overall weak and strong points.

This study demonstrated an example of the mAI approach on a module of the Chemical Engineering Fluid Operations (CHEN 304) course at Texas A&M University at Qatar. Author implemented the approach for two consecutive terms (2013 and 2014) on CHEN 304. A similar course (PETE 314) served as control group. Three different evaluation tools assessed the impact of the proposed approach: active time spent by the students, questionnaires, and students’ performance. The first two tools aimed to assess, mainly, students’ perception, in other words their engagement and motivation to learn and participate. Indeed, the majority of the students agreed that the collected information helped the instructor to adapt properly the teaching to their individual needs. Similarly, the vast majority believed that the platform enhanced their understanding. On average students spent 37 active minutes on the platform while a quarter spent more than 60 min. This duration is quite significant compared to the necessary minutes just to scroll through the material (less than 10 min).

The third tool attempted to quantify the overall improvement in comparison to other modules of the same course and the control group. Unfortunately, it was not possible to identify any significant variation between the different modules of the same course. This could be attributed to: (a) the small size of classes (number of students 17 Fall 213 and 20 Fall 2014) and (b) the fact that adaptive learning is a technique implemented throughout the whole course in various approaches, so there are not many variations within the same course. On the other hand, the comparison with the control group showed a significant improvement (two tail p-values <0.05 a medium effect size d).

Despite all the positive feedback and impact of this approach, it should be noted that significant effort is necessary from the instructor to upgrade existing teaching material to the level of the presented platform. On the other hand, this process can take place gradually or even be adopted by the educational publishers. In the future, they may provide directly such multimedia platforms (electronic service) along with the textbooks. To the best of my knowledge, there is already a handful of similar services able to evolve to this. Future research steps include the adaptation of mAI for the whole course. Thus, the performance of more students and for longer periods will be studied. Finally, the case of the indentical curricula between the main campus (College Station) and the Qatar branch campus offers a unique opportunity to study the impact of various approaches to different cultural mixtures of students.

Acknowledgments

The author would like to thank Academic Affairs and the Educational Technology Group of Texas A&M University at Qatar for the initiative to organize the Teaching Innovation with Technology Competition (Fall 2013), where this study won the 1st prize. A presentation of this work also won the best paper award at the World Engineering Leaders Conference in Doha 2014, under the Engineering Education Models for 2020 and Beyond category. Finally, the author would like to extend his appreciation to the people that with their valuable input contributed to this study Dr. Nasser Alaeddine, Karawan Alsaleh and Miklos Kovacs.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ece.2015.06.001.

References


