

A methodology for delivering manufacturing technology and workshop appreciation to undergraduate engineers & technologists

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Abstract

The paper describes an experimental method of delivery using the flipped learning approach in which students were asked to observe three Audio Visual clips in preparation to a scheduled class. The objective was to determine whether, by this approach, an enhanced learning experience could be achieved, compared to the usual form of delivery. The level of student willingness to participate and level of success of this method have been established by means of feedback questionnaires from over 100 participants and peer observation.

1.0 Introduction –background and purpose

Manufacturing technology and workshop appreciation forms a core module for undergraduates in Engineering and Technology studies and is therefore introduced at an early stage of their Higher Education studies. A proportion of undergraduates join degree courses with a good grounding in the practical or vocational aspects of the engineering degree gained through apprenticeships or higher national vocational BTEC qualifications. Engineering degree courses attract students from diverse educational and training backgrounds which can vary from school leavers with GCSE Advanced level subjects, international school leaving certificates/diplomas or baccalaureate to mature apprentice trained or experienced students. The challenge lies in educating such undergraduates in manufacturing technology so that they are able to gain a wide appreciation as pre-requisite knowledge and understanding to deal with practical design problems. This rationale applies to all engineering students no matter what their core engineering discipline (Automotive, Mechanical, Energy, Design etc.), as all have an association with manufactured goods and the processes involved in making them. The subject of manufacturing technology should therefore be taught effectively. It forms an important part of the curriculum and is clearly defined in terms of learning outcomes within the UK-SPEC (ref. 1 <http://www.engc.org.uk/engcdocuments/internet/Website/UK-SPEC%20third%20edition%20%281%29.pdf>).

The UK-SPEC is based on the demonstration of key competences and is the UK Standard for Professional Engineering Competence (UK-SPEC) and describes the competence and commitment requirements that have to be met in order to attain Engineer status at either Technician, Incorporated or Chartered level.

2.0 Structure of delivery of the subject and rationale for changes

Current method of delivery takes the form of a 20 credit foundation level module. Students attend lectures that cover a wide array of manufacturing technology topics and a series of practical day long workshop practice sessions. Some of the lectures are intended to underpin knowledge gained during the workshop practice sessions. Learning from the lectures is structured such that students acquire a broad knowledge of manufacturing by *remembering* (facts, definitions and terminology) *understanding* (differences in processes and their relevance to the manufacture of disparate products or artefacts) and *applying* to design assignments. Understanding and applying are reinforced through the practical sessions which also give students the opportunity to develop their psychomotor skills. This also helps build their confidence in attempting practical hands-on craft type work that they may require in future. The combination of lectures and practical sessions are designed to complement each other. Students enjoy being engaged in the practical sessions as they are learning by doing which forms an important aspect of engineering education. The importance of class based learning can be underestimated by learners. The challenge for the educator is to maintain a high level of interest through various means. When describing manufacturing processes, visual stimulation is important in order assist the learner in the learning process. This can be achieved through use of graphical illustrations and still photographs. Case examples also help. A collection of DVD or short demonstration films also help further understanding. Wider possibilities for such demonstrations are becoming ever more available through the advent of material available in the public domain such as YouTube. Students are often keen to explore such resources outside the timetabled class, particularly with direction and guidance. Such resources (particularly those selected by the tutor for showing during class) are important because upon delivery of a subject through the imparting of knowledge, students are inclined to form a visual perception of a process which can lead to further curiosity of the subject especially if only a partial understanding is formed. Curiosity in a subject after class delivery is regarded as good because it is a positive sign of stimulation for further learning. The audio-visual demonstrations serve to satisfy this curiosity and also clarify any misconceptions that the learner may have had regarding the context in which the process is applied in practice.

3.0 Reinforcing knowledge

Good practice has been established by the presentation of review questions once a subject has been covered, including the demonstration films. Review questions offer multiple choice answers which are directed at students at the will of the educator (learners are therefore aware in advance that they may be individually asked to answer questions). This serves several purposes:

1. Maintain the attention of the learner who may be called upon to answer questions
2. Provide the learners with a flavour of what they can expect in an end of year assessment in the form of a timed examination.

3. Provide an opportunity to emphasise some critical issues of the topic covered with key discussion points.
4. Structure the learning session such that an element of light hearted humour is introduced.

Guessing is discouraged through the request of rationale behind the given answer or through a process of elimination such that the given answer is justified. This also helps build an aspect of analysis when reviewing Bloom's learning outcomes (*ref. 2- Anderson L, Sosniak LA (1994)*). In examinations, incorrect answers receive a negative score therefore discouraging students from guessing their way through questions associated with topics.

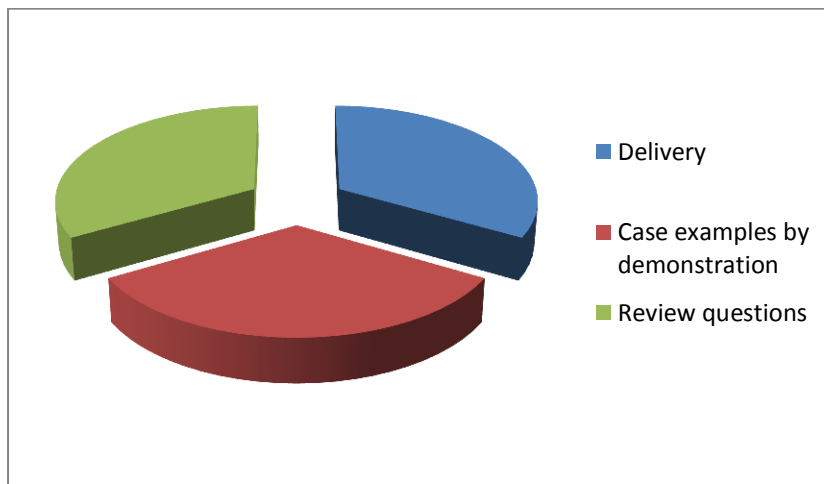


Figure 1 – Example of how a session is currently delivered. There can be a time variation between each of the three aspects (delivery, case examples by demo DVDs and review questions)

4.0 Educational material

The lecture based material provided to students includes a copy of the PowerPoint slides supplemented by an attached script. The learner is encouraged to make further notes around the slides that provide the main visual aid for the subject covered. Such notes along with the provided script allow for a valuable source of information when it comes to revisiting the subject matter later. Students are also encouraged to purchase a recommended text which will serve them beyond the duration of the module. This is also a source of reference for further curiosity and queries of the subject matter.

5.0 Workshop Exposure

The workshop exposure forms the practical aspect of the module where students are given the opportunity to develop their psychomotor skills. It is important in that it provides a fundamental appreciation in working safely and the development of skills required for the operation of machine tools. These will consist of lathes, milling and other machine tools.

Students are made aware during the class based sessions that in the wider world of manufacturing, a plethora of complex machines exists.

During workshop exposure, hand tools will feature as part of the activities for the manufacture of a simple engineering artefact and students will be exposed to the effective use of CNC machine tools and appreciate their application in an industrial environment.

6.0 An experimental delivery method of a flipped learning approach

In this method it is proposed that current delivery be altered to make further use of short demonstrations available within the public domain, particularly on the website YouTube. Such short clips can follow a verbal explanation of a process and accompanied by running commentary by the tutor. The aim is that visual impact short clips will deepen understanding more than a description with simplified diagrams. Simplified diagrams serve the purpose of putting a concept across but can often also cause confusion thus raise questions by the learner.

The principle of restructuring delivery of sessions is easier to achieve with certain topics than others. It also relies on the availability of relevant short clips. Bite sized chunks of videos offered within the YouTube environment implies that several short videos from differing sources can easily be accessed. This has proven to work in the delivery of nursing practice education (*ref. 3 Clifton A, Mann C (2011)*). By similarity, Engineering and Manufacturing education encompass vocational subjects that can benefit in similar ways of delivery for teaching and learning.

An experimental method offers the opportunity to assess the flipped approach. We can then quantify the outcomes by comparison to a usual method of delivery. This may be done by means of questionnaires directed at the students. By firstly selecting just a few (no more than three) video clips, students shall be asked to view these online, prior to the scheduled class. They will also be requested to come to the session with a question based on the viewings. Some of the raised questions may be listed for everyone to see and therefore form focus points to address for discussion. Clarification or explanation of queries may be made on reflection of the delivered session (which will also include short video clips with commentary, explanations and expansion where necessary). *Ref. 4 Godwin (2007)* reports that group discussions stimulated by using YouTube in the classroom environment can lead to deep learning on the subject as well as a critical evaluation in information literacy.

6.0 Timing and evaluation

Delivery of the experimental session took place during the first academic term 2014/2015. Time was allowed to select a suitable subject topic with adequate online resources. Evaluation of the session was by peer observation of teaching. This can therefore be compared to delivery of more usual sessions for the same module. The primary means of feedback was an evaluation questionnaire given to students to complete immediately after

delivery. Feedback was also taken in the form of informal discussion. Students were well placed to express their preference of delivery method as they were able to compare to a more usual delivery style of the same module.

7.0 Educational Framework

An inclination from past experience was a motive for the experimental session (students often comment on technically inspiring things they have observed either on TV or online). Experience indicates that greater learner participation is a recipe for improved learning success. Some prior knowledge, even when limited, can further improve the knowledge acquired during the delivery session, by providing a basic foundation by better utilising the time during the teaching and learning session. This can be further substantiated through an appropriate educational theoretical framework (or frameworks). Theoretical Frameworks are formulated to explain, predict and understand phenomena. They can also be used to challenge and extend existing knowledge, within limits of the bounding assumptions (ref 6, <http://libguides.usc.edu/content.php?pid=83009&sid=618409>).

Lev Vygotsky's Theoretical Framework on Social Learning Theory has been identified (ref 7, <http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm>). Social Learning theories help us to understand how people learn in social contexts (from each other) and how teachers act as facilitators to construct active learning communities. Consequently, teachers can create a learning environment that maximises the learner's ability to interact through discussion (discussion of AV case studies and demonstrations in this case), collaboration (group viewing and creating questions prior to scheduled classes) and feedback (through addressing questions in class as points of discussion thus eliminating incorrect answers by reason – a form of formative feedback). In Vygotsky's framework this is discussion-based learning using Socratic Questioning Methods where the teacher or instructor manages a Socratic dialogue that promotes deeper learning.

Vygotsky also recognized that learning always occurs and cannot be separated from a social context, therefore the essence here is to encourage learners to be inquisitive by identifying processes discussed in class with everyday artefacts. Through deeper understanding the learner can acquire the knowledge to challenge traditional methods of production by proposing alternatives. In Bloom's Taxonomy this is the Application, Analysis and Evaluation stages in the Cognitive Process Dimension (ref. 5, Krathwohl (2002)).

8.0 Prior to delivery

The subject topic for delivery was on materials used for making cutting tools in the manufacture of components ('Cutting Tool Materials'). This was chosen partly due to the availability of AV material on the web. It also forms an important topic within the module that students can find interesting if presented in an appropriate manner. The availability of good quality and interesting material prior to such a flipped learning approach to teaching and learning is important yet not always entirely possible. After some time was spent

exploring the web for suitable material, three links on YouTube were identified. These were as follows:

https://www.youtube.com/watch?v=1K2_zb9kQ-8

This covers six popular Cutting Tool Materials and lasts 7.5 minutes. It offered a short introduction to the subject which would hopefully lead to the desire to view a more thorough and comprehensive viewing of the next recommended viewing.

<https://www.youtube.com/watch?v=GVLp-IXPEt0>

This forms part of an extensive collection of the BBC Technical Studies series. Now available in the public domain, it remains highly educational. The only anticipated drawback with this clip was its duration of 24 minutes, which may exceed the time some students are prepared to dedicate prior to class, despite recommendation by the tutor – this was something else to be established from the experimental session.

<https://www.youtube.com/watch?v=tpXd5Dds27w>

This covers two Super-Hard cutting tool materials and is of short duration of 1.6 minutes.

The students were notified by email, the week prior to delivery, to view the three AV clips. They were also informed during class the week prior to delivery and reminded by a follow-up email the day before delivery.

The total time involved in viewing the three AV links was 33 minutes and it was recommended that they view all three in order that they attend prepared with questions. The aim was that the delivery sessions would develop in to a more interactive session than usual, through pre-prepared questions that would lead to greater open discussion and dialog.

Cutting Tool materials

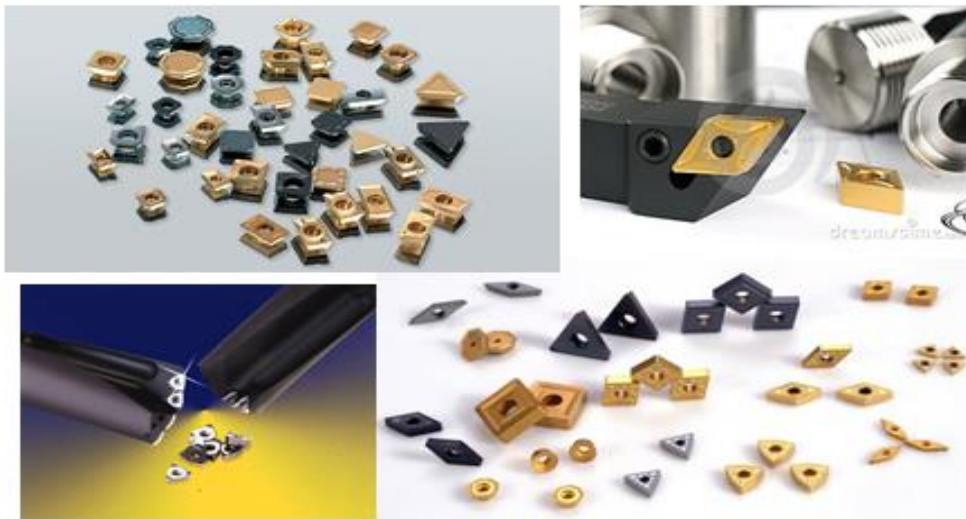


Fig. 2 - The Subject topic (introductory slide) that was covered during the experimental teaching and learning delivered session

8.1 Delivery

Learners were given a copy of the slides to be presented. Additional supplementary notes were added to the Virtual Learning Environment (VLE) prior to the session, enabling student access to detailed information as covered during the lecture. Although the lecture started in the usual manner with an introduction to subject followed by scope of the session, it gradually became increasingly more interactive than usual. This was because, in anticipation of prior knowledge, it was possible to direct questions to the learners which would sometimes go beyond the reciting of basic knowledge but more to establish their understanding. Questions can sometimes be aimed at testing the students' ability to deduce answers through reasoning based on known facts. This would indicate that within the learners' cognitive domain they are acquiring Knowledge, Comprehension and certain Application (see figure 3).

What remained to be determined at the end of the session was whether the learners felt that they had:

1. Gained a greater depth of understanding by prior viewing of the AV material, compared to not having done so.
2. Had enjoyed and benefited from the session through certain prior familiarity with the subject material, than if they hadn't viewed it.
3. Had they enjoyed the increased level of interaction during the session.

The means by which to establish the answers to these questions was by a feedback questionnaire, consisting of 10 questions. A copy of the questionnaire is included in the addendum of this paper and the analysis by students' selected answers to the given questions is also detailed.

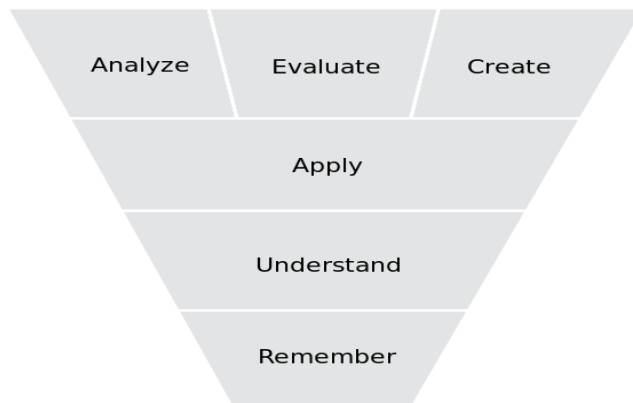


Figure 3 – Categories in the cognitive domain of the revised Bloom's Taxonomy (ref. 6, Anderson 2002).

9.0 Summary of findings, analysis and conclusions from feedback questionnaire

A total of 104 questionnaires were returned by the students that were present in the experimental delivery session. The purpose of the questionnaire was to determine the effectiveness of the flipped learning approach. The first question aimed at establishing the proportion of students that attended and prepared for class by having watched the AV material. Of the sample group 51% had watched all three viewings, 30% had only watched some of the three viewings and 19% hadn't watched any of the viewings (Figure 4, chart 1). Analysis of these results are detailed in the proceeding sections.

9.1 Students who partially viewed the recommended AV material

Reasons why only 30% of the class watched some and not all of the viewings were identified by further questions and explanations on the questionnaire. Of the 30% respondents who admitted watching part of the viewings, almost all (29%) claimed to have watched only the two short AV viewings lasting 7.5 and 1.6 minutes (a total of 9.1 minutes duration). The reasons claimed were:

They were too long and I didn't have time or didn't want to dedicate the time outside lecture time to view all three and/or lost interest.

This was the response of most students who hadn't viewed all of the recommended viewings, despite the longest, of 24 minutes duration, being of most educational value as was indicated to the learners.

One respondent commented that the low audio quality of the longest viewing was the reason for not viewing it and the remainder commented that they were under the impression that they didn't have to view all three viewings. A false claim as they weren't given any indication that this was the case.

Question 3 of the questionnaire was aimed at establishing whether the learners considered prior viewing worthwhile as a learning enhancing experience. 81% claimed it was worthwhile, whilst 19% were unsure. None of the responses claimed an outright 'NO'.

Asked whether more class sessions should be planned like this by taking the approach of recommended prior viewing, this group of 30 (1 didn't respond), 14 said 'YES', 6 said 'NO' and 10 said 'DON'T KNOW' (**figure 4, chart 2**).

Over half of these 30 respondents considered the session to be more interactive, more informative and more interesting than usual, partly due to prior viewing.

9.2 Students who didn't view any of the recommended AV material

Nearly 1 in 5 students or a total of 20 (19%) had not viewed any of the recommended AV viewings prior to the class. Although not entirely surprising, we wanted to identify the reasons through the questionnaire.

The reasons cited for this included:

'I forgot'

'They were too long and I didn't have time or didn't want to dedicate the time outside lecture time'

'Looked at my email too late'

'Were not interested'

'I didn't know about it'

'Didn't think I had to'

'Already knew about the subject matter'

This would indicate that most of these students have an apathetic attitude to learning and their responses relating to their learning experience, in which comment is invited on an enhanced learning experience, is invalid. Their responses were on whole, indifferent and they failed to participate as interactively as other respondents who had prior knowledge. This was clearly indicated in their feedback.

9.3 Students who viewed all of the recommended AV material (figure 4, chart 3)

Over half (51%) of students had viewed all of the recommended AV viewings. This committed them to over 30 minutes of their own time, prior to the class session. Their views and feedback with regard to their learning experience are important as they provide us with greater integrity of the outcome of the experimental delivery method due to this being a better informed sample group than the remainder.

Nearly all the group (52/53 or 98%) had claimed that they benefitted more throughout the session by having viewed the AV material before than if they hadn't. One respondent was unsure. Yet when asked whether more classroom sessions were preferred to be organised and delivered like this, a fewer number (43/53 or 81%) responded positively with a definite yes and 9/53 or 17% were unsure. 2% said no (figure 4, chart 5).

9.4 Comparison with usual method of delivery (figure 4, chart 5)

Of the 53, 83% had agreed that the session was better than usual delivery due to increased interaction between learner and teacher (or amongst peers) and that they considered the session more informative and interesting due to prior viewing. 13% thought it was no different and 4% were indifferent.

9.5 Subject matter and relevance to the course (figure 4, chart 6)

79% considered that it was and 21% were indifferent. None thought it was irrelevant.

9.6 Evaluating participation of learners

32% had participated by either direct interaction with the tutor or a peer during the session (either by expressing an opinion, replying to or responding to a question). This is high considering that the group size was in excess of 100 students and the timetabled session of 1 hour. The remainder 36 (68%) claimed that they just listened. None claimed to have lost interest.

9.7 Should future subjects within the module be delivered like this? (figure 4, chart 7)

74% responded with a positive 'yes', 2% with 'no' and 24% wanted some more sessions like this but not all future sessions. This is conclusive that the learners benefitted from the flipped learning experience.

9.8 Conclusions and Future Work

It would appear that whilst students are prepared to dedicate time for prior learning in preparation for class, this time is limited to less than 10 minutes for a fair proportion (30%) whilst 19% are unwilling for various reasons, including apathy and time constraint. Even of the 30% of students that had prepared with up to 10 minutes of viewing, over 80% considered this to be a learning enhancing experience. 98% of these students thought that future topics within the same module ought to be delivered in a similar manner due to the learning benefits.

A small minority of the group (less than 20%) have an apathetic attitude to learning in that that they were merely prepared to attend timetabled sessions and be informed without a will to participate in an interactive manner or even to undertake some prior preparation. The experimental delivery has been worthwhile in verifying an enhanced learning experience for learners. More sessions should be organised and delivered in this manner though not all. This should be down to the discretion of the educator and be based on subject and topic. It also depends on availability and quality of material. The group size in this case was large enough to limit the number of learners that interacted in class. It is anticipated that delivery to smaller groups would results in greater engagement by in-class participation. In order to further this work, a similar experimental delivery is proposed within another School for a science based subject. A similar questionnaire will be issued in order to compare results across both subject groups.

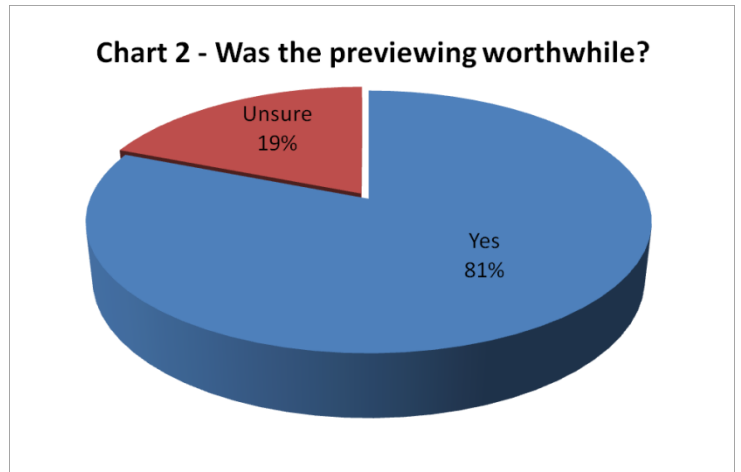
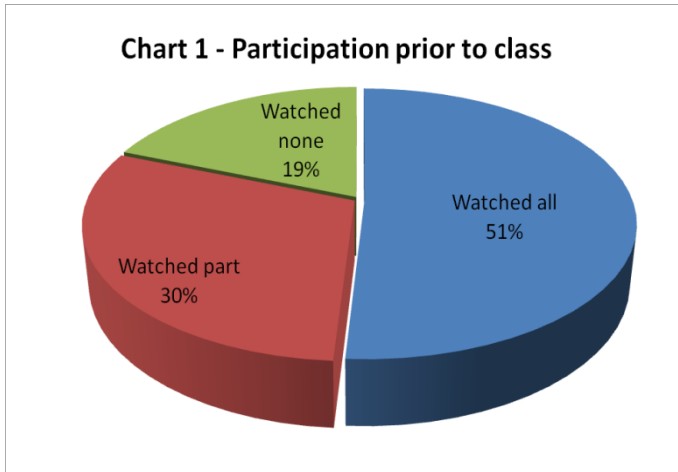


Figure 4 – Charts 1 and 2 indicating level of participation and value placed in doing so.

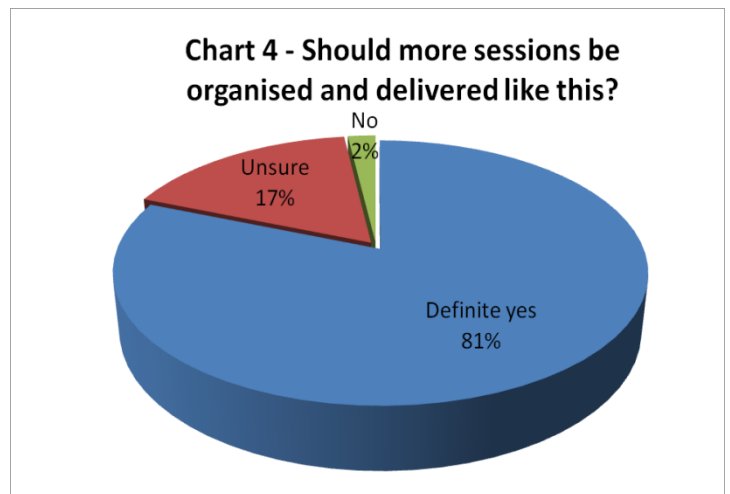
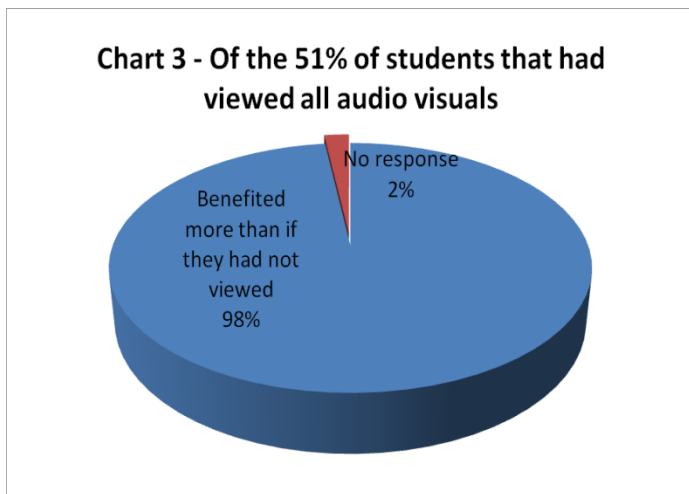


Figure 4 – Charts 3 and 4, referring to perceived benefit in viewing all AV and whether more sessions should be like this.

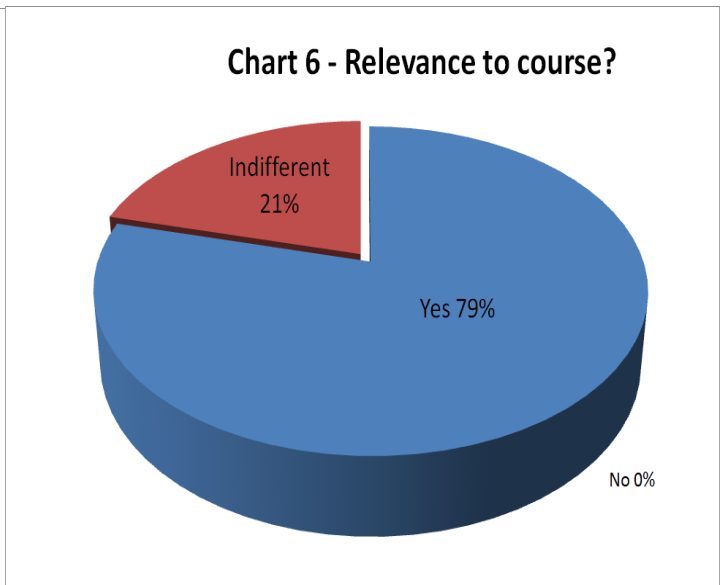
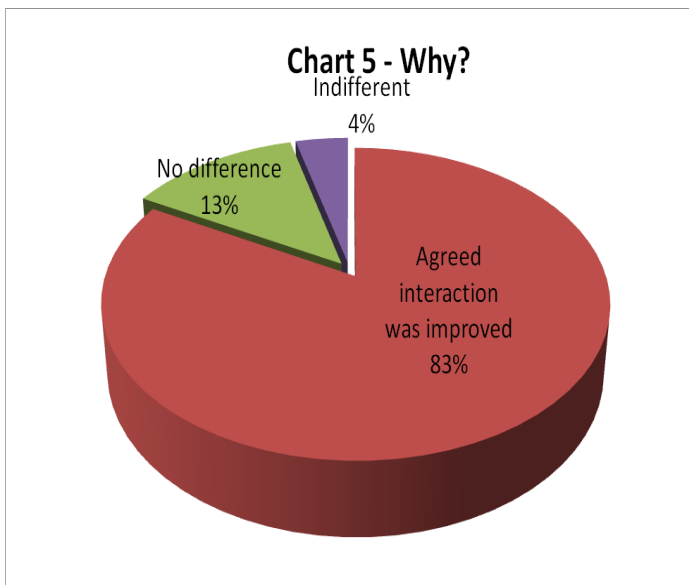


Figure 4 – Charts 5 and 6 referring to justification for method of delivery and relevance to course.

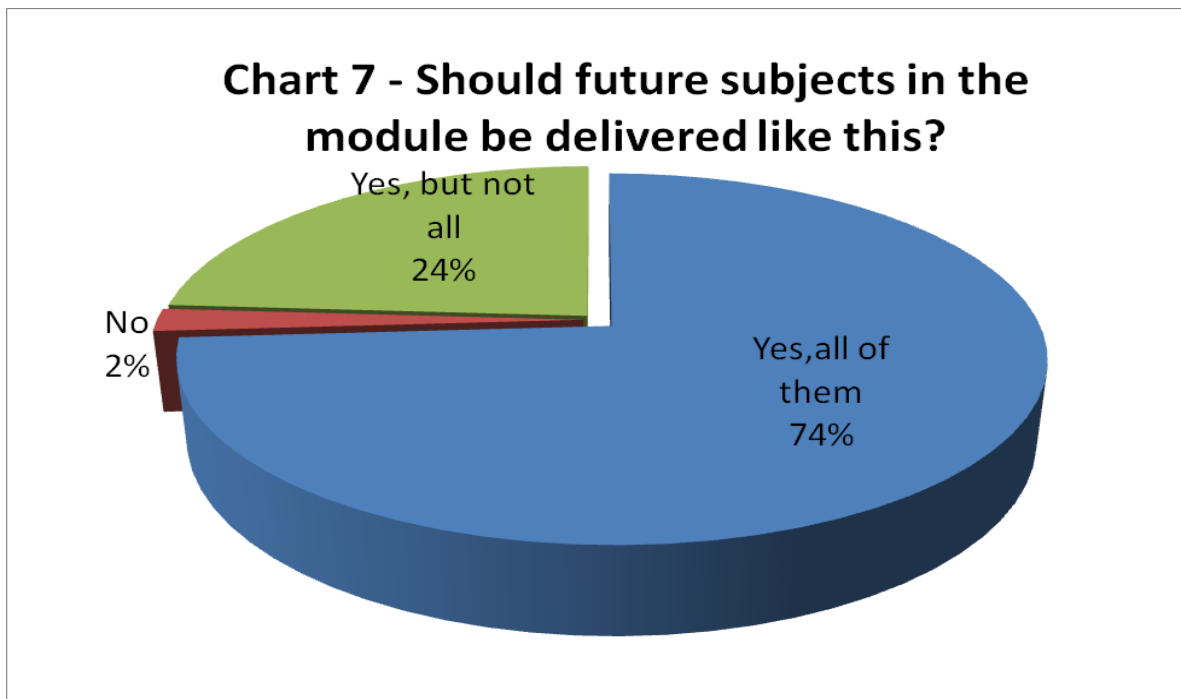


Figure 4 – Chart 7, referring to response as to whether future subjects should be delivered like this.

Figure 4 – Summary charts of findings

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5. David R. Krathwohl (2002) A Revision of Bloom's Taxonomy: An Overview, Theory Into Practice, 41:4, pp212-218, DOI: [10.1207/s15430421tip4104_2](https://doi.org/10.1207/s15430421tip4104_2)
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Educational Frameworks:

7. <http://libguides.usc.edu/content.php?pid=83009&sid=618409>
8. <http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm>

This is a summary of Vgotsky's emphasis on the social dimension of learning

Addendum

Copy of Questionnaire

Following delivery of the session, please answer the following questions:

1. You were asked to watch three AV clips on YouTube prior to the scheduled class. Three clips were given of duration 7.5 mins, 24 mins and 1.6 mins

Which of the following best fits what you did? Tick all that apply

- Yes I watched all three fully
- No I didn't watch any of them
- I only watched some of them, partly or fully
- I only watch the short ones (7.5 & 1.6 mins)
- I watched part of the longest one

2. If you didn't watch all three clips, what was your reason?

- No interest
- They were too long and I didn't have time or didn't want to dedicate the time outside lecture time
- I didn't think I needed to watch all three as watching was recommended and not essential
- Other (Please state).....

3. If you watched any, did you think it was worthwhile watching the recommended viewings prior to class?

- Yes
- No
- Not applicable as I didn't watch
- Not sure

4. Do you think you benefitted more during the timetabled lecture session by viewing the AV material, more than if you hadn't?

- Yes
- No
- Not applicable as I didn't watch
- Don't know

5. Do you think more classroom sessions should be organised and delivered like this?

- Yes
- No
- Don't know

6. How do you rate delivery of the session in comparison to usual sessions?

- Better than usual sessions in that it was more interactive
- I found it more informative and interesting than usual sessions, partly due to prior viewing
- It was no different to usual sessions
- Not sure/indifferent

7. I liked the subject matter, in that I found it interesting and relevant to the module and course

- True
- False
- Indifferent

8. Did you participate in the discussion in any way?

- Yes, by asking the tutor a question, or a peer/fellow student

No, I just listened

No, I lost interest

9. Would you like more sessions in this module (lectures only) to be conducted in the same way (by prior viewing or demonstrations)?

Yes

No

Some but not all

Add your comment here (optional).....

10. If you answered No in the last question, what is your reason?

Disliked having to prepare before class

Would rather be given all the information during class, including AV demonstrations

Other, please specify

Add your own comments here if you wish

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Links to bibliographical websites

<http://users.ipfw.edu/sternber/339/framework.html>

On Theoretical Frameworks

<http://www.trentu.ca/history/workbook/theoreticalframeworks.php>

Online History Workbook on Theoretical Frameworks

http://en.wikipedia.org/wiki/Bloom%27s_taxonomy

On Bloom's Taxonomy

http://books.google.co.uk/books?id=JC1tIpDBt_IC&pg=PT223&lpg=PT223&dq=finding+theoretical+framework+in+pedagogical+research&source=bl&ots=uHKQMd1ThN&sig=KC9M2_vuohGsh4pdKaeSWxgz9C4&hl=en&sa=X&ei=JnHXU4S1B8mw7AavkIBo&ved=0CD0Q6AEwAzgK#v=onepage&q=finding%20theoretical%20framework%20in%20pedagogical%20research&f=false (p.191)

Extracts from Anfara VA and Mrrtz NT on Theoretical Frameworks in Qualitative Research

Other:

<http://transformativelearningtheory.com/corePrinciples.html>

Transformative learning theory explores the kinds of learning that make us re-assess our way of looking at the world, ourselves, or knowledge.

<http://www.muskingum.edu/~psych/psycweb/history/vygotsky.htm>

This focuses a bit more on Vgotsky's description of the 'zone of proximal development' – something that might be useful if you were concerned about differentiation – enabling students of different abilities to make progress.

<http://wenger-trayner.com/theory/>

Discussions about 'communities of practice' can be very helpful if you are developing professionals or supporting people through work based learning.

http://www.ucdoer.ie/index.php/Education_Theory/Constructivism_and_Social_Constructivism_in_the_Classroom

Helpful if you are thinking about getting students to recognise that they have to create, not absorb knowledge.

http://www.infed.org/biblio/eisner_arts_and_the_practice_of_education.htm

Eisner argues that teaching is an art, not a science, and draws many techniques from the world of the artist.

<http://infed.org/mobi/donald-schon-learning-reflection-change/>

Schon's work on the reflective practitioner has influenced teaching and learning across a wide range of professions.