Technology-enhanced Pathways to Active Learning: Student Response Systems Facilitating Peer-instruction and Self-assessment in Large Classrooms.

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Abstract

This paper describes an active learning approach implemented in a first-year undergraduate course in Introductory Macroeconomics taught at the University of East Anglia. The first part of the paper explains the motivation that led me to introduce this approach, which builds on powerful pedagogies such as self-assessment and peer-instruction, as well as on technology-enhanced learning through Student Response Systems. In the second part of the paper, I report on the mixed-methods evaluation strategy implemented to appraise pedagogical effectiveness. Whilst only briefly commenting on quantitative indicators, which have been the focus of previous publications, the focus of this paper is on qualitative data that conveys students' perceptions of their learning experiences when using the approach. Analysis of the qualitative data highlights that students view my pedagogical approach, as well as its technology-enhanced implementation, as supportive of student learning, and as a means of enhancing their self-efficacy beliefs. The pedagogic approach is especially welcomed by students coming from an international background, characterised by diverse previous learning experiences. The approach also appears to be particularly effective for students who are struggling with their learning.

Keywords: Active learning, peer instruction, self-assessment, self-efficacy, student response systems.

1. Introduction.

Recent pedagogical research advocates the use of active learning approaches to engage students and maximise the achievement of learning outcomes (e.g. Hake, 1998; Prince, 2004; Freeman et al., 2014). However, very few contributions that evaluate the effectiveness of active learning pedagogies have employed an encompassing evaluation strategy that combines quantitative measures of student achievement of intended outcomes with qualitative data that illuminates students' perspectives on their learning experience. Having taught the same module in Introductory Macroeconomics for a period of 7 years, I was able to design, develop, implement, and evaluate an active learning approach that engages students in mastering basic principles of Macroeconomics through peer-instruction, and that fosters the formation of self-efficacy beliefs through self-assessment tasks. Whilst in previously published research contributions I focussed on the quantitative outcomes emerging from the evaluation of my approach (Aricò, Gillespie, Lancaster, Ward & Ylonen, 2018; Aricò & Lancaster, 2018; Aricò, 2016), this paper develops an exploration of students' perceptions of their learning, with a focus on their use of Student Response Systems (SRS) employed as technology-enhanced aids to in-class discussion and self-assessment tasks. The reminder of this paper is organised as follows. Section 2 describes the motivation and the drivers for my pedagogical approach, as well as the practical features of design and implementation of my active learning strategy. Section 3 reports on the evaluation of the teaching approach. The section begins with a summary of quantitative data analysis; the second part centres on qualitative data, derived from interviews which illuminated student perceptions of active learning sessions. The analysis focuses upon the ways in which SRS can: (i) enhance the student experience, and (ii) facilitate an appraisal of how students learn. Finally, in Section 4, I develop my conclusions reflecting on lessons learnt from my pedagogical research outputs and my teaching experiences.

2. Active learning in Introductory Macroeconomics at the University of East Anglia.

Since 2012, I have been teaching a large module in Introductory Macroeconomics at the University of East Anglia (UEA). All students enrolled in an Economics degree at UEA are expected to take this compulsory first-year module establishing the foundations of macroeconomic analysis on which students will build over their second and third years of studies. As the School of

Economics has been expanding over the past years, the number of students enrolled in the module increased from 140 in 2012-13, to more than 250 in 2017-18. Students joining the School of Economics at UEA are not expected to have previous knowledge of Economics or Mathematics from Secondary School. The proportion of international students enrolling in the module has varied from 45%-30% over the past years. Therefore, the student population of Introductory Macroeconomics consistently features diverse backgrounds, both in terms of previous learning experiences and different learning cultures. This high heterogeneity in the classroom, compounded with the challenges of transitioning from secondary to higher education, is a cause for concern for many students. Students experience difficulties adjusting to university teaching, and they also struggle to identify reference points to assess their own competences. Student confidence can be severely hindered within this learning environment, with detrimental effects on both attainment and engagement. At the same time, operating in a large class environment, the teacher struggles to foster a pedagogical approach that caters for individual and diverse needs, and that allows him to establish a meaningful dialogue with the students.

To address these challenges, I designed a pedagogical approach that aims to: (i) engage students and facilitate an in-class peer-support network, (ii) increase understanding of concepts and mastery of skills in Macroeconomics, and (iii) foster student confidence and self-efficacy beliefs. To meet the first two objectives, I make use of peer-instruction (Mazur, 1997), while the re-iteration of self-assessment tasks threaded throughout the process allows me to develop students' awareness of their own skills and increase their self-efficacy beliefs. The introduction of SRS to establish better communication with the students also represents an essential factor of success to improve pedagogical effectiveness. In my approach, I adhere to the model outlined by Nicol and Macfarlane-Dick (2006), who identify self-assessment in formative assessment tasks as one of the most powerful drivers of self-regulation and learning. In the next two paragraphs, I describe the characteristics of my teaching approach, as well as the role played by technology-enhanced learning methods.

2.1. Pedagogical design and development.

Introductory Macroeconomics is a year-long module. Students attend 2 hours' lectures per week, where I deliver the material. In each semester, students practice the material in small-group seminars (1 hour) and large-class workshops (2 hours). Practical activities involve applying the theories and the concepts learnt in lectures to real-world scenarios (e.g. explaining or

predicting change in economic indicators) or hypothetical situations (e.g. suggesting policy-intervention within specific economic frameworks); the approach is predominantly problem-based.

Seminars and workshops start in Week 4 of each semester and take place every 2 weeks, 4 times per semester. The organisation of seminars adheres to a standard model, widely adopted in Economics education. Students are expected to tackle a pre-assigned problem set and bring their solutions and questions for discussion during seminars. A team of seminar leaders facilitate class discussions in groups of 15-17 students.

Workshops are led by the module convenor and are characterised by large-class events, as the whole class is divided in just two groups (of approximately 125 students each, in recent years). When attending workshops, students are exposed to a problem set never seen before, which is composed of 8-10 multiple-choice questions, with 4 possible choices each. It is in workshops that my active learning approach plays out, adhering to a specific teaching procedure organised as follows. For each multiple-choice question:

1. Students choose the answer that they believe correct independently and autonomously. The distribution of responses is not revealed to them at this stage.
2. Students are invited to reflect on their ability to address the question and they are asked to rank their confidence in mastering the skills necessary to answer the question correctly. At this stage, the distribution of confidence level-related responses is revealed by the facilitator, so that students can appreciate the general level of confidence in the classroom.
3. Students are invited to discuss the question and they collaborate with their peers to confirm or to review their answers.
4. The same question is asked again. At this stage, the distribution of responses is shared with the class and the correct answer is revealed and discussed in detail.

The same teaching procedure is repeated for each of the multiple-choice question composing the problem set[1]. Depending on the time left available, further problem-based questions might be also discussed.

[1] In recent years, I extended the teaching procedure re-iterating Stage 2 with a further repetition of the self-assessment task. This allowed me to craft a measure of Confidence Gain, as discussed in Aricò *et al.* (2018).

2.2 Technology-enhanced Learning through SRS.

In order to facilitate the running of my teaching procedure during workshops, as well as promoting general interaction in lectures, I make intense use of SRS, also called 'clickers'. Each student enrolled at the School of Economics at UEA receives a personal SRS device during induction week. Students retain their devices for the duration of their degree free of charge, but they are expected to return it before graduation. A fee is payable if the SRS are broken or lost. UEA uses TurningTechnologies equipment and holds a campus license for TurningPoint, the software interfacing SRS with the lecturer's computer. TurningPoint enables users to create interactive slides on PowerPoint, where multiple-choice questions can be polled. A wide set of functionalities allow the user to reveal or hide the distribution of responses, show polling results in real time, or after the polling is closed. A USB receiver connects to the user's computer to collect responses sent by clickers. TurningPoint also has the facility for enabling reports to be shared with the class at the end of each interactive section, and to download session data in Excel format ready for statistical analysis and elaboration. Since each clicker is associated to a specific ID code, which is listed in Excel reports, the lecturer can track all responses given by each individual student over time.

TurningPoint is also able to collect responses sent by mobile phones. However, my personal choice is to stick to the use of clickers for two reasons. Firstly, given the diverse background of the School of Economics' student population, the choice of providing students with the equipment they need is perceived as more inclusive, compared to a 'bring your own device' approach. Secondly, while mobile devices can be used to perform many tasks at once, clicker devices are bespoke learning tools, which might be better suited to encourage students to focus on the learning tasks they are facing in class.

3. The Role of Student Response Systems.

SRS are a widespread teaching device in HE, and their positive effect on student engagement is widely recognised (e.g. Hoekstra & Mollborn, 2012; Crossgrove & Curran, 2008). However, investigations of the impact of SRS technology on student attainment and learning have generated controversial results. For instance, Anthis (2011) highlights that an evaluation of the pedagogical effectiveness of SRS is affected by the type of questions asked to students. Elicker

and McConnell (2011) find that students react more positively to formative questions posed to them through SRS, rather than through more traditional methods, such as hand-held cards or hand-raising; however, student performance in final exams appears to be independent of the pedagogical choices of formative assessment. In this section, I consider how SRS facilitate the collection of learning data for pedagogical evaluation, as well as students' own perception of the impact of technology-enhanced active learning.

3.1 Using SRS to gather and analyse learning data: practice and results.

As described in Section 2, SRS software such as TurningPoint allows teachers to produce reports from active learning sessions, as well as to download learning data in Excel format ready for statistical analysis. The individual SRS ID code appearing in these reports enables teachers to track student responses longitudinally. In analysing the data obtained from SRS, I investigated the association between attainment and confidence levels.

Students develop good self-assessment skills as high attainment is significantly associated to higher confidence levels. The result of extensive analysis conducted in these data can be summarised as follows[2]:

1. Peer-instruction is effective, as the proportion of correct responses to formative multiple-choice questions significantly increases after students have had an opportunity to discuss them.
2. Learning Gain (the increase in the proportion of correct responses pre/post peer-instruction) is positively correlated to Confidence Gain (the increase in the proportion of statements of confidence in students' own ability pre/post peer-instruction); in other words, when students learn this way, their confidence levels increase as well.
3. Learning Gain and Confidence Gain are maximised when the proportion of correct responses before peer-instruction (initial knowledge) is neither too low or too high; in other words, students maximise their learning when multiple-choice questions are crafted in a way that does not trivialise learning, yet not rendering the task excessively challenging.

[2] Findings of this research are further discussed in Aricò *et al.* (2018), Aricò & Lancaster (2018), and Aricò (2016).

3.2 Student Perspectives on the use of SRS to facilitate active learning.

To appraise the impact of technology-enhanced active learning on the student population, I designed an evaluation strategy grounded on focus group interviews. Focus groups were run over the academic year 2013-14, exploring the experiences of different groups of students. The study was ethically approved by the University of East Anglia. To prevent any form of perceived pressure from the module convenor, the recruitment and the chairing of focus groups were based on an ethical protocol that involved the presence of facilitators external to the teaching team. Moreover, to prevent bias in responses, students were not informed that participants were selected according to demographic or attainment characteristics. Access colour-coded tickets were made available from the School of Economics' administrative office, so that participants could preserve their anonymity. However, students belonging to different demographic or attainment groups would receive invitations to collect tickets of a colour associated to their group.

Interview recordings were transcribed, coded, and processed through thematic analysis. The first focus groups (2 sessions) contrasted the experience of overseas students with the views of home students, with the aim to investigate whether imbalances emerged on the grounds of previous learning and language barriers. Ten students (5 female, 5 male) participated in these focus groups. The second set of focus groups (2 sessions) tackled the difference in responses between high-performing and low-performing students.[3] Ten students (6 female and 4 male) participated in this second set of focus groups.

Among the cohort of students interviewed, none had experience of SRS prior to enrolling in the Introductory Macroeconomics module. Student learning styles and preferences were extremely diverse, and this diversity was reflected in their attitudes towards SRS. Their narrative often interlinked their views of the use of technology with the quality of teaching (e.g. attitude of the lecturer) and the other learning resources (e.g. VLE material) available for the module. A few participants mentioned their interest in learning how their fared academically compared with their peers and identified SRS as a useful device to gather this information.

[3] Students were identified as high-performing or low-performing on the basis of the distribution of marks awarded in a mid-module summative assessment test.

3.2.1 The experience of SRS of international and home students.

These focus group sessions focussed on the use of technology and its contribution to learning, comparing the experience of home and international students. Initially, when students were asked whether clickers contributed to their learning, responses did not seem to provide robust support for using SRS. Two students felt that clickers had an impact on time in the workshops: a male student felt clickers were used "too much" and a female said: "it's just one more thing to do". However, deeper probing of the role of SRS from different perspectives generated a more enthusiastic response. One overseas student reported that she found clickers "really useful" in comparison with their absence in her own country:

> *'I found it's really useful because we don't have anything in my country … …the computer asks you if you are confident or not, and you can say ['yes'], if 'no' you can tell the truth*.'

In addition to being able to "tell the truth", this student added that "they don't know your name". The capacity of clickers to allow this student to be truthful while remaining anonymous seemed to hold particular value for her. In a similar vein, the anonymity provided by clickers was valued by a male student. After describing that clickers have a "useful" impact on his learning of Macroeconomics, he added that he liked their anonymity because: '*…you are confident to answer the question even if you are not confident about the answer.'* When asked to explain further, he reported that he was "*more confident to answer with a clicker than in front of* [a group]".

The potential of SRS to generate engagement and motivate learning was also praised by respondents:

> *'The ones that use it are more fun and more engaging and I pay attention more.'*
>
> *'I think it actually motivates me to focus on what I've actually missed, like go to the lecturer or study more.'*

As mentioned, views were not uniform amongst respondents. One male home student shared his concerns towards the use of clickers and multiple-choice questions, and he emphasized the need to focus on problem-based questions, whose format is similar to those asked in the final exam. In his view, investing effort on multiple-choice questions implies that there is less time to finish: '*all the questions that you've prepared … and those are the questions we're going to get*

in the exams'. By referring to 'questions prepared' the student seems to display a well-developed degree of autonomy in his learning, which makes him less enthusiastic about the teaching procedure presented in Section 2.1. However, the interpretation of such reaction is also shared by students displaying a surface-approach to learning, who prefer to practice the teaching material through problem-based activities that are much closer to the structure of final exam papers.

3.2.2 The experience of SRS amongst high and low-performing students.

Considerations about the usefulness of SRS also emerged in the second set of focus groups, contrasting the experience of students displaying different levels of attainment within the module. As this focus group took place later in the second semester, it was interesting to observe how the student narratives became more articulate, and how student opinions delved more deeply into their experience as learners. Some student comments resonate with previous interviews, especially when referring to the role of SRS in stimulating engagement, motivation, and raising awareness of one's performance:

> *'It sort of engages you a lot more in lectures… and especially in the workshops because you go through loads of different questions and sort of click away and that way you can know where you are.'*

An interesting contrast emerged amongst the opinions of students belonging to different attainment groups. Students who were identified within the high-performing group, seemed to display clearer study-strategies. Some of them acknowledged the usefulness of SRS:

> *'The adversity of not doing well on clicker questions: It stressed me out… I worked harder! It gave me the motivation to look over it [the material] because I wanted to correct it*.'

but also displayed more independence of them, as well as growing awareness of their own preferred learning approach:

> *'I am confident, if I stick to my revision schedule'.*
>
> '*…when I read the hand-outs myself…after the lecture, I understand so much more than when I'm actually in the classroom.'*
>
> '*Work out what works best for you quite quickly – whether making notes or going through the slides when you go home is best.'*

On the other hand, while students identified within the low-performing group reported lower levels of engagement:

'…doesn't actually matter…'

'…only needing 40% to pass…'

some of them also displayed stronger recognition for the role of clickers in guiding their learning:

'*It sort of engages you a lot more in lectures… and especially in the workshops because you go through loads of different questions and sort of click away and that way you can know where you are.'*

'*I know that I need to go in and speak to someone or go to a support session can know where you are. … [W]hen I wasn't doing so well, I felt a little bit low but then I realised that the clickers are a way of letting me know that, so I can go and improve.'*

The insights emerging from this set of focus group interviews are that students with different approaches to learning perceive the value of clickers differently. Students who display higher performances in coursework seem to display better developed learning strategies, which also make them more independent of the use of clickers. On the other hand, students displaying lower performances seem to value the use of SRS more. They appreciate them as useful devices to self-assess their preparation and seeking for support if needed. To this extent, student narratives evidence how the use of clickers facilitates self-assessment practices that lead to student motivation and learning (McMillan & Hearn, 2008; Henderson & Harper, 2009). In line with the principles outlined by Nicol and Macfarlane-Dick (2006) and Zimmermann (2002), students report how these self-assessment practices contribute to transform them in self-regulating learners.

4. Discussion and Conclusions.

The large set of empirical evidence accumulated to evaluate the impact of technology-enhanced active learning for students enrolled in Introductory Macroeconomics benefitted from a mixed-method approach, appraising outcomes in terms of student attainment, self-efficacy levels, and students' own perceptions about the learning experience. Quantitative results confirm the effectiveness of the active learning environment that I have developed; there is evidence that students can improve their learning when they interact collaboratively with each other, and that

learning is associated with increased self-efficacy beliefs through the successful development of self-assessment skills.

The qualitative analysis I conducted allows to shed light on the reasons for this success. Students appreciate the anonymity granted by technology; this feature allows them to share their thoughts with confidence, which is a catalyst to the productive discussions instigated over peer-instruction. In this sense, my addition to the standard Mazur's peer-instruction algorithm allows students to feel more engaged and bolder in sharing their reflections with one another. Visualising the distribution of confidence rankings over the material covered allows students to realise that hesitation, lack of confidence, and doubt constitute a shared experience. Similarly, visualising the distribution of final responses to formative questions allows the class to see that opinions might still diverge, which incentivises students to ask for further clarifications.

Students' narratives highlight that their perceived learning experience is a composite construct, which they cannot disentangle into pedagogy, use of technology, ways of assessment and teacher's attitude and style. This is a positive outcome because, in a student-centred approach, the lecturer designs and reflects on the different components of his/her pedagogical approach precisely with the aim of simplifying and easing the experience of students. Nevertheless, in my day-to-day teaching practice, I often share the pedagogical rationale of my technology-enhanced teaching approach with the students, inviting them to make use of SRS to self-assess their performance and seek for help when needed. For this reason, I ought to recognise that my enthusiasm in the pedagogies I use displays an impact of its own on students' perceptions of such pedagogies.

On a related point, as argued in Anthis (2011) and Aricò and Lancaster (2018), the issue of disentangling the role of pedagogy, technology, and teacher's actions also emerges when considering the quality of the teaching material employed. The use of technology in polling multiple-choice questions can only be successful if the questions themselves are pitched at the right level, and consistent with what taught in lectures. Nielsen, Hansen & Stav (2013) also suggest that good practice in the use of SRS is essential for pedagogical effectiveness. This good practice includes the timing of questions, the teacher's commitment and mastery of the technology, as well as correct interpretation of polling results as essential factors of success.

High heterogeneity in the distribution of students' skills and previous learning experiences is particularly relevant when considering pedagogical impact in a first-year undergraduate module such as Introductory Macroeconomics. The narrative emerging from interviewing international students is particularly relevant, as it provides strong support for my approach in the specific context in which it is deployed. Following the innovations introduced in Introductory Macroeconomics, engagement and attainment of international students were a major concern of mine because non-native speakers, who were possibly exposed to more passive forms of learning in previous experiences, might have encountered difficulties. Even though international students are expected to read and elaborate on multiple-choice questions within a limited time-frame and under pressure, it was pleasing to observe that they enjoy active learning as much as home students, suggesting that anonymous use of the technology empowers them to have a voice, yet enabling them to remain within a safe space.

Consistent with related literature on active learning (e.g. Walker, Cotner, Baepler & Decker, 2008), student narratives evidence that my pedagogical approach displays a stronger impact for students belonging to the low-performing group. This result is particularly important because closing attainment-gaps amongst students belonging to different socio-demographic groups cannot be tackled through bespoke intervention, especially within a large class environment. The academic debate on student attainment calls for more attention to inclusive practices which serve the diverse needs of international students, students coming from disadvantaged background, disabled students, as well as students belonging to Black, Asian and ethnic minority backgrounds (e.g. Universities UK and National Union of Students, 2019). However, rather than embracing interventions driven by a deficit-model approach, high-power pedagogies, such as self-assessment and peer-instruction, support the promotion of more inclusive education, which can significantly contribute to learning for the whole student population. In this context, judicious, pedagogically-informed use of technology, such as SRS, unlocks the full potential of teaching approaches which embody active learning.

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