Scholarship of Teaching and Learning: Incorporating Active Learning Methods into Physics Courses

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Abstract

This paper details the results of a small study researching the effectiveness of interactive teaching methods in a high level university physics course. The test subjects consisted of a group of 11 students, who were enrolled on a course at the PhD / Masters level. The course lasted over the period of 1 semester and included both non-interactive and interactive based teaching methods. The study introduced a new element to the course in the form of a 1 week interactive workshop whereby the students worked in small groups analyzing computer based datasets. In previous years this had been taught using non-interactive based methods through a series of lectures and reading assignments. The aim of the seminars was to enable students to bridge the gap between knowing the mathematical equations and concepts taught in the course to applying that knowledge to explain trends in actual data. The findings of the study indicate that the students felt the new interactive methods improved their understanding of how to utilize their knowledge of physics when interpreting and understanding data. They felt they also gained an insight into the methodology utilized by scientists when interpreting data. The study also indicated a higher level of enthusiasm and interest in the students. The result of this study shows the benefits of utilizing interactive teaching methods when introducing students to working with data even at this higher level of study (PhD and Masters).

1. Introduction

Teaching methods at Universities have followed a certain structure for several decades. The largest portion of teaching has traditionally involved the students attending a series of lectures on the various elements of the course which are supplemented by suggested reading material. This reading is to be conducted in the students own free time. In the last 20 years however, newer methodology has been introduced which is steering away from the traditional lecturing based (non-interactive) methods and adopting more interactive based methods. This includes having small tutorial groups with question and answer sessions as well as small group assignments. In recent years, partly due to better access to new technologies (such as computers) and the availability of interactive media on the internet this trend has increased still further. This interactive based methodology falls under the umbrella of 'active learning' and is generally accepted to include any methods whereby the student is actively engaged in the learning process and activities within the classroom. This is in contrast to the traditional based lecturing technique, whereby the students passively receive information.

It has been documented through several previous studies (see Meltzer and Thornton 2011) that while students can often quote mathematical equations and recognize simple trends in data they often struggle to connect the two elements together. Making this link is essential when teaching subjects such as physics, where the language is that of mathematics. As a simple example, students can be given an equation which describes the specific

heat capacity of certain materials but then struggle to relate that to data showing the dissimilar temperature increase in a block of iron and a block of wood being heated by the same source.

This problem has been shown to extend to higher levels of the education system. In a publication by Redish and Steinberg (1999) they note that 'we have heard numerous (but anecdotal) complaints from advisors of physics Ph.D. students who approach their research by "turning the crank" without thinking about the physics'. They developed the Maryland Physics Expectations (MPEX) survey, which expanded on a previous study by Hammer (1984). The MPEX survey looked at how students utilize their physics knowledge when presented with a complex problem. 1500 students from large calculus-based physics classes across 6 universities were asked to agree or disagree with a set of 34 statements. The statements were designed to test the student beliefs along six different dimensions: independence, coherence, concepts, reality link, maths link and effort. The elements are described as 'cognitive attitudes' or 'student expectations'. The same statements were then shown to a group of expert physics instructors who were asked to choose the answers they would like the students to give. When the student opinion agreed with the expert the outcome was described as favourable and when it disagreed it was described as unfavourable. The favourable and unfavourable outcomes for each dimension are shown below in table 1.

	Favourable	**Unfavourable**
Independence	Learns independently, believes in their own need to evaluate and understand	Takes what is given by authorities (teacher, text) without evaluation
Coherence	Believes physics needs to be considered as a connected, consistent framework	Believes physics can be treated as separate facts or 'pieces'
Concept	Stresses understanding of the underlying ideas and concepts	Focuses on memorizing and using formulas
Reality link	Believes ideas learned in physics are useful in a wide variety of real-world contexts	Believes ideas learned in physics are unrelated to experiences outside the classroom
Math link	Considers mathematics as a convenient way of representing physical phenomena	Views the physics and the math as independent with no strong relationship between them
Effort	Makes the effort to use information available to them to modify and correct their thinking	Does not use available information about their own thinking effectively

Table 1 (taken from Redish and Steinberg): Student attitudes can be at either extreme or somewhere in between.

As shown in table 1, the favourable outcomes clearly relate to students who have achieved a deeper level of understanding in comparison to those who give unfavourable outcomes. This deeper level of understanding is the level a Masters/PhD student should demonstrate.

2. Interactive Seminar Design

The study undertaken introduced a new element to the course in the form of a 1 week interactive workshop whereby the students worked in small groups analyzing computer based datasets. In previous years this had been taught using non-interactive based methods through a series of lectures and reading assignments. It was decided to re-design this part of the course and take a more cognitive approach. This was in part due to experience from previous years where, later in the course, it was obvious that several students were struggling with the data interpretation when under taking the fieldwork section of the course. The fact that the students were already at the Masters / PhD level meant that their level of background knowledge of the subject was high. These two facts meant that the focus of the seminars was not to teach the students about the physics itself but rather how to apply their physics knowledge when interpreting trends in data as well as working with large datasets. The course was designed utilizing Blooms Taxonomy (Bloom et al. 1956), namely to split the components up into the various levels of understanding (knowledge, understand, apply, analyze, evaluate, create). Once these separate elements were identified and applied to the course it was decided to utilize several aspects of active learning, as have been defined by several previous publications (e.g. Felder et al. 1994), specifically:

a. Co-operative groups in class

b. Working through specific case studies

c. Utilizing hands-on technology

d. Providing information through small interactive lectures

e. Encouraging inquiry learning between the groups

These key elements (a – e) then formed the basis of the seminars and these were tailored such as to enable the students to bridge the gaps between the unfavourable and favourable outcomes shown in table 1. The goals identified were:

1. to enable the students to become comfortable with working with and combining large multi-instrument datasets (coherence, reality)

2. to show them how scientific research works ie. the data is subject to scientific interpretation and sometime there is no definite 'correct' answer, merely a scientifically valid hypothesis (independence, concept)

3. To give the students chance to see how the mathematical side of the course provides the underpinning for interpreting the data (mathematic, concept)

4. To inject enthusiasm into the students for the subject (effort)

3. Student Background

The students attending the course were from a variety of European educational institutions and a variety of social backgrounds and cultures. All students attending the course had to be enrolled as a Master or PhD student in a relevant course at their home University and have obtained 60 ECTS (European Credit Transfer and Accumulation System) credits within the field of geophysics. The ECTS system provides a common measuring system by which courses and grading scales can be evaluated across European educational institutions. The course was taught in English. 36% of the class had English as a second language whilst and 64% had it as their mother tongue. At the time of the interactive workshop the students had been at the University for 5 weeks with a total of ~60 hours of classroom time and ~20 hours of fieldwork time, (when incorporating all of their enrolled physics courses).

4. Introduced Active Learning

The academic level of the course utilized in the study was that of a PhD/ Masters student level and accounted for 15 ECTS credits. The course lasted for 1 semester. The focus of the course was upper atmospheric physics and the use of radar systems to investigate the fundamental physical processes inherent in that environment. During the course the students are taught fundamental plasma physics, electromagnetic theory (including derivations) and signal processing techniques. These can then be utilized to describe processes such as energy transfer occurring in the upper atmosphere and how these are observed using radar systems. The course also involved a field work session utilizing a high power radar system. This fieldwork was conducted after the new interactive sessions.

The 1 week session took place in a computer lab. 8 hours of scheduled time was allotted, during which time the teachers took on a dual role of both lecturer and facilitator. Instructions in the form of small interactive lectures were given and examples were provided for the students to work through and the teachers were available in the lab the entire time. The rest of the session consisted of the student working unsupervised but with two lecturers on hand should the students need assistance. Each student had his / her own computer which to work from.

The initial session focused on providing the students with the knowledge of how to use the online databases. This involved the lecturers working through the steps on a computer, set up to an overhead projector and the students following the steps at their own computer terminals. Whilst one lecturer worked on the computer the other monitored the class, providing help where needed. Once the students understood the basic principles of how to download data, utilize the software and plot out the data then the following sessions focused on getting the students familiar with working with different datasets, This included downloading and analyzing data from multiple sources and instruments, plotting and a manipulating the data and finally interpreting the data. The instruments included radars, magnetic field monitoring stations and satellites. After these initial sessions, a series of smaller (~20 - 40 min) sessions where the students worked through some simple examples of data interpretation (ie. how to recognize an increase in atmospheric density) as well as being given time to become familiar with the data and to investigate different data sources. Some of these smaller sessions included a small

amount of lecturing interspersed with practical computer time. A total of 6 simple examples had been prepared by the lecturers and in the end only 4 were utilized. The reasons behind this will be discussed later in the paper

After this the students were split up into groups of their choosing (the size was dictated by the lecturer to be between 3 – 4 people). Each group was given a date and time and told to download and analyse whatever datasets they deemed appropriate to investigate changes that occurred in the upper atmosphere during this time. Each group then gave a short [~20 min) group presentation whereby they presented and described the data before summarizing as to what type of physical process were evident and (if possible) the underlying cause for each. The dates in question were chosen by the lecturers as they contained examples of specific physical processes occurring and had been published in scientific papers in international, peer reviewed journals. After each presentation the lecturers discussed the findings with the class and then (if needed) explained what the data was actually showing.

In addition, the seminars were constructed in a relaxed manner with the students dictating the pace of the lessons to some extent (i.e. if a group found some additional data, in addition to that suggested, this was then made into a class discussion about how and why the data is useful). Breaks of 15 minutes where scheduled during the initial sessions every 45 minutes, however several of the student groups worked through one or two of these break since they were involved in a particular analysis procedure and wanted to wait for the results.

5. Testing the Student Response

Each student was given a confidential questionnaire which was estimated to take ~20 minutes to complete. They were given 5 weeks over which to complete the questionnaire after they had finished the 1 week of interactive learning (although most of them handed it in within a few days). The only personal data taken were gender and age. The questionnaire consisted of 2 questions designed to briefly test the student knowledge on the subject of the seminars, 8 non directed questions and 12 directed questions. There was an opportunity to add comments at the end of each question. This method allowed the basic statistics of the study to be easily quantified whilst allowing student opinions to be taken. There was also some overlap between the questions to investigate if the students gave coherent answers throughout their questionnaire or whether they contradicted themselves. Out of 11 students given the questionnaire, 8 completed it. The questions from the questionnaire are shown in appendix A.

6. Results

Out of the students who completed the questionnaire 4 were female and 4 were male. They were all aged under 25.

6.1 Non-directed Questions

The first question (2.1) was designed to briefly test if the individual student had been paying attention and not just relied on being carried by others. Whilst this was an unlikely scenario, given that each student had their

own computer to work from and the class size was small, this question was included as to investigate this in the study. The students were asked to indicate what the data sources were and how they were to gain access to them. They were also asked to summarize the scientific event they were given as part of the group presentation. All 8 of the student were able to list some of the data sources they had used and describe some of the procedures used. Only 3 of the students summarized the scientific event they had studied. However, all 3 students who did answer the question demonstrated a level of deeper understanding through being able to apply scientific reasoning to the trends observed in the data. Since all the students participated in the group presentations at the end of the seminars it is unclear why only 3 students managed to summarize the scientific event. There was no testing undertaken during the presentations to accurately ascertain the level of learning attained individually by each student. During the presentations, the students all managed to produce the required data plots and discuss what each was showing. All provided theories regarding what processes they thought the data was indicating and related this to the underlying concepts taught during the rest of the course. They also managed to combine the datasets well to provide added evidence with which to base their scientific conclusions. However, given that this was the first time the students had worked with these data, they struggled to fully identify the overall underlying causes. After each presentation the lecturers discussed the case study with the students. After this, with some guidance, the students then reached the full scientific conclusion for their case study. The fact that the students needed this additional guidance is not unexpected, given their lack of experience of data analysis. What is important is that during the exercise as a whole they demonstrated characteristics that would all be described as favourable in table 1.

The result of the questionnaire (in that only 3 students chose to answer question 2.1b) could be compared to that of Redish et al. (1997) where they noted that although student understanding was significantly increased using active learning techniques where the students were tested using multiple choice questions, the same large increase was not observed when utilizing free response questions. It could also be, however, that the students did not want to answer long academic questions that were not part of the course examination.

The results of the remaining 7 non directed questions are now discussed. All the students stated that having access to a computer greatly helped with their understanding of the subject matter (question 2.2). This method of using a combination of hands-on technology and interactive lecturing worked well as it allowed the students to utilize the skills and techniques in real time. The students indicated that the relaxed atmosphere of the seminars made them more comfortable with respect to asking questions as they did not feel they were disrupting the lesson (questions 2.3 and 2.4). Whilst this is not surprising in itself several of the students also indicated that the format of the seminar encouraged them to engage more with their peers through discussions focused towards solving the questions posed. In several instances the students themselves answered each other's questions, promoting greater engagement of the students with the subject (question 2.6). Whilst this behavior was encouraged the lecturers also had to monitor the groups, to ensure the peer to peer teaching was correct. Such issues have previously been identified when the teacher takes on the role of the facilitator as opposed to a lecturer.

As mentioned in section 4, although 6 examples were provided for the students to work through, only 4 were utilized. This was due to the fact that the students wanted to discuss the data in more detail and come up with their own suggestions for data analysis techniques. This in turn promoted further discussions. Since the purpose of the class was to get the students interested in the data itself and how, as scientists, analysis and

interpretation of datasets forms the backbone to any scientific publication, this behavior was encouraged. In some occasions the students were placed into a realist scenario faced by a researcher in the field (such as a data file is missing from an instrument or data errors). Such cases allowed the lecturers to highlight the fact that caution must be applied when working with real datasets and, as a scientist, it is important to be able to recognize such issues. In such a cases, the students were again encouraged to discuss if there could be a way around this such as data availability from another instrument or how to recognize data errors. The students began to use free-thinking techniques in that they were posing questions and then using their own knowledge and reasoning to answer them. One result of this (which can occur when teaching students at a PhD / Masters level) is that there is sometimes no definite answer, merely scientific interpretation of the available data. In such occasions the students were encouraged to evaluate the available data, utilizing their knowledge of underlying physics concepts, to investigate whether they agreed with the interpretation. Such exercises again, promoted more favourable attitudes, as defined in table 1.

The students all indicated that they preferred the fact that the seminars were assigned an organized time period within their course timetable, rather than if they were free to work on the assignments when they chose (question 2.7). Several stated that although they enjoyed working independently in small groups they still wanted the lecturers present to provide guidance and to answer questions.

The fact that all students had access to their own computer allowed each student to work at his or her own pace. The databases the students were using were all available online. Whilst the URLs to all the websites were given, several of the students showed initiative and used search engines to investigate data sources outside the ones suggested by the lecturers. Not only did this encourage free thinking from those students but it also allowed them to increase their in depth knowledge of the subject by then explaining it to other students. An interesting comment made by one of the students was that even though they also had access to facebook, news sites etc. they remained focused on the tasks given to them. This demonstrates a clear willingness to learn but also an enthusiasm for the subject.

All the students indicated that for this type of activity (applying the mathematical equations to data interpretation) the seminars were are far better method of teaching than traditional lectures (question 2.8). They also stated that traditional lectures were still the best method with regards to teaching of the background theory and the mathematical side of the course. They all indicated that the seminars brought their understanding of the subject to a deeper level.

6.2 Directed Questions

In question 2.9, the students were given a set of statements (a –k) and asked to state whether they agreed or disagreed (and how strongly) with that statement. The results are shown in figures 1 – 4. In each figure, the different statements are colour coded and marked in the plot label. The results have been combined together under the following topics: Knowledge skills, learning environment, group dynamics and learning outcomes. In all figures the x axis represents the 5 scores the students had to rate each statement, with a score of 1 indicating they strongly agree with the statement, and 5 indicating they strongly disagree with the statement. The

cumulative total for each question is shown on the y-axis. For example, figure 1 shows that 5 students strongly agreed with statement (a), 5 students with statement (b) and 2 students with statement (c).

6.2.1 Knowledge Skills

These skills would fall primarily under the categories of coherence and reality in table 1. The students were asked to what extent they thought they had improved their understanding of the 4 main academic aspects of the seminars. These different aspects are:

- (a) I have a better understanding of working with online databases
- (b) I have a better understanding of identifying trends in data
- (c) I have a better understanding of combining multi-instrument datasets
- (i) I have the ability to provide a basic overview of the seminar focus to a peer

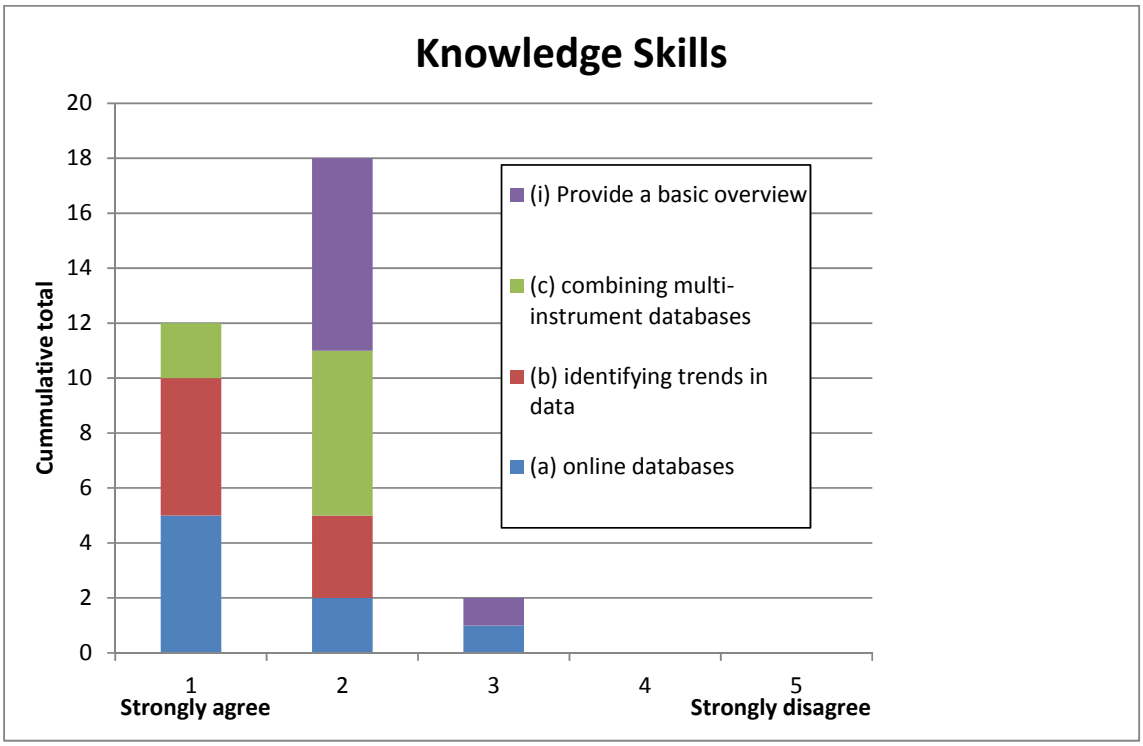

Figure 1: Student evaluation of improvement in knowledge skills

The students all indicated that their knowledge skills had been improved through the seminars. The main point this is reflected in is that the 7 out of the 8 students felt they could provide a basic overview to a fellow student regarding the work undertaken in a seminar. For a student to feel comfortable teaching another student shows that they have achieved a deeper level of understanding of the topic.

6.2.2 Group Dynamics

This part of the questionnaire was designed to see how the interaction between the group members may have played a role in the amount of learning achieved. The students were given 3 statements related to this:

- (f) Working within a group increased the amount of learning
- (h) Knowing people in the group beforehand helped the learning process
- (g) Everyone within the group contributed adequately

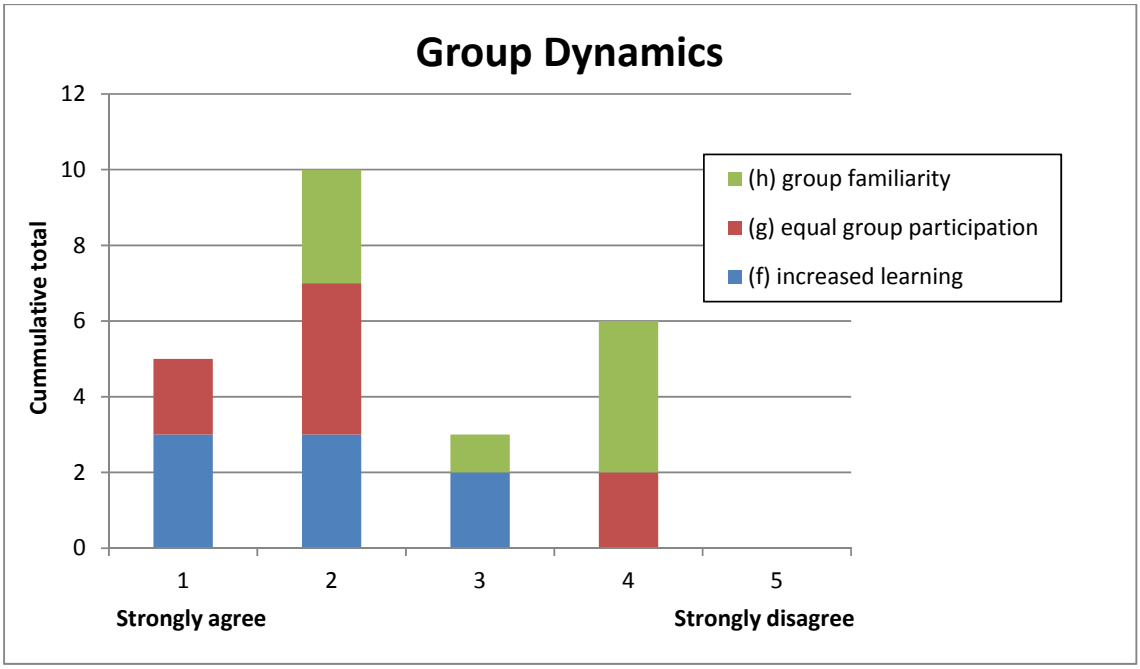

Figure 2: Student evaluation of group dynamics

The results are shown in figure 2. In a separate question (question 2.9e) the students indicated that they felt the size of the group was ok. The students decided whom they would work with during the seminars. As expected, friends decided to work together. However, this was such a small group that everyone knew everyone else in the class and most of them also socialized together outside of class. The 'group familiarity' question asked whether they felt the fact they already knew their group members influenced how they participated within the group. Interestingly, on average, they indicated that this did not influence how they interacted (with an average score of 3 indicating they neither agreed nor disagreed with statement 2.9h). They all felt that the amount they learnt during the seminars was enhanced by the fact they worked as a group. Several students noted that they found it easier sometimes to explain things to each other rather than listening to a lecturer do it as 'sometimes lecturers can use technical language that is confusing'. These results are similar to those of Johnson et al. 1998 who showed that collaborative learning have been shown to improve learning outcomes in comparison to individual work in previous studies also (e.g. Johnson et al. 1998). Throughout the week a higher level of enthusiasm for the subject (in comparison to previous student groups) was also noticed by the lecturers during the seminars.

6.2.3 Learning Environment

This part of the questionnaire was designed to ascertain how the learning environment itself affected the learning process. The students were given three statements related to this:

- (d) the presentation required allowed me to focus on the tasks
- (j) the learning environment allowed me to ask more questions
- (k) working in a group made me more enthusiastic than if I'd have worked alone

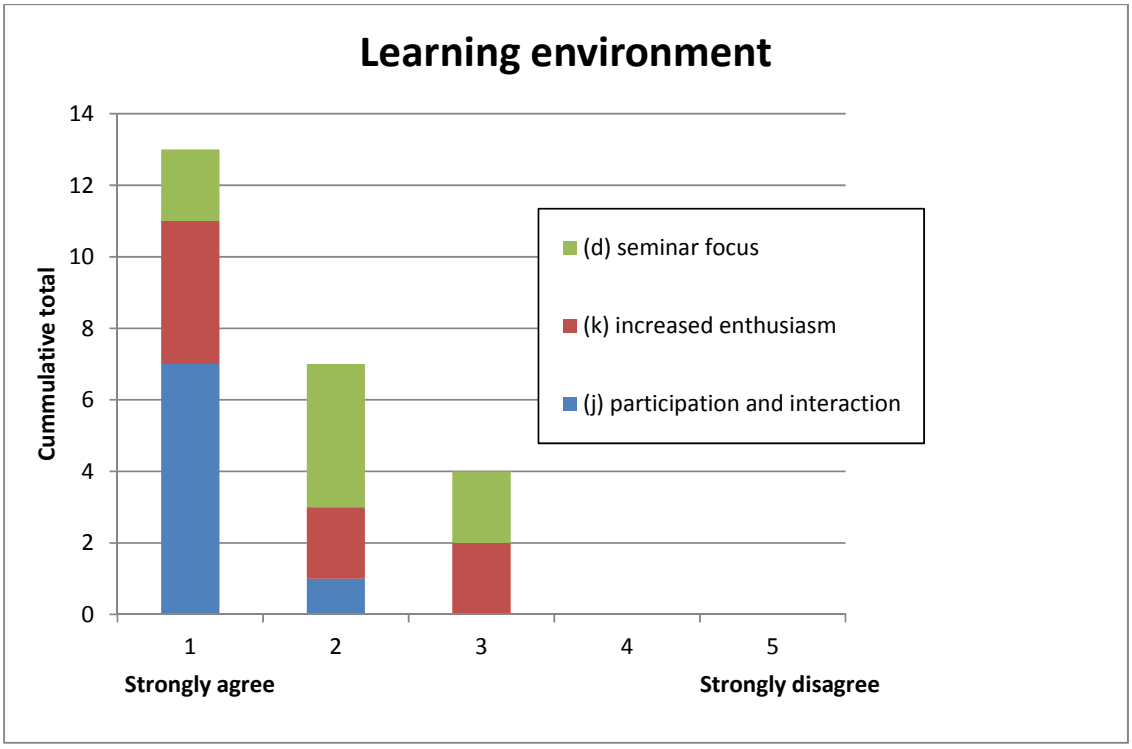

Figure 3: Student evaluation of the learning environment

6 of the students agreed that the learning environment increased their enthusiasm for the topics as opposed to if they had worked alone. The main outcome here is that the students felt that by being able to discuss the tasks informally between themselves they were inclined to participate more than if the subject matter had been taught using standard lectures. This would be either through asking questions to the lecturer or participating more in group discussions. Several students also indicated that the fact that they were not interrupting a lecture played a major part in their decision to ask questions (question 2.4).

6.2.4 Learning Outcomes

In question 2.5, the students were given 6 learning outcomes and a free choice statement which they had to rank in terms of importance (from 1 – 7) with regards to what they thought felt they gained from the seminars. In each case a score of 7 was awarded to the aspect they felt was the most important and a score of 1 to the least important. The learning outcomes were:

a. Improved presentation skills

b. Improved understanding data availability

c. Improved understanding as to the limitations in data

d. Improved understanding of how data is utilized in scientific research

e. Improved understanding of how to interpret data

f. Increased enthusiasm for the subject

g. Other

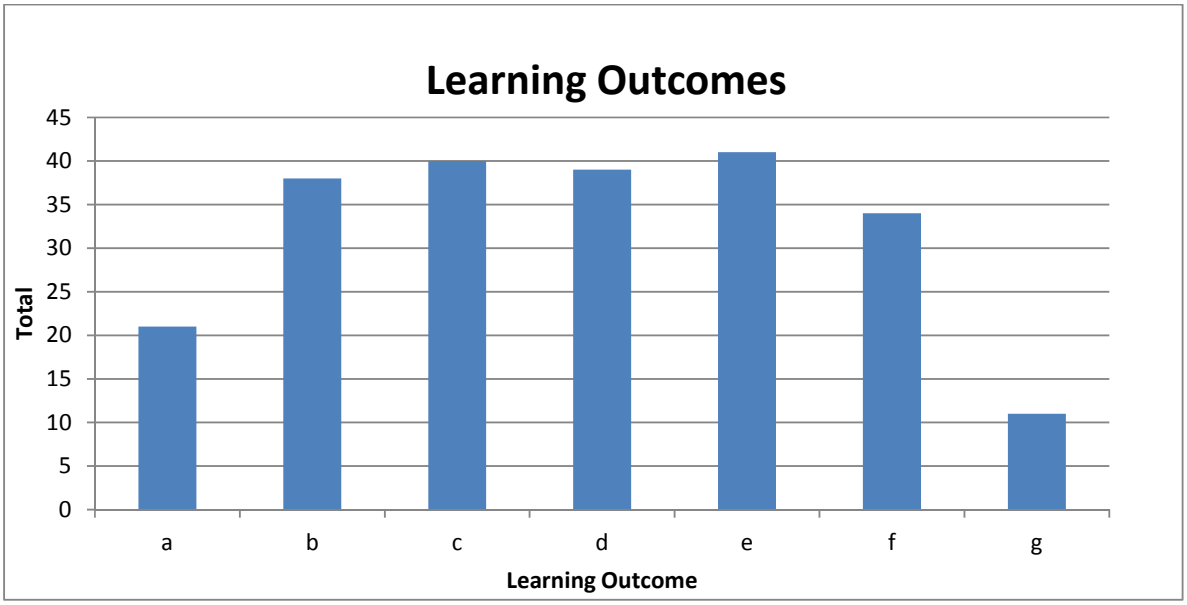

Figure 4: most important learning outcomes. The students were asked to rank 7 learning outcomes which best identified what they felt they gained from the seminars.

If all the students had rated a single statement the most important then this statement would have a maximum score of 56. In the case of statement (g) (which the students were free to list an outcome they felt was not included on the list) 1 students indicated that teamwork was the 4th most important learning outcome (thus assigning it a score of 4). The remaining 7 students assigned statement (g)with a score of 1 and out of this only 2 provided a statement as to what they assigned to this ('team work' and 'was already super enthusiastic'). All students stated that the seminars had not particularly improved their presentation skills (awarding only 21 points out of a possible 56). This is not surprising since the focus of the seminars was not presentation skills. The presentation itself was utilized to provide the students with a focus point, ie. describe what data sources were used, what the trends the data were showing and how this can be interpreted using physical concept. The students felt they achieved all the learning outcomes, (b)-(f). The top 4 outcomes (b – e) were all ranked within 4 points of each other. Looking at these results shows that, as far as the students were concerned, the seminars

achieved the goals (1-4) outlined in section 2. The lecturers also noted that as the seminars progressed the students began to delve further into the datasets. They often used their own initiative to investigate alternative datasets which they felt could answer their own questions. In some cases, as highlighted in learning outcome (c) and has been previously discussed, the data could not provide an absolute answer. Such cases enabled the students to extend their knowledge to real life situations introducing then to the fact that data cannot always provide an answer.

7. Conclusions

The main aim of the introduction of the new interactive seminars into the course was to enable the students to bridge the gap between the favourable and unfavourable outcomes as defined in table 1. The students in the study had a high level of physics knowledge but had very little experience of applying this knowledge to data interpretation. By providing some basic examples of data interpretation, in combination with access to online databases and data analysis tools the seminars allowed the students to bridge this gap. The groups were provided with a date and told to investigate atmospheric changes that occurred on that date using whatever data they felt was appropriate. The results from the student questionnaire, completed after the seminars, indicate that the new methods did fulfil their aims in bridging this gap. They felt their level of understanding regarding a number of aspects was improved and also that the environment itself played a part in that. The learning environment was specifically mentioned by several of the students in the fact that the relaxed atmosphere made them able to interact with both their peers and the lecturers more.

It is difficult to ascertain exactly how effective, in academic terms, the new interactive seminars are due to a number of reasons. Firstly, the sample size is very small. Secondly the students had no experience of how the same part of the course would be taught using traditional non-interactive methods. This means that there is no absolute baseline with which to compare the results to.

In conclusion, whilst interactive methods should certainly be incorporated more into physics teaching, the methods utilized here will only work if the students already have achieved a high level of physics knowledge in the subject area. In the study here, the students are all at the PhD / Masters level and therefore have the knowledge, they just lack experience in applying this knowledge to scientific data analysis.

The higher levels of enthusiasm noted was a positive outcome from the introduced methods at it hopefully provided incentive for the Master students to continue on to a PhD level and for the PhD students to be enthused as to new methods and datasets to utilize in their studies. As such, the new interactive seminars will form part of next years course syllabus.

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Appendix A - Questionnaire Regarding Active Learning Seminars

This questionnaire is designed to get feedback for the seminar part of the course conducted in week 9 of the course in the computer lab. This questionnaire will form the basis of a pedagogic publication regarding teaching methods at Universities. It is not designed to test your abilities in anyway.

The questionnaire is completely anonymous. Please feel free to leave as many comments as you like.

Section 1: Personal Information

1.1 Gender ☐ Male ☐ Female

1.2 Age ☐ <25 ☐ 26 – 30 ☐ 31 – 35

Section 2: Questions

2.1 In a few sentences describe:

a) the process that you go through to get hold of data (ie. what websites you would use, what type of things were available).

b) the scientific event that you studied and gave your presentation about

2.2 Did the fact that you had access to a computer during the seminars help in remembering and understanding things? Please elaborate on your answers if possible

☐ Yes ☐ No ☐ Don't know

2.3 Would you have preferred a more formal setting and structure (ie. a lecture room with lectures) without computers? Please elaborate on your answers if possible

☐ Yes ☐ No ☐ Don't know

2.4 Did you feel more comfortable asking questions during the seminars than at other points in the course? Please elaborate on your answers if possible

☐ Yes ☐ No ☐ Don't know

2.5 What do you think is the most important skill / knowledge you got from the seminars. Mark each item with numbers 1-7 with '7' being the most important and '1' being unimportant. You can only use each number once.

☐ Presentation skills

☐ Understanding of data availability

☐ Understanding of the limitations of data

☐ Understanding how the data is utilized

☐ Better interpretation methods for the data

☐ Enthusiasm for the subject

☐ Other (please state):

2.6 Did you feel that discussing the scientific topics with your peers made it easier to understand the scientific background behind the data? Please elaborate on your answers if possible

☐ Yes ☐ No ☐ Don't know

2.7 Would you have preferred to receive instructions regarding the assignment and allowed to work at it outside of an organized time period (ie. there would be no formal contact or lab time arranged)? Please elaborate on your answers if possible

☐ Yes ☐ No ☐ Don't know

2.8 How did you find this compared to a standard lecture? Please elaborate on your answers if possible

☐ Better ☐ Worse ☐ No difference

2.9 Please indicate your preference for each of the questions below?

a) I felt I got a deeper understanding of how data online databases work

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

b) I have a better understanding regarding identifying the signatures of ionospheric processes in radar data

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

c) I have a better understanding of how multi-instrument datasets can be combined together

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

d) The presentation required at the end of the course allowed me to focus on exactly what was needed to complete the tasks.

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

e) I would've preferred to

☐ Work in a smaller group

☐ Work in a bigger group

☐ Work alone

☐ The group size was just fine

f) I felt I learnt more when I worked in a group

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

g) Everyone in the group contributed adequately to the task.

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

h) If I had just met the people in my group at the start of the session I would've been less inclined to participate fully in the task

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

i) I would feel comfortable giving a basic overview to a fellow scientist in the same field of how to use the databases and utilize radar data in ionospheric studies

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

j) I think the fact I could discuss the tasks informally with fellow students and teacher during the seminar meant I asked more questions than I would've done in a lecturing environment

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

k) Working as part of a group made me more enthusiastic about the subject than if I had have worked independently

☐ Strongly agree ☐ Agree ☐ No preference ☐ Disagree ☐ Strongly Disagree

2.10 Any other comments regarding week 9 of the course: