Student-active learning in mathematics: Operationalisation of 'constructive alignment'

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ABSTRACT: This presentation/paper describes the beginning of a developmental process leading to the creation of a survey instrument to explore the use of active learning approaches in higher education mathematics. The paper begins by arguing a relation between active learning and the conference theme "constructive alignment". The first stages of the developmental process are based on a "Delphi-study" research design in which the meanings of "active learning" and teaching/approaches that may promote active learning are elicited from a selected group of students, mathematics instructors, mathematicians and mathematics education researchers. The Delphi-study is described and the analysis of outcomes from the first stage of the study are reported in this paper. The conference presentation will also include details from the second stage of the study that is planned at the time of writing. A working definition of "active learning" is established from the study, together with a number of teaching/learning approaches that might promote active learning in mathematics. The paper concludes with reflections on how the outcomes of the study will influence the design and content of the survey instrument. It is hoped the discussion at the conference will also inform the further development of the instrument.

1 INTRODUCTION

Active learning in higher education (HE) has been advocated for many years. An extended paper discussing the nature and implementation of active learning approaches in HE published in the USA in 1991 (Bonwell & Eison, 1991) described the state of the art at that time and promoted active learning amongst university and college instructors. At the present time there are several approaches used by HE mathematics teachers in Norway that can be included within a broad definition of 'active learning', such as, for example: problem-based learning, inquiry-based mathematics education, and project-based learning. These approaches include the principle that students will be active participants in their learning. The notion of active learning is also intimately connected to the theme of this 2019 MNT conference 'constructive alignment' as evident in a brief paper by John Biggs published by the UK Higher Education Academy:

Constructive alignment' has two aspects. The 'constructive' aspect refers to the idea that students construct meaning through relevant learning activities. That is, meaning is not something imparted or transmitted from teacher to learner, but is something learners have to create for themselves. (Biggs n.d.)

Students' active engagement in their learning and the constructive alignment of teaching, learning and assessment can be argued from different theoretical perspectives (Biggs, 1996), but the most convincing arguments arise from solid research evidence. A large meta study carried out by Freeman and colleagues (2014), was based on 225 studies that compared 'active' with 'conventional' approaches in science, technology, engineering and mathematics (STEM/MNT) subjects. The evidence reveals students in active learning classes performing on average 6% better than those in conventional classes, and 1.5 times less likely to fail.

With this background, The Norwegian Mathematics Council (NMR) and MatRIC, Centre for Research, Innovation and Coordination of Mathematics Teaching are collaborating in a survey of the incidence of active learning approaches in HE mathematics in Norway. A working group including NMR and MatRIC representatives has been set up to develop a survey instrument to be completed by mathematics instructors and students on STEM/MNT programmes. In this paper we report work in progress to construct the instrument and, it is hoped, stimulate a discussion that will inform the on-going development of the instrument. It is hoped that in the discussion following the presentation fresh insights will emerge that will contribute to the validity and reliability of the survey.

1.1 Related studies

In 2013 The Norwegian Association of Higher Education Institutions (UHR), The Norwegian Council for Engineering Education, and the Norwegian Faculty Meeting for Mathematics and Natural Sciences conducted an extensive survey of students' experiences of mathematics education in their transition from upper secondary school to higher education STEM programmes. As background to the present study, we present a limited selection of relevant questions and responses. Students were asked to indicate the extent to which they agreed with the statement "the lecturers activate/have activated students," responses were invited on a scale of one (total disagreement) to six (total agreement). Just over 50% of respondents indicated 4 or greater, that is agreeing that there have been efforts to promote active learning. Interestingly, students with lower grades from upper secondary school appeared more likely to agree with the statement, but it is not clear whether this "appearance" has statistical significance. A parallel question posed to instructors asked whether their students were made active in lectures. Less than half of the instructors responded positively to the same degree, the frequency drops to under 40% if only responses from university instructors are considered. Students were asked if they "missed anything in the educational provision," activities attracting the highest responses were reviewing problems' solutions in plenary (around 30%), e-learning (around 25%) and group work (around 20%). Instructors were also asked to indicate the type of teaching approaches used in mathematics, we include only a selection of responses with the frequency of each: lectures (99%); task practice, individually and in small groups (95%); homework tasks (51%); individual work/projects (40%); group work/projects (26%); problem-based tasks (6%). In the proposed NMR-MatRIC survey our intention is to ask some questions in common with the 2013 survey to see if there has been any change in the provision of mathematics education in Norway.

Over several years researchers in the USA have engaged in developing survey instruments for exploring the incidence of different teaching approaches in HE institutions in the USA. The survey instrument for Postsecondary Instructional Practices (PIPS) was published some years ago (Walter, Hendersen, Beach & Williams 2016). Now Charles Hendersen and colleagues at Western Michigan University are close to finishing a new instrument to inquire about instruction practices in differential and integral calculus, introductory quantitative physics, and general chemistry. We are in contact with Charles Hendersen and have been sent a late draft of the new, pre-published instrument. The developments in the USA will prove very valuable as we work on the Norwegian instrument.

This paper reports from our empirical work in the Delphi study, it purposefully does not include a survey of literature on active learning approaches in higher education.

2 METHOD

We recognized from the outset that there would be little point in asking mathematics teachers (or students) questions that referred directly to 'active learning approaches' because there is no agreement about a common definition or understanding of the term "active learning". It will be more productive to ask about specific teaching and learning actions that may be used or experienced within a study programme. Then, it would be necessary to associate these actions with some measure of active learning. To facilitate this, we decided as a first step to undertake a 'Delphi' study. This entails a multi-stage approach that involves a small number of people ("experts") known to the working group for their expertise in higher mathematics education. They are requested to provide an informed opinion, first about the meaning of active learning, and actions that might lead to students' active learning. Next, following analysis and synthesis of the first stage responses, to seek the same experts' opinion on the outcome and their rating of actions against a synthesized definition of active learning. In the group of experts, we include experienced mathematicians, mathematics teachers and mathematics education researchers from Norway, UK and USA, and a group of students from five Norwegian higher education institutions. In this paper we report especially from the analysis of the first stage of the Delphi study, in the presentation we hope to include responses from the second stage.

We asked the experts five open questions, using SurveyXact, an on-line survey tool that enables the anonymous gathering of data. The survey was produced in both Norwegian and English versions, and the same survey was used for instructors and students. Respondents were asked to indicate whether they were a student or instructor/researcher. It appears that some Norwegian respondents chose to answer the

English version of the survey. Figure 1. Shows the five questions that comprised the stage-one questionnaire.

1. *What do you understand by the term "active learning"?*
2. *Please write down a list of different student activities that characterize different degrees of 'active' learning. Indicate the extent to which they are 'active' (not at all – highly etc.).*
3. *Please write down a list of teaching/learning approaches in mathematics education that can characterize different degrees of active learning (e.g. inquiry-based learning, problem-based learning etc.).*
4. *Please write down a list of different class organisation – (e.g. lecture, group, etc. and indicate class size, subject, level etc.) – that can be used to discriminate between different degrees of active learning in higher education.*
5. *Please write down any other comments that you believe are important to include in a survey about active learning approaches in HE mathematics.*

Fig. 1. Questions in the Delphi study stage 1.

3 ANALYSIS AND RESULTS FROM DELPHI STUDY STAGE 1.

Twenty-one responses to the stage one survey were received, (12 instructors and 9 students).

3.1 Towards a shared meaning of "active learning"

As anticipated the responses revealed uncertainty of the meaning of "active learning", some critique of the term, a lack of clarity between 'active learning' as a theoretical construct and teaching/learning actions that might promote active learning. All comments were helpful in some way, especially one respondent who cited the paper by Bonwell and Eison (1991). Two responses with fairly high frequencies occurred:

Students must work themselves (or similar) (8/12 teachers, 6/9 students)

Discussion with lecturer or with students (or similar) (8/12 teachers, 7/9 students).

Other responses were shared frequently:

Cooperative learning (or similar) 5/12 teachers, 1/9 students)

Individual problem solving (or similar) (3/12 teachers, 5/9 students).

Overall there was greater variation in teacher responses (36 different suggestions), than students (17 different suggestions), although 12 of the teacher responses were given by just three teachers.

The responses lead us to propose a definition for 'active learning' that develops that provided in Bonwell and Eison (1991):

Active learning implies a relationship between the learner and the material to be learned, the relationship is characterized by mental/cognitive activity – reflection, metacognition, thinking, etc. that enables learners to create mathematical meaning. "*Students must engage in such higher-order thinking tasks such as analysis, synthesis, and evaluation*" (Bonwell & Eison, 1991, iii). Active learning is learning with meaning attached to the material or content to be learned. Observable, behavioural activity is neither necessary nor sufficient as an indicator of the desired mental/cognitive activity.

The above definition assumes shared interpretations of 'learning,' 'meaning' and 'understanding'. Thus, to add further explanation to the definition above we propose, "learning" in the context of "active-learning" implies "making meaning", gaining understanding or making the mathematics studied meaningful. This can be contrasted with other forms of learning such as "learning that the 'fundamental theorem of calculus' is proved on page 56 of the text book," this knowledge is viable until a new text book is used (i.e learning that results in knowledge that may be useful, but is bound to a time or context that is not generalizable). Or learning to reproduce without any sense of meaning a proof of the fundamental theorem (i.e learning to reproduce without meaning through repeated rehearsal). Or learning that occurs as behaviour changes due to a repeated stimulus and the reward of a desired response.

We use responses to the Delphi study to make sense of the terms "mathematical meaning" and "understanding". The terms imply following, and making sense of, the logical connections within a mathematical argument, completing as necessary intermediate steps in an argument that may be omitted because they are considered "obvious" or "self-evident". Being able to appreciate the key idea or concept of a mathematical statement/object and appreciate the mathematical object in context (of other mathematical ideas or other phenomena) and connect it to other mathematical ideas. To be able to explain the concept in one's own words. Attaching accurate boundaries and explanations to a mathematical concept and representations. To be able to represent the mathematical idea in a variety of forms – words/text, tables, graphs, symbols, etc. and to be able to explain the connections between the representations. To be able to apply the mathematics accurately to new situations and use it to solve non-routine problems and in the process of mathematical modelling.

3.2 Activities that might promote 'active learning'

The second question asked respondents to name different activities that might characterize active learning, and to indicate the extent that students might be active when participating in the activity. About 60 activities, which could be differentiated from each other were named. These activities could be organized into 5 types: (*i*) learning activity in plenary sessions, in auditoriums; (*ii*) learning activity in groups; (*iii*) individual activity; (*iv*) activity related to assessment practices; (*v*) peer tutoring. The use of for example, digital technologies and published (research) articles are embedded within these groups. Some respondents referred to well-defined teaching/learning schemes such as 'Jigsaw', as an approach for managing cooperative learning, eduScrum, as an approach to peer coaching, and Gallery walk, as an approach for managing small group activity. (On-line information for each of these is included at the end of the references).

Different forms of group work were identified as having the potential to promote very active or active learners by 8/12 teachers and 5/9 students. Perhaps unsurprising, standard lectures, without special additions such as audience response systems (e.g. clickers, Kahoot, Socrative) were claimed to result in little, very little or not at all active learning 4/12 teachers and 7/9 students. One teacher respondent claimed lectures to be 'active'. Given the discussion above that 'active' means cognitively or mentally active, the teacher's claim in this response could be reasonable, stimulating students' mental processes is surely a purpose of lectures. However, if as appears, the majority of students do not experience lectures as a forum for 'active' learning, the effectiveness of lectures is open to question.

3.3 Teaching approaches

Question 3 provoked some confusion because the notion of "teaching approaches" was not widely shared, and many responded with further examples of teaching/learning activities that fitted better with the responses to question 2. The following broad approaches to teaching were named: Problem-based learning (7 times), collaborative learning and cooperative learning (1 each), inquiry-based mathematics education (or similar, 7 times), project-based learning (7 times), flipped classroom (2 times). Surprisingly, given the high profile across Europe (e.g. see HEA 2017), "blended learning" did not feature at all.

The question (#4) about classroom organisation did not produce any new information. The responses were useful because they confirmed the evidence from previous questions, the organisation of students into smaller groups supports group work, problem-based and inquiry-based learning. Conversely large classes were seen by many respondents to be less likely to promote active learning.

Question 5 was included to ensure that respondents had the opportunity to add to their earlier responses and perhaps provide us with new lines of inquiry. One issue raised that is consistent with the paper by Bonwell and Eison (1991) is that of time constraints. The preparation for active learning does require more time from the teacher in preparation, and there is the concern that active learning approaches demand more 'curriculum time' and thus puts syllabus coverage at risk. The assessment of active learning outcomes or student performance could also be more time demanding. Questions about factors obstructing the use of active learning approaches may not be compatible with the intentions of the survey, but its inclusion could give some explanation about an informant's responses to other questions.

4 REFLECTIONS

There are several positive outcomes from the first stage of the Delphi study. First is the confirmation of our belief that in the survey instrument we should focus on the activities of teaching and learning that may be arranged or experienced rather than abstract concepts such as “active learning” for which there is no commonly held meaning. However, the number and range of teaching/learning activities that were identified through the study is somewhat surprising, it will take some care to work these into a survey instrument that does not take too long to complete. The development of a definition of active learning is of value to us, first in the next stage of the Delphi study, in which we will ask participants to rate the potential of different teaching/learning actions to promote students’ active learning as described in the definition we provide.

One respondent in the stage one Delphi study reflected on experience with previous surveys of teaching/learning. The respondent was critical of a perceived critical edge or value judgement embedded in the questions. That the promoters of the survey were already convinced that active learning is superior, and that some teaching/learning actions are better at promoting active learning than others. We recognize that we will need to be very careful to avoid a subliminal communication of such a message, which could irritate potential respondents, or bias responses towards a perceived ‘correct’ answer. This is always a challenge in such surveys.

We hope the presentation of the outcomes of the Delphi study, stages 1 and 2 (to be completed) and the discussion following the presentation of this paper at the MNT conference will contribute to the development of a survey instrument that will enjoy the confidence of our Norwegian (and international) HE mathematics community.

5 ACKNOWLEDGMENTS

Thanks to students, mathematics instructors, mathematicians and mathematics education researchers who contributed to the Delphi study, and to Professor Pauline Vos at the University of Agder for explanation about conducting the study. Also, to MatRIC for funding the work.

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Jigsaw. https://www.jigsaw.org/#overview