CHERIL Report

Projects with the 'E' factor: a model for innovative interdisciplinary final year projects to enhance the student experience and employability

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Abstract

The Faculty of Life Sciences (FLS) has pioneered different types of non-laboratory final year research projects, requiring students to explore a bioscience topic in the context of a new discipline: science communication (education, elearning, media), business, and the history of science. Currently, our students work alone or in a team under the supervision of an FLS supervisor and learn the skills appropriate for the new discipline through seminars given by subject specialists. This CHERIL-funded project aimed to add a new dimension to our current provision and develop a model for the delivery and assessment of interdisciplinary project work involving students in life sciences working with students (and staff) in other disciplines. In order to examine whether current assessment criteria for the final project report were suitable, two research assistants (RAs), one from Life Sciences and one from Education, were recruited to validate these criteria. They used NVivo10 to analyse a range of FLS final year project reports (30 in total) at the first (1.0) and upper second (2.1) classification (both lab- and non-lab-based) for critical thinking (CT) skills. They demonstrated excellent agreement in coding for critical thinking skills using descriptors that we developed based on Bloom's taxonomy, which provided evidence that interdisciplinary work could be assessed at the individual School level in an equitable manner. However, no statistically significant difference in the percentage of CT was found between 1.0 and 2.1 reports overall, although Lab reports showed more 'higher order' skills in the first class reports than second. It is possible that the descriptors were particularly appropriate for Lab reports, that insufficient numbers of reports were coded to demonstrate a statistically significant difference overall, or that supervisors were less able to discriminate between 1.0 and 2.1 work in areas outside their main discipline (for non-lab project reports). Based on these findings, the criteria for CT were revised, and new guidelines and tutorials were designed on CT for students and staff. An employability skills audit was also conducted across all FLS project types (N=111) in order to identify skills gaps that could potentially be filled by these collaborative projects. Results demonstrated that all project types were very effective in developing the intended skill sets to a similar degree. With the exception of the team-based business projects, the only skill gaps identified related to teamwork, a valuable attribute to employers. Interdisciplinary projects should address this gap. A pilot scheme has been implemented involving four students from Life Sciences working with

four PGCE students for 2015-6. They will collaborate through a flexible approach, meeting to exchange ideas and share resources, through to generating and evaluating a common output as appropriate (educational materials in this instance). Assessment of student work for the pilot scheme will be done within each School using their standard protocols, and the success of the project as judged by appeal/engagement, enhanced employability and output will be evaluated by questionnaire, focus group, skills audit and an analysis of marks. The intention is to liaise with other Schools in the forthcoming semester to identify other interested parties and extend the collaborative approach to student project work where appropriate.

Project Rational

Final year research projects (FYPs) are the ultimate capstone experience for students across many disciplines in higher education, and, in an HEA-commissioned review, Healey *et al* (2013) recommend that FYPs should take many shapes to prepare students for the increasingly complex and multi-disciplinary challenges ahead, thereby enhancing their employability. Key skills such as teamwork, problem solving, communication, and analytical and critical thinking are recognised by employers as essential to equip students for the world of work (Grice and Gladwin, 2004). Indeed, at the University of Manchester (2014), 'independent critical thinking and analysis' are actively encouraged to prepare students for employment. FYPs provide an opportunity to develop a wide range of both discipline-specific and transferable skills. In FLS, we offer a variety of novel alternatives to the traditional laboratory-based project to appeal to the wide spectrum of learners that comprise our undergraduate population. These include projects in Science Media (SMP), Bioscience Education (EDU), eLearning (ELP), Enterprise (BUS) and the History of Science, Technology and Medicine (HSTM). The projects are centred on a core model for training and supervision, and are conducted as far as possible under a common set of guidelines, assessment criteria and descriptors to ensure parity with respect to attainment and the development of key skills. Assessment varies slightly according to the type of project, and in particular, most non-lab projects contain an assessment component relating to some form of output. BUS projects generate a group Business Plan; SMP, a creative piece that might be a video, podcast, story, or artwork for example; EDU produce educational materials and ELP produce online educational resources.

This project aimed to develop our current model to offer interdisciplinary projects each involving two or more students from different Schools. It was anticipated that the projects would be attractive at many levels and provide a unique opportunity for students to maximize their employability, to generate high-quality outputs that may be of value to the University, the community, or commercially, and to foster interdisciplinary collaborations within the University of Manchester. In an environment where universities must demonstrate the added value that they bring to students, it was hoped that they would offer an exciting, authentic, and novel addition to the curriculum, enhancing both the student experience and employability; projects with the 'E' factor!

Specifically, the aims were to establish a robust model for the implementation and assessment of interdisciplinary FYPs, validated by stakeholders from other schools, and explore the added employability value that these new projects would provide compared to current FYPs in FLS; this was achieved by 3 routes:

1. **Development of assessment criteria and descriptors** appropriate for interdisciplinary projects.
2. Design and implementation of a **skills audit** to facilitate student reflection on and identification of key skills that they acquired during their FYP. This audit aimed to enable measurement of the skills development in current projects, and to allow identification of skills gaps that could be filled by interdisciplinary collaborative projects.
3. Design of a **model for interdisciplinary projects** that could be used University-wide, or be applied in other HE institutions. This involved negotiation with stakeholders in other Schools to explore the potential for joint projects.

1.0 Assessment criteria and descriptors for critical thinking

Critical thinking (CT) and the ability to translate this into critical writing are important attributes which should be apparent in *all* final year project reports, both laboratory-based and non-lab based. Hence the skills contributing to CT were selected for analysis in this work. The aims of the initial research were to

(a) explore whether CT was more evident in 1.0 reports than 2.1, which is what we would anticipate, and
(b) determine whether staff from 2 different disciplines (in this case, Education and Bioscience) could both recognise CT to the same degree in these project reports, as would be required in true interdisciplinary projects with common outputs.

In order to address these aims, it was necessary to define CT and to detail how it might be recognised in student work. However, there are many definitions of CT and these largely arise from the educational or psychological perspectives (Table 1.1). The definition used in this project was adapted from a statement by Scriven and Paul (1987), which describes CT as

"the process of conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by research, observation, experience, reflection, reasoning, or communication, as a guide to belief and action."

Many of these attributes can be recognised in Bloom's Taxonomy of educational objectives that comprise the cognitive domain of learning (Bloom, 1956), so it was decided to develop descriptors for CT based on the levels described in Bloom's taxonomy. Subsequently, 'identifiers' were developed, which are words or phrases that might be used to recognise various aspects of CT (Appendix 1).

Bloom's taxonomy was revised by Krathwohl (2002) who replaced the nouns with verbs, added a range of dimensions of knowledge, and transposed synthesis and evaluation in the hierarchy, but these modifications did not impact on our analysis, since we were interested in the *amount* of higher order versus lower order skills. However, we did transpose Evaluation and Synthesis in the table shown in Appendix 1, because in scientific writing, synthesis is frequently considered to be the highest level in the hierarchy.

Table 1.1 Definitions of Critical Thinking

...the ability to analyze facts, generate and organize ideas, defend opinions, make comparisons, draw inferences, evaluate arguments and solve problems (Chance, 1986).
...skillful, responsible thinking that facilitates good judgment because it (1) relies upon criteria, (2) is self-correcting, and (3) is sensitive to context (Lipman, 1995).
...the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action (Scriven & Paul, 1992).
...active, systematic process of understanding and evaluating arguments. An argument provides an assertion about the properties of some object or the relationship between two or more objects and evidence to support or refute the assertion. Critical thinkers acknowledge that there is no single correct way to understand and evaluate arguments and that all attempts are not necessarily successful (Mayer & Goodchild, 1990).
...a conscious and deliberate process which is used to interpret or evaluate information and experiences with a set of reflective attitudes and abilities that guide thoughtful beliefs and actions (Mertes, 1991).
… art of analysing and evaluating thinking with a view to improving it. …mode of thinking - about any subject, content, or problem - in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them (Paul & Elder, 2001).

1.1 Methods

Two research assistants from different disciplines (Bioscience and Education) using NVivo 10 software coded the introduction and discussion sections of a range of project report for aspects of CT. Thirty reports were coded in all; six reports each from five different types of project, three with a 2.1 classification, and three with a 1.0. Science Media and Business projects have unconventional formats, so corresponding sections were selected for coding. Each sentence was coded for the level of Bloom's taxonomy that it represented as determined by reference to the table in Appendix 1. If the sentence fitted two or more levels, then the higher level was selected. The last and first sentences of adjacent paragraphs were coded for the levels of 'analysis' (sequencing and linking) if the paragraphs flowed logically from one to the next.
Any sentences that were considered to be repetition were filed in a 'repetition' node.

The resultant data were interrogated using NVivo to:

- Compare the agreement between coders
- Compare CT in 2.1 and 1.0 class reports
- Compare CT in the different types of report

1.2 Results

1.2.1 Agreement between coders

Coders from SEED and FLS agreed to within a few percent on the coding, as shown in Figure 1.1. This demonstrated that it is possible for staff from different disciplines to use the descriptors to assess the quality of reports regarding CT.

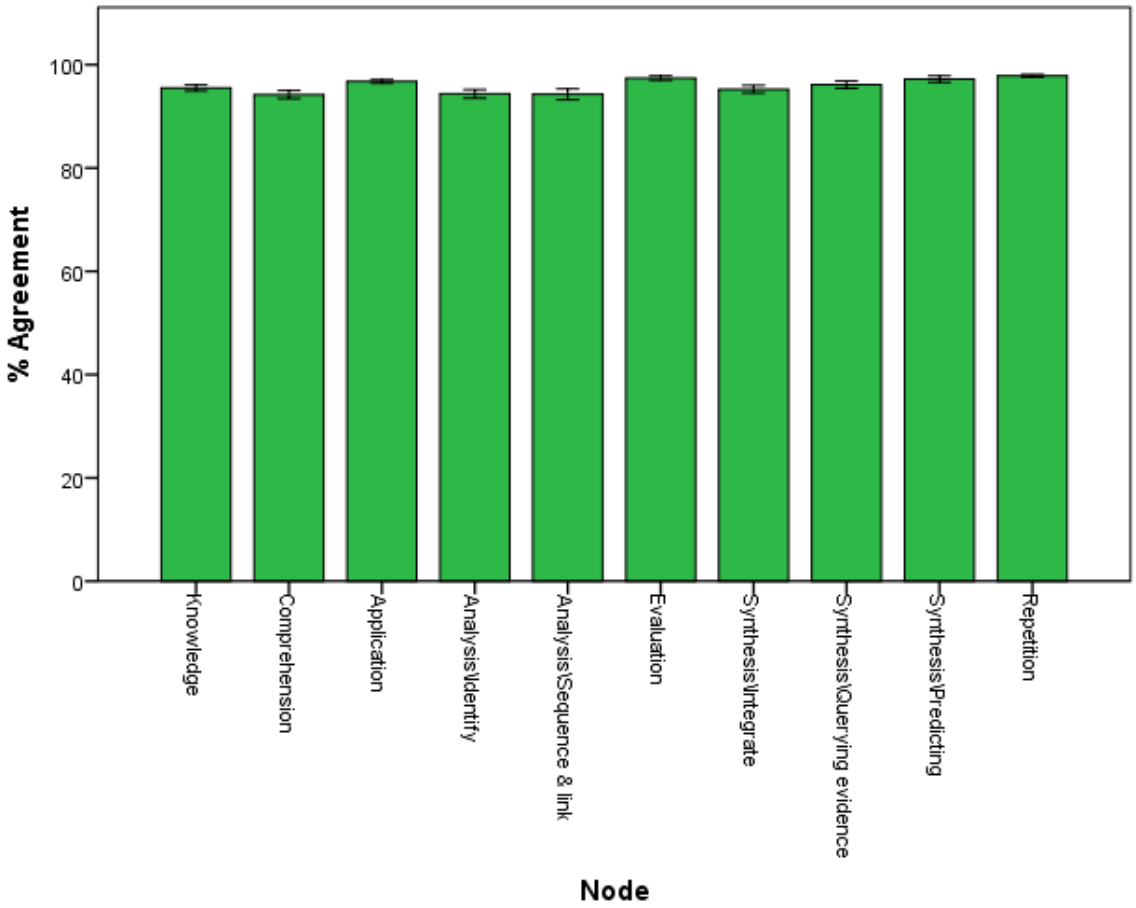

Figure 1.1 The percentage agreement in text coded by 2 coders (Bioscience and Education). *Repetition in the text is also indicated alongside the levels of CT. N=30 reports for each Level (green bar)*

1.2.2 CT in 1.0 and 2.1 reports

For each level of Bloom's taxonomy, there was no significant difference in the amount of text coded in 1.0 and 2.1 reports, as shown in Figure 1.2, although 2.1 reports showed higher amounts of knowledge and repetition, and lower amounts of evaluation and comprehension.

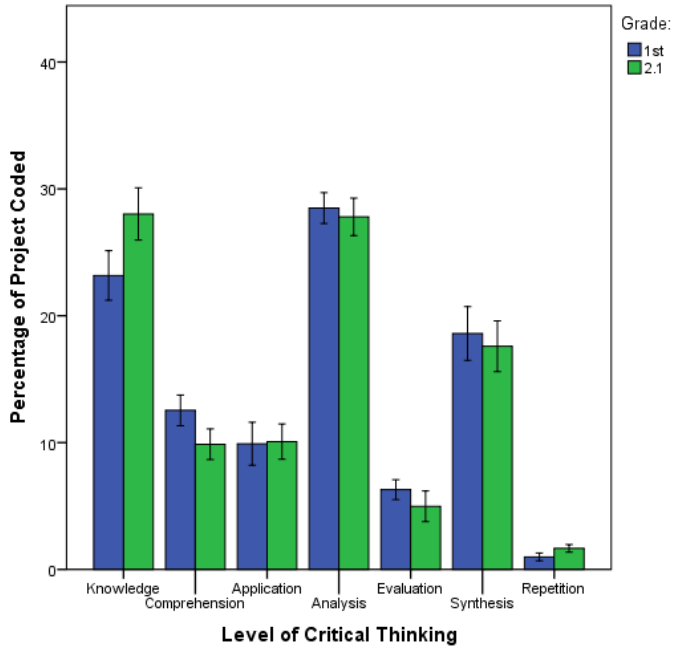

Figure 1.2 Mean percentage of project report coded for each level of Bloom's taxonomy (as defined by Descriptors) in fifteen 1.0 and fifteen 2.1 reports (from 2 coders)

1.2.3 CT in different types of project report

Five different types of project report were analysed for both lower order skills, Knowledge, Comprehension and Application, and higher order skills, represented by Analysis, Evaluation and Synthesis, as shown in Figure 1.3. Reports were from traditional laboratory projects (LAB), business projects (BUS), science media projects (SMPs), education (EDU), and elearning projects (ELPs).

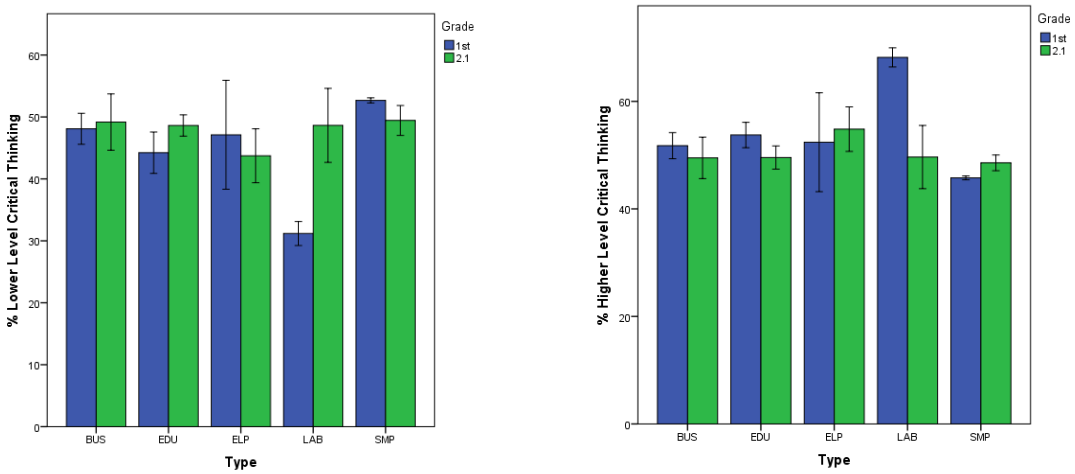

Figure 1.3 Percentage of lower and higher order thinking skills in different types of project report. *Each bar represents 3 reports coded by two staff from two disciplines.*

Overall, the percentage of thinking was very similar in all, with no significant difference between types of report or classification of report. For LAB reports, however, a higher percentage of higher order CT skills (Analysis, Evaluation, Synthesis) was found in 1.0 reports than in 2.1, and conversely, a higher percentage of lower order skills were seen in 2.1 LAB reports.

1.3 Discussion

Across the five project types it might be assumed that some reports would have been easier to code than others based on the coder's own background (Education vs. Bioscience). However, this was found *not* to be the case. The coders did find that some reports were much more difficult to code, but this was deemed to be due to the style of writing rather than the subject matter. The reports that were the most difficult to code were those where the students had either used very short sentences with no sequencing or linking, which made it difficult to follow their reasoning, or they had written very long meandering sentences, and used bad grammar with incorrect use of full stops, which sometimes split a sentence into two incoherent parts. The coders found that on occasion the sub-themes, such as weighing evidence, analysing arguments and making judgements, which comprised 'Evaluation', were difficult to distinguish. In the final analysis, therefore, it was decided to combine these to give a value for the percentage of each overall level, such as Evaluation. The three sub themes under the level 'Synthesis' were found to be the easiest to identify and code in all types of report. In addition, the coding of individual sentences did not lend itself to giving credit for the development of reasoning or argument over many sentences, although this was classed as sequencing and linking where it was identified.

The high degree of agreement between our two coders suggests that it is possible for markers from two different disciplines, such as Bioscience and Education, to use the CT descriptors defined in this report to identify CT in a range of project reports. The intention is to use this as evidence to develop marking criteria for interdisciplinary projects, citing CT as a key attribute, rather than to expect assessors to mark using a coding rubric as in this project.

Encouragingly, the amount of CT was fairly uniform across all types of project, indicating a high degree of parity between project reports. Unfortunately though, no statistically significant difference was found in the amounts of CT between 1.0 and 2.1 reports (Figure 1.2), so it is not possible to use CT alone as a discriminator between these two classifications. However, when further analysed by project type (Figure 1.3), LAB reports showed statistically significantly more higher order CT skills than lower order skills in 1.0 reports, although this was not apparent in the other types of project report. It is possible that more reports are needed in order to obtain statistically significant differences. Alternatively, the descriptors may be more appropriate to LAB reports. One coder reported that in BUS reports "it was often difficult to find evidence of synthesis in terms of querying evidence and predicting", and also that "the figures are sometimes highly integrative", and since figures themselves were not coded in this scheme, this may have led to an underestimation of Synthesis in BUS (and indeed other) reports. It is also possible that the actual classification given to the non-lab reports was based on additional factors, or even that supervisors are less able to discriminate between good and less good written work that is outside of their normal discipline (using current assessment criteria). We have addressed this by writing a **Guide to Critical Thinking** (Appendix 2) for both staff and students in order to facilitate the development of CT throughout the narrative of a piece of written work. Moreover, we have produced a document describing how an EDU, ELP and SMP report should be planned and written, highlighting areas where CT would be anticipated.

2.0 Employability audit of skills developed in final year projects

Learning through research and developing graduate employability are key points for Goal 2 of the UoM 2020 agenda (UoM, 2015), and FYPs address both of these points. In FLS, employability is embedded in non-lab FYPs through various means such as training workshops, provision of a skills toolkit, and reflective portfolios (Fostier et al., 2014 for the BUS projects). The current provision of FYPs in FLS should help students develop/hone 5 of the 8 UoM graduate attributes (UoM, 2014a) and 13 to 18 of the 18 core skills listed on the Careers webpage (UoM, 2014b), depending on the project type.

Evaluating the impact of these projects overall on employability is complex, and current proposals to measure employability are frequently targeted at the Institutional level (Harvey, 2001). The work of Denise Jackson and colleagues in their attempt to measure employability development through a four module programme is very useful. They first developed a table of ten industry-relevant competencies sub-divided into forty constituent behaviours (Jackson, 2010; Jackson and Chapman 2012). They later enhanced this framework by generating rubrics for each constituent behaviour, to define 1) level of competency for self-evaluation (novice, developing, competent) and 2) criteria for assessment purposes (Riebe and Jackson, 2014; Jackson, 2014 a and b). These comprehensive tools proved very effective to engage both staff and students with employability and establish a shared understanding and benchmark, but discrepancies were found when students self-reported their skills level compared to when staff assessed the same skills level. The authors identified factors such as gender, culture (in broad terms confident vs introvert), and academic ability, as having an influence on rating accuracy, which they compared to the findings from early studies on self-assessment.

The coordinators of the team-based BUS project developed a similar approach to embed and monitor employability development when they launched their course in 2007 (Speake et al., 2007). Each year, their students complete an ongoing portfolio to reflect on course situations and capture evidence of their skill development, and an end of course skill audit with short descriptors where needed where student rate their level at the 'start' (reflecting back) and 'end' of the course using a simple 1-4 scale based on the amount of time they have used a skill and the type of evidence they have gained (1: never done it, 2: beginner: done it once or twice, 3: competent: done it several time; 4: skilled: wealth of varied experience). The point of the audit is to capture their self-perceived skill development via the project work.

Given that most of other FYPs in FLS do not have an associated reflective portfolio, it was decided to adapt the BUS skill audit to capture the self-perception of skill development of our students for each project type. The intention was to evaluate how our current project types compare in terms of skill development and possibly identify skill gaps, and to set a benchmark against which new collaborative interdisciplinary projects could be measured. Ultimately, this tool could be used to monitor the development of employability skills in all FYPs in the future, as well as encourage students to self-reflect on their performance and engage with employability.

2.1 Methods

An audit was designed comprising 26 skills grouped into four sets: Communication, Research, Project Management, Personal, with situational descriptors to facilitate a common understanding, and few closed and an open question (see Appendix 3). It was deployed in two rounds to 474 final year students, and 69 students completed it. The data generated were analysed in conjunction with the results of the original compulsory skills audit of the 42 BUS project students (noted as BUS* in the figures/tables) which contains 32 skills. The additional skills pertained to team work and team-based project management.

For both audits, students self-reported their competency level on a scale of 1-4 at the start and end of the project, as described in section 2.0. The audit was implemented at the end of the project, so students had to reflect on their experience prior to the project for the start ratings.

The Wilcoxon signed rank test was used to test whether the skill ratings at the start and end were statistically different.

To analyze each skill development per project type and at the cohort level, the mean 'start' & 'end' ratings and their differences (that we call 'gain') were calculated for each skill. Skills gaps were defined by a mean 'end' rating ≤ 3.

To analyze overall skills development of each student in a FYP, several calculation were made with reference to the maximum possible score a student could get, i.e. a rating of 4 for all the skills on the audit (i.e. 4*26 for the general skills audit and 4*32 for the BUS skills audit).

- % start score = sum of all start ratings for a student *100 / maximum possible score
- % end score = sum of all end ratings for a student *100 / maximum possible score
- % gain score = (% end score) - (% start score)

2.2 Results

2.2.1 Detailed skills analysis per project and identification of skill gaps at cohort level.

In total, 111 out of 474 Life Sciences final year students (nearly 25% response rate) completed the project skill audits, 69 completed the general audit (26 skills) and 42 completed the BUS specific audit. Traditional lab project students (LAB, N=45) and team-based enterprise project students (BUS*, N=42) were the most represented, followed by education (EDU, N=10), elearning (ELP, N=6) and science and media (SMP, N=4) project students. The descriptors of both audits differed slightly; as a result the *cohort* scores presented in figures 2.1 and 2.2 were derived from the general survey (N=69).

For this section, each skill development was analysed at the cohort and project type level (see Methods). First it was found that for each skill, the 'end' rating was significantly higher than the 'start' rating ($P<0.0001$) when the data were compared both at the project type and cohort levels. This was a good result, but skill gaps could still occur. On our 1-4 scale to define competency level, it

was decided that a mean 'end' rating <3 (competent level) would highlight a skill gap. Out of the 26 skills surveyed, five gaps were identified at the cohort level (see figure 2.1 and 2.2), but analysis at the project type level revealed that these gaps were project-dependent.

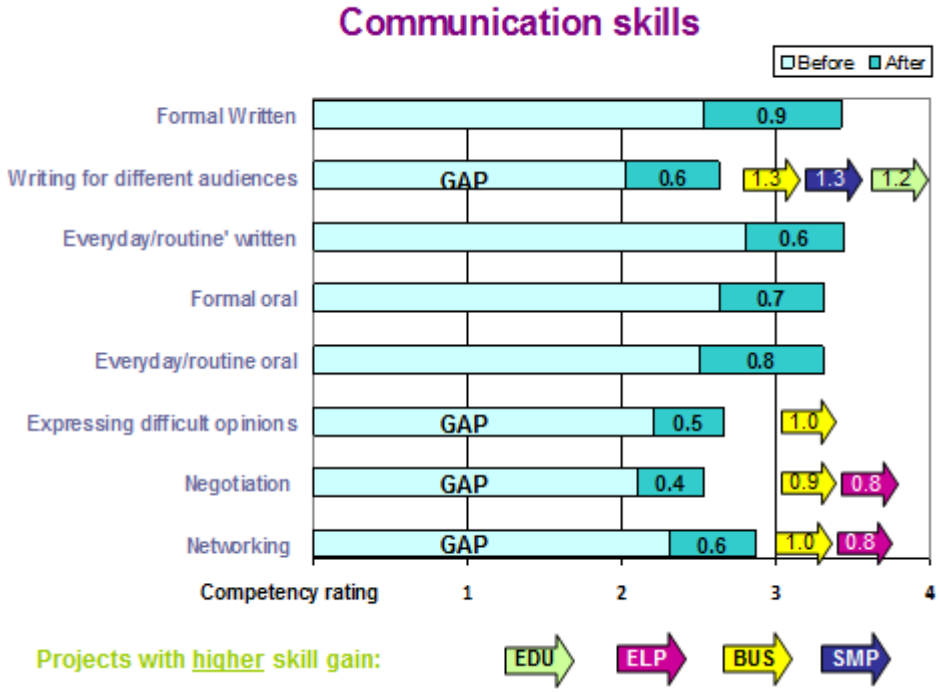

Figure 2.1 Mean start and end ratings for the communication skills set at the cohort level (N=69). *For each skill, the light blue bar represents the mean start competency rating and the end of the bar represents the mean end rating. The mean numerical gain ('end' minus 'start' rating) is indicated on the green bar. A skill gap is identified when the end rating is below 3. The arrows indicate the mean gain for four project types (EDU, ELP, BUS, SMP). For these FYPs, a skills gap was not identified because the end rating was above 3.*

In the communication skill set, four skill gaps were identified at the cohort level: writing for different audiences, expressing difficult opinions, negotiation and networking with mean gain scores ranging from 0.4-0.6 (see Figure 2.1). These gaps were found in skills with the lowest mean start ratings of the set (2-2.3) but they were not found across all project types, highlighting the differences in the nature of the project work or assessment. Unlike the other students, ELP and LAB students were not formally required to write for different audiences, although it could be argued that ELP, like EDU students had to adapt their writing to the target audience of their learning resource. LAB, EDU and SMP were not required to cooperate with each other in general, so they gained little team working skills unlike their BUS colleagues who worked in teams and contacted business advisors and professionals to obtain advice or desired information. The ELP students were 'in between' for team working skills, because cooperation was fostered through many common training sessions and the informal requirement to review each other's work.

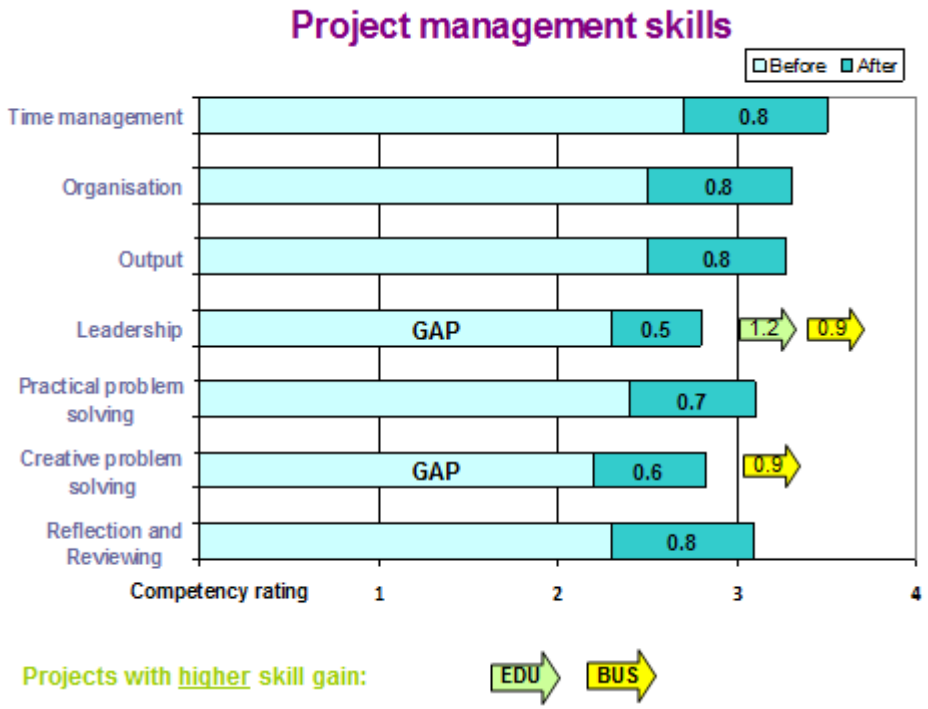

Figure 2.2 Mean start and end ratings for the project management skills set at the cohort level (N=69). *For each skill, the light blue bar represents the mean start competency rating and the end of the bar represents the mean end rating. The mean numerical gain ('end' minus 'start' rating) is indicated on the green bar. A skill gap is identified when the end rating is below 3. The arrows indicate the mean gain for four project types (EDU, ELP, BUS, SMP). For these FYPs, a skills gap was not identified because the end rating was above 3.*

In the project management skills set, two gaps were identified at the cohort level: leadership and creative problem solving with mean gain scores ranging from 0.5-0.6 and mean start ratings ranging from 2.2-2.3 (see figure 2.2). Again, these gaps were project-dependent. For leadership, LAB, ELP and SMP had no opportunity to really practice this skill throughout their project so the results were not surprising, whereas BUS and EDU students, due to the nature of their work had a chance to practice leadership; BUS student work in a team and rotate chairs weekly in semester 5 and EDU students lead a class activity in semester 6. For creative problem thinking, LAB students which represent a big proportion of the respondents often may not have a chance to practice the skill, but the other students should have been creative (perhaps they did not use their creativity to solve problems though). The highest gain was perceived by the BUS students who had to solve problems weekly and had two workshops on the subject.

2.2.2 Overall skills development for FYPs.

For this section, overall skills development per student was analysed at the cohort and project type level (see Methods). At the cohort level, examination of overall skills gain revealed that higher gains coincided with lower start scores (Figure 2.3). Interestingly, the end scores were all levelled by the end of the project to a mean of 80%. This can be taken as a good outcome where FYPs, regardless of the initial student skills level, can bring each student to a competent/skilled level for each intended skill by the end of the course. Analysis of the gain per project type revealed scores varying from 18

to 24% (20% may indicate a 1 point increase for 20 out of 26 skills on our 1-4 scale), with the BUS projects achieving the highest gain because of the team work, networking opportunities and the requirement to produce several assignments in very different styles.

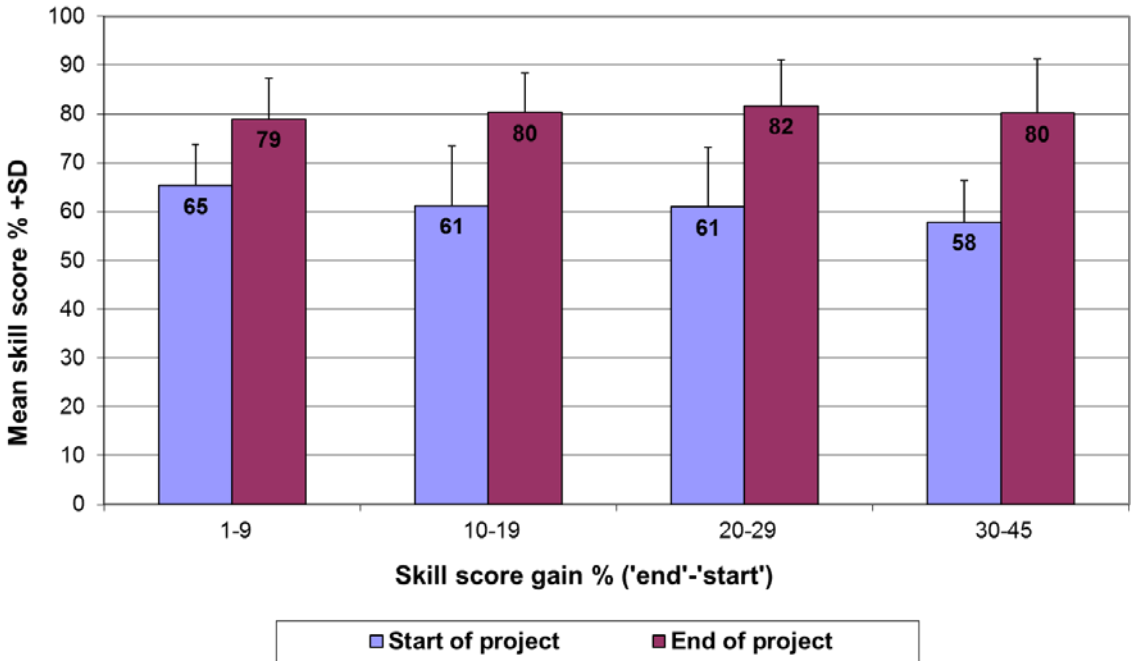

Figure 2.4 Relationship between skills gain, and start and end of project skills scores. *Out of the 69 students surveyed, starting skills scores varied a lot whereas end of project skills scores levelled up around 80%. The skills gain score from projects (on the x axis) as a result varied from 1 to 45% and is a function of the starting score, as described by the four groups presented. For gain 1-9%, N=11; 10-19%, N=25; 20-29%, N=24; 30-45%, N=9.*

2.2.3 Student perception of the added value of interdisciplinary projects?

The last question on the survey was as follows: *We are aiming to launch interdisciplinary projects in the near future where, for example, a student from the education Faculty will work with an EDU student to produce class activities, or a student from the computer science Faculty will work with an ELP or bio-informatic project student to produce their resources. Do you think this is a good idea and would it have appealed to you personally?*

78% of the 69 students surveyed thought that interdisciplinary projects would be a good idea and 45% would have been personally interested (mostly non LAB students as this was not relevant to them). 5% gave a reserve yes upon conditions and 1% said that it would not be a good idea.

Positive and interested students mentioned several reasons:

- To gain skills
- To have support for projects (especially bioinformatics)
- To gain a better understanding of the nature of some projects from the offset and so they don't have to learn concepts (e.g. business concepts) from scratch

Many students said that their decision to choose an interdisciplinary project would depend on:

- Who they were working with – their partner should put in as much work as they do
- How the projects were marked – would students get individual marks or would they be marked together
- The weighting of the projects should be equal for both students (e.g. 40 credits each) so that equal work is put in

Potential concerns/conditions were as follows:

- Worried it would take extra time.
- Should not be compulsory.
- Working with others on such a high stake project.
    - Nature of the assessment: *"The projects would need to be equally weighted for the two students and require the same assessment to avoid a situation where one student is more focused on the project than the other."* Some students would not want to see team-based assessment.
    - Student selection, equal contribution, its monitoring and the stress involved: *"Could be problematic if students do not co-operate well together"," Would need careful monitoring to be sure that equal work is being in put by both students", "Issues should be reported and taken into account".*

Negative students mentioned the following reasons:

- They want complete control of their own work
- It doesn't suit their personality
- They don't want to work with other people for something that is worth so much of their degrees

2.3 Discussion

Analysis of the skills audit has shown that regarding perceived overall skill gain, our FYPs were comparable, on the whole, although those FYPs promoting an entirely new experience (ELP and BUS) and a team-based experience (BUS) obtained the highest skill gains. Similarly, where skills gaps where identified at the cohort level, especially for team working skills, these gaps were project type-dependent.

The new collaborative interdisciplinary projects proposed here should address all the gaps identified and promote new experience to test and hone existing skills to another level (see below). Students undertaking these projects should thus become very employable and fulfil the following UoM Goal: ". [Our students be highly employable] because they will at the forefront of knowledge and understanding both in their own discipline and beyond." (UoM 2020, p11).

Interdisciplinary projects lend themselves to solve unique and new problems (Tait and Lyall, 2007):

- Language and communication issues
- Different institutional structures and procedures
- Divergences in worldviews/research approaches across disciplines

Which requires the following skills:

- Flexibility, adaptability, creativity
- Curiosity about, and willingness to learn from, other disciplines
- An open mind to ideas coming from other disciplines and experiences
- Good communication and listening skills
- An ability to bridge the gap between theory and practice
- A good team worker

Interestingly, the majority of the students surveyed found the proposal for interdisciplinary FYPs appealing for the laudable reasons (interesting projects and skill/experience enhancement).

Finally, the skills audit proved a good basic tool to monitor student perception of their skills development. Although a more robust evaluation would be required to evaluate the real impact of a project on skill development, such as presenting evidence to justify the skill levels allocated (as suggested by Riebe and Jackson, 2014 and Jackson, 2014 a and b), FLS has found it a useful indicator and will implement the audit for FYP students across the board in the forthcoming academic year.

3.0 A Model for Interdisciplinary Projects

Final year projects provide an opportunity for independent student-led learning through research. However, the diverse range of projects on offer in FLS places additional demands on both students and staff as they have to embrace a new discipline. The aim here was to evaluate the effectiveness of developing an interdisciplinary, collaborative approach to research projects that would potentially improve skills, confidence and the quality of any output. We have broadly interpreted 'interdisciplinary research' according to the definition of Bruce et al (2004):

"*Research which aims to further the expertise and competence of academic disciplines themselves, e.g. through developments in methodology which enable new issues to be addressed or new disciplines or sub-disciplines to be formed".*

We have developed a model, with reference to the statement made below in a recent HEA-commissioned report (*Thomas et al*, 2015), to facilitate, deliver, support and assess interdisciplinary research projects that epitomise directed independent learning (DIL):

"*DIL places increased responsibility on students when compared to the forms of learning they are most likely to have undertaken prior to entering HE. But students should be engaged, enabled, facilitated and supported by staff through relevant and guided opportunities, suitable pedagogies and an appropriate learning environment. Staff should ensure students have informal and formal opportunities for feedback, and monitor participation and understanding. DIL is integral to students' development as autonomous learners and their graduate attributes*."

The model developed in this project work aims to offer this innovative opportunity to students, and support them as described below.

3.1 Current FLS model for FYPs

3.1.1 Project selection

There are two methods of recording project preferences for staff and students:

a. Potential supervisors and second year (and returning) students in FLS complete an online form to opt for a type of project (LAB, HSTM, BUS, EDU, ELP, SMP) at the beginning of June, and record their preferred topic areas. Students and supervisors are then matched according to these 2 criteria by administrative staff, and the matches are overseen by the Deputy Associate Dean of Teaching and Learning.
b. Alternatively, a student can self-arrange (pre-arrange) a particular project with a member of staff by mutual agreement. The signed self-arranged form is submitted alongside preferences in the usual way.

Allocations ultimately depend on preferences submitted, the mean second year examination result of the student, and the availability of particular types of project (for example, ELP numbers are capped to the size of the PC Cluster; LAB projects by the availability of bench-space.)

3.1.2 Project Timeline

A schedule of work and student support runs across 2 semesters of final year (Table 3.1). The focus in Semester 5 is to write a Review of the Bioscience literature pertaining to the project, develop a 2-

page Project Proposal, and begin preliminary project planning, preparation and any appropriate work. The project-proper takes place predominantly in Semester 6 up to the Easter vacation, when students are expected to begin writing up for submission of a final report or equivalent around week 10-11.

Table 3.1 Timeline for FYPs in FLS (shown in black) and in collaborative projects (blue)

	Week	Deadline or milestone
Semester 5	**Week 1-3** **Week 0-1**	Student/supervisor **Meeting 1**: obtain starter references where appropriate for Literature Review and discuss preliminary ideas for the project and how it relates to the Literature Review. Students and supervisors from 2 Schools meet to exchange ideas, pair students according to interests and decide on a topic.
	Week 2-10 **Week 2-12**	Attend lab meetings and seminars where applicable to your project (LAB Projects), or seminars and workshop training sessions (EDU, ELP, SMP, BUS, HSTM). Undertake Ethics Survey in Blackboard as soon as possible; apply for full ethical approval if this is flagged up by the survey. *Student pairs communicate F-2-F or remotely to discuss ground rules for collaboration (contact details, frequency of communication, dealing with issues etc), exchange ideas and resources, formulate plans and draft a project proposal. Students should formulate a research question and/or hypothesis to underpin the project.
	No later than week 5 Week 6-8	Student/supervisor **Meeting 2**: to discuss A4 plan for Literature Review*, progress in seminars and target group (for EDU, ELP, SMP). Students and supervisors to meet F-2-F or remotely for a progress update/review and to determine the extent of collaboration ('loose or tight') and finalise project proposal (how the collaboration works in practice; what is done by whom and when, including evaluation)
	Week 7/8	Student/supervisor **Meeting 3**: to discuss project aims and scope, and obtain feedback on a paragraph of writing to include references, plus a figure or table with legend**.
	Week 9	**Submit 12 page Literature Review to include a 1-2 page Project Proposal,** including a summary of the rationale for and aims of the project, research question and/or hypothesis, and a project plan including key milestones (or Gantt chart, or story board for ELP) **(10 + 1-2 pages).**
	Week 10-12	Students should **begin preliminary project work** towards the end of Semester 5. Student collaborators should meet to firm up plans and produce a detailed schedule of work.
Semester 6	**No later than week 2**	Obtain feedback from supervisor on work submitted so far: Lit review mark (subject to confirmation by Examination Board), verbal feedback, written feedback in Grademark.
	Week 1-10	Maintain records in elab book or ejournal, and/or lab book (to track progress, notes from meetings and seminars, monitor time spent on project, describe challenges, record ideas etc). **Meet regularly with supervisor** (including suggested progress meetings below); obtain **feedback on a full draft** of Project Report, probably around week 9. Conduct project work. Liaise regularly with collaborator and record progress.
	Around weeks 3-4 & 7-8	**MEETINGS: Progress Reviews** to check that project work is going to plan, review output thus far, review e/lab book, discuss remaining work and content/format of the project report.
	Between weeks 7-9	Oral presentation on project work to tutorial group. **MEETING**: Supervisor to provide feedback on a **full draft** of Project Report and provide constructive criticism to help the student to improve. EDU, ELP, SMP supervisors should also look at the resource that has been created.
	Week 11	Supervisor submits project performance mark. Collaborators submit Project Report via Blackboard, or equivalent (depending on School and Programme) PLUS resource for ELP & EDU & creative piece for SMP.

3.2 Interdisciplinary collaborations in project work

Interdisciplinary collaborations will be self-arranged between students and supervisors of the participating Schools. We anticipate retaining our current timeline to facilitate submission and marking of reports, and until the scheme for interdisciplinary projects can be evaluated, student assessment will remain in-house. Support and day-to-day running of the projects, however, will be flexible and student-driven to enable collaborations to be as tight or loose as appropriate for the project and students involved.

3.2.1 Pilot of interdisciplinary projects/dissertations between FLS and PGCE

A scheme is being piloted in 2015-6 for collaborative projects between 4 FLS students and 4 PGCE students from the School of Education; each FLS student is working with a student from SEED. This collaboration can be accommodated because PGCE students conduct an enquiry during the course of the academic year, addressing a research question related to their interests and teaching activities. The timeline for this enquiry maps onto the FLS projects timeline as shown in Table 3.2.

Collaborations between students might involve any of the following activities:

- meeting periodically (face-to-face or online) to discuss and exchange ideas for the design, delivery and evaluation of an educational intervention;
- observing teaching (FLS student observes PGCE student) to learn from him/her and to provide feedback;
- delivering/using(and provide feedback on) an activity designed by the FLS student in a class of PGCE student;
- designing an intervention together, along with an evaluation strategy, which might then be co-delivered. This would be assessed individually within each School.

This pilot will be evaluated in June 2016 by questionnaire delivered to the participating students and by F-2-F meeting. It is hoped that the outcomes will be positive, and support the conclusion drawn by Thomas et al (2015) who acknowledge that engaging students in DIL is important, and that success can be achieved by making it relevant to vocational and professional practice, since the students involved with the pilot all have vocational aspirations to become teachers.

The topic areas of interest for the pilot are:

1. How does dyslexia impact on learning aspects of bioscience? Two sets of students are exploring this question with reference to two different bioscience topics (alcohol metabolism and the gut microbiome).
2. How does the use of language affect the learning of bioscience, explored using stem cells as a topic?
3. Why do most students prefer to learn about human biology over plants?

Tasks to be completed by collaborating students, as detailed in Table 3.2:

- Draft a proposal describing the aim of the project or dissertation/enquiry and the approach that will be used.
- Describe the role of each student in the collaboration; e.g. The PGCE student may ask for expert bioscience help from the FLS student; the FLS student might also create bioscience

lesson materials for the PGCE student. The FLS student might benefit from the educational expertise of the PGCE student, and have access to pupils for evaluation of project resources.

- Describe the anticipated outcomes of the work (to make a judgment based on your research question, to create and evaluate educational materials).
- Write and submit report or equivalent.

Table 3.2 Timeline for Interdisciplinary collaborations between bioscience and PGCE

Time	PGCE	Collaboration	FLS
Sept/Oct	On placement; start to think about inquiry.	Pairing of collaborators Allocation of supervisors	Choose bioscience topic area and educational inquiry
Sept - Nov	Select inquiry topic	Meet* at least twice to discuss ideas	Research bioscience and education topics
Nov-Dec	Define inquiry and plan approach; develop research proposal	Meet* at least once to input ideas into proposals	Define inquiry and plan educational intervention; develop research proposal
Jan-April	Undertake enquiry-based research. Possibly gain feedback from FLS student observation; possibly use, co-design and/or co-deliver educational intervention/s.	Collaboration and meetings as appropriate for 'tight' or 'looser' collaboration.	Observe teaching in situ. Design, deliver and evaluate educational activity through collaborative interaction with PGCE student.
May		Discuss ideas for final submissions ensuring joint contributions and individual contributions to any final output and research are clearly defined.	Submit project report and resource (intervention).

3.3 Further potential topics for collaborative project work

Bioscience/Education (SEED); PGCE

- Scholarly research to provide an evidence-base for faculty teaching and learning.
  e.g. How people learn (biology); determining the added value of HE for biology students & education students; effectiveness of educational interventions; why some topics are more/less appealing than others.
- Production of educational materials to support the curriculum, museum activities, school curriculum, science teacher training.

Bioscience/English Language Education

- An investigation into the effects of culture shock on international students in FLS at the University of Manchester.
- To what extent do cultural differences in education impact on the implementation and success of spoken communication activities involving International students in a second language learning context within FLS?

- It's Good To Talk: applying Critical Discourse Analysis theory to a collection of naturally-occurring conversations, e.g. within the FLS PASS scheme or in other student led teaching and learning contexts.
- How does the use of analogy/metaphor in the classroom (biology) influence learning?
- How to overcome problems with literacy or numeracy in students of Life Sciences at school level or in HE?

Bioscience/Learning Disabilities Studies

- How to overcome problems with literacy or numeracy in students of Life Sciences at school level or in HE?
- What are the particular challenges for dyslexic studying Life Sciences (school level or in HE) and what are the best ways to overcome them?
- What are the common misconceptions about biology (at school level or HE) and how might these be overcome?

Bioscience/Computer Science

- Production and evaluation of novel eLearning resources to support the curriculum.
- Design of Apps (health, diet, exercise, lab protocols, diagnostics).
- Design of Bioinfomatics and Biomodelling tools (metabolic pathways, biological systems).

Bioscience/Art

- Creation of Arts/science materials for public engagement (installations/exhibits, publications, creative writing pieces).

Bioscience/Law

- Research question-based projects on ethics, IP, criminology/forensics.

Bioscience/Social Sciences

- Research question-based projects on social statistics regarding health, lifestyle etc

Bioscience/Manchester Business School MBS

- Research question-based projects on sustainability, marketing/market research, knowledge transfer etc in the biosciences

4.0 Concluding remarks

How has your project contributed to the strategic goals of the University and CHERIL?

This CHERIL-funded project involving development of a model for interdisciplinary collaborative student project work has contributed to both the strategic goals of the University and of CHERIL. It aligns with Goal 2 of the 2020 Strategic Plan of the University on' Outstanding Learning and Student Experience', which states that "*the University will provide a superb higher education and learning experience to outstanding students, irrespective of their backgrounds, and will produce graduates distinguished by their intellectual capabilities, employability, leadership qualities and their ability and ambition to contribute to society*." Further, this work maps onto the CHERIL theme (2014-5) of learning through research.

Outline the robustness of your evaluation approach and what can be learnt from your project

Please see Methods and Discussion sections above.

Outline the innovative aspects of your research and explain how it might trigger pedagogic change

Innovative aspects of research:

- Design of descriptors for CT based on Blooms Taxonomy
- Analysis of FYP reports for CT
- Investigation of agreement in marking between staff from two different disciplines
- Design of employability skills audit to measure skills acquisition in FYPs and identify skills gaps

Pedagogic changes:

- The data from NVivo text coding for CT was used to develop guidelines and criteria on which to assess CT in project reports, although it is recognised that this is only one aspect of assessing reports overall. These criteria are suitable for assessors from different Schools.
- Current FYP Assessment Guidelines were enhanced and clarified as a result of the CT analysis.
- A Guide to CT was produced for students
- A tutorial and workshop on CT were designed for staff and students respectively.
- The Employability Audit is to be rolled out across all project types in 2016 to measure and monitor self-perception of skills acquisition by students.

Outline your project dissemination plan to ensure its outcomes are capable of making the greatest possible impact

The project has been disseminated at a variety of meetings and events as follows:

- European Conference on the Scholarship of Teaching and Learning, EuroSoTL, University of Cork, 8-9 June 2015. A thirty minute presentation was given entitled 'Student Projects with the 'E' Factor' (Appendix 4).
- Improving University Teaching, IUT, University of Ljublijana, 15-18 July 2015. A one hour workshop was conducted entitled 'Engaging staff and students in critical thinking in interdisciplinary projects'.
- OUP Bioscience Summit, Ulster University, 8-9 September 2015. A fifteen minute swop-shop presentation was given on 'Bloom-based descriptors for critical thinking.

In addition, the preliminary findings on critical thinking in different project types and employability skills was presented to the FLS Education management Team on 1st July 2015, and a one-hour workshop on coding text for CT will form part of the FLS Teaching and Learning Seminar Series on 2nd December 2015.

Summary of outputs

- Conference presentations
- Workshop and Tutorial activity on coding text for Critical Thinking
- Critical thinking descriptors based on Bloom's Taxonomy
- Guide to Critical thinking for students (flyer)
- How to write up a Science Communication Project (document)
- Scheme/model for pilot of 4 interdisciplinary collaborations between FLS and SEED for 2015-6
- FYP skills audit

How well were you able to keep to budget (explain). What is the sustainability plan for the project?

The project kept to budget, with the main costs being incurred by employment of two research assistants to undertake the coding of reports, and a more minor sum for dissemination at conferences and swop-shops. The skills audit was converted into an online survey and distributed with the assistance of our employability intern at no cost to CHERIL. This audit will continue to be used for all FLS final year project students and will be integrated with their PDP and will require no further monetary investment.

If you were to undertake the project again, what would you do differently?

A greater number of project reports would be coded across a wider range of degree classifications in order to obtain more robust data; more funding would be necessary for this.

A strategy would be developed in advance to facilitate more effective identification of potential stakeholders or contacts in other Schools who are involved with student projects. We now have contacts with Head Administrators in each Faculty who can direct us to the member of staff involved with student projects.

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Appendix 1: Critical Thinking Descriptors based on Bloom's Taxonomy

Bloom's level	Descriptor	Identifier
Knowledge **report** Addresses the Q '*who, what, where, when*?'	**Report** /record/list factual & conceptual information/knowledge; report and describe (experimental) results **Describe** information/facts (often referenced) **Define** terms **Clarify** & restate (frame the Q or problem); provide context	*This happened/was done* *This occurred at…* *The method was to….* *So and so reported that…/stated that../described…* *My results are… (basic reporting)* *This means….; …is defined as……* *In other words….; meaning….*
Comprehension **demonstrate understanding** Addresses the Q '*Why? How*?'	**Explain** in order to illustrate understanding of information **Paraphrase**; put information into own words; make explicit **Justify** the aims by explaining rationale, or justify an issue by citing evidence to support it	*This means….* *This is because….; …was done because…* *In other words…; therefore….; thus….* *To summarise…*
Application **apply** Use of abstractions, generalisations, rules and theory to contextualise knowledge/problem/issue; Use or implement a procedure	Use **examples** to illustrate the application of knowledge to new or different situations; Use of **abstractions** and **generalisations** by the application of theories, rules or abstract concepts to real life scenarios; relate theory to practice e.g. apply educational theory to the strategy for the development of an educational resource, or apply theory to an experimental strategy Use **analogies** to illustrate a point/argument	*For example….* *In general…..* *I am doing this in my project, based on this theory.* *...for this work…./ in this project...* *The majority of studies suggest…* *My method is based on….* *My results are…. (with some practical or theoretical justification, possibly using calculations)* *This is like ……..*
Analysis **analyse** A key point, problem, aim or issue/topic is	**Identify** key points/issues/problems (often at the start of a paragraph or section) **Breakdown & categorisation** of	*The aim / hypothesis is…* *Importantly....* *Also….* *Thus…; However...; Whilst....*

identified and linked to related information in a logical sequence	info into sub-topics or different interconnected themes Sequence & Link information/sub-topics in a logical manner. Organise and make connections between themes, ideas, concepts (from different sources) to form a logical narrative.	*This leads to....* *Following this….* *In connection with….*
Evaluation evaluate **Making judgements** about the relevance and usefulness of information on the basis of evidence. Presentation of opposing viewpoints (**comparing and contrasting**), and developing a line of thought (with supporting references); observing differences in methods, approaches, rationales and; **justifying** the argument/information.	Make judgements (**assess/justify claims**) about the value or merit of info/issue; assess the acceptability, the level of confidence, the probability or truth of the information, situation, belief or opinion. Analyse arguments/ present both sides of an argument (work of others): identify and differentiate: (a) the intended main and intermediary conclusions, (b)the premises and *reasons* supporting the main conclusion...., the overall structure of the argument or intended chain of reasoning that **develops reasoning** Query/Weigh evidence – is it relevant/useful Look for bias, seeing errors identify gaps in the argument; be able to discriminate/distinguish between facts/arguments/evidence	*This is likely to be due to …* *This could be….* *It is clear then....* *This demonstrates/suggests that….* *X said this, but y said the other; however, x did this, but y did that* *Nevertheless; therefore; whilst; however...* *Sometimes this happens, and other times* *In contrast to…* *Likewise/similarly….* *The alternative to this is….* *The strengths are….* *This is useful because….* *This contradicts….* *This supports…..* *This may be because…* *On the one hand…., but on the other hand…* *However…….. although…..*
Synthesis create Evidence of joining together different pieces of knowledge, supported by evidence (multiple references) , and **making inferences** about these in order to **create a new claim or**	Integrate knowledge to form a new statement Be able to make **inferences or conclusions** by drawing together disparate knowledge to form a *new* concept, idea, opinion Predict Demonstrate an understanding of the **implications & consequences**	*On balance….* *In conclusion….* *Therefore ….* *There are many factors….;* *Together...* *This suggests....* *On reflection…* *Further studies....; in future…* *If..., then....* *Perhaps….*

output May include reflective thinking creative thinking Output might be the production of a plan, proposal	Addressing the questions '*So what? What is the impact?*' How does this fit into the wider field? What needs to be done to clarify the evidence? Recommendations? **Hypothesise** Addressing the question '*What next*?' Realising the implications and limitations of work and suggesting creative/alternative approaches	*This could mean….* *Results are limited by…* *The next step would be…* *An improvement would be…; This could be done/tried* *Alternatively….*

Appendix 2: Guide to Critical Thinking

Critical thinking, reading and writing

What is critical thinking?

Critical thinking is at the heart of higher education. It is an **active** process that involves asking questions, evaluating, categorising, and finding relationships in information from one or more sources. To be critical is to ***question*** the information, results, conclusions and opinions in a text/s and present an overall objective evaluation or judgment based on the evidence that is reported. We can define **critical thinking** as

"the process of conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by research, observation, experience, reflection, reasoning, or communication, as a guide to belief and action."

*Adapted from a statement by **Michael Scriven & Richard Paul**, presented at the 8th Annual International Conference on Critical Thinking and Education Reform, 1987*

Reading critically

In order to *write* critically, you must be able to *read* critically; to analyse and evaluate the sources of information that you gather. Applying critical thinking when reading academic texts will help you to review material appropriately for critical writing in essays, dissertations, literature reviews and reports. Table 1 presents a grid to help you critically read (and write) research papers.

Critical review

A critical review is a *written* summary and evaluation of a text or topic. A critical review can be of a book, a chapter, a journal article, or web-based resource, or a *combination* of these. Critical writing involves reporting, describing, clarifying and explaining information in a clear and comprehensive manner, and identifying key aspects, ideas, issues or problems within, linking these in a coherent narrative, and evaluating the evidence supporting them in order to make valued judgments and synthesise reasoned conclusions with reference to broader knowledge and concepts/the wider context.

Typically critical thinking and writing should be evident throughout a review/essay/dissertation, and in the introduction and discussion sections of a scientific report. The results section should also demonstrate elements of critical thinking/writing (here reasoning) by the way the information is grouped or categorised, and analysed. Although an essay, dissertation or literature review may not have a 'Methods' or 'Results' section, the **main body** of the work should be structured into **paragraphs or sections**, each of which should focus on one aspect of the topic. This aspect should be stated clearly, **described, explained and developed** by integrating information from a variety of sources, citing these sources as **evidence** supporting your statements. Each paragraph or sub-section should end with something (piece of information, or an idea) that links logically to the next and sometimes back to the title to ensure that the relevance is clear.

For each source, or when comparing different source, you should **analyse and evaluate** not just results or data, but claims or conclusions, argument or opposing viewpoints, or research findings. Think about the accuracy and reliability of any data, and consider why different sources might agree/disagree. **Weigh the evidence**; look for bias, errors, assumptions and limitations that might have influenced the outcome, so that you can make an objective **judgement** about the value and validity of the argument or claim, based on the evidence. Look for flaws in any argument, and think about what might be missing or needed to make a claim more robust.

Tips for critical writing: structuring your work

Critical writing is conveyed through BOTH format (sequence, structure and logic of your arguments) and content (breadth and depth of your reasoning).

Plan your work carefully:

- **Identify** key topics, issues, problems or aims that you will address. State any working hypothesis.
- **Gather sources of evidence** to reference any factual information that you present, and to support any issues, ideas or problems that you describe; make sure that you understand what you read!
- **Categorise** your literature research and into **sections/subsections** relating to different aspects that you want to cover (a detailed mind map or an Excel matrix may be helpful tools here).
- **Sequence** these categories to form a logical narrative.
- **Link** the ideas into a logical sequence so that your writing flows from one item to the next.

Once you have reached that stage, you have a **detailed plan** and can start drafting your work.

Key points to consider in critical reading and writing

To help you identify critical thinking in the literature and implement critical thinking and critical writing in your assignments, we have also developed a set of descriptors and guidelines **(Table 2)**. We have based the descriptors on **Bloom's taxonomy** (Bloom, 1956), which describes a hierarchy of cognitive skills (attributes or actions) involved in learning. There are six major categories starting from the simplest to the most complex, which can be further classified into 'lower order skills' (Knowledge, Comprehension, Application), and higher order skills (Analysis, Evaluation, Synthesis). **It is the higher order skills that distinguish critical writing from mere reporting**, and so you need to develop and showcase the latter in your assignments.

Use the table to help you produce more sophisticated, critical pieces of writing.

Table 1 Tips for Critical Reading and Writing of research papers (but can be adapted for reviews)

What is in this section?	What questions should I ask myself?
Introduction	
Background information to set the scene. Frequently ends with a justification for the rationale of the work. May include aims or hypothesis if appropriate.	Is the title clarified? Are terms defined? Is the aim, problem, or issue clearly identified? Is a hypothesis stated? Is background information described, explained and clarified? Is a rationale given for the research?
Methodology or approach	
How the work or research was carried out (if applicable)	Are the methods consistent with qualitative or quantitative research? Are the methods clearly explained and justified? Are important details provided, so that the research could be replicated by someone else? Are details of data collection clearly described and justified? Are any ethical considerations explained?
Results	
Presentation of data Analysis of data Description of findings	Are the results presented clearly and consistently? Are any graphs or tables clearly and coherently presented? Is sufficient detail provided? Are any gaps in the data explained?
Discussion	
For a **scientific report**, the discussion section should explain and comment on the Results. **The concluding section** of a review and **discussion** of the scientific report should **integrate** or draw together the information, ideas or main findings into concise concluding points. Interpretation may be in relation to a framework or theory. It might be appropriate to discuss whether there is a balance of evidence supporting one view or another, how valid this evidence is, and what the **implications and consequences** are in the wider context. The **limitations** of the work might be presented alongside creative/alternative approaches that should be **hypothesised**. This might take the form of a **plan or proposal**. Finally, the **context** of the work should be considered with respect to the wider field; how does this fit in with other work, plans, or research? How might it be used or applied?	Are the results accurate, valid and reliable? Are the results explained logically? What claims are made and what conclusions are drawn? What evidence is provided to support the claims? How valid and reliable is the evidence/are the conclusions justified Is the discussion and analysis balanced? What analytical framework, if any, is used to discuss the results? Do different sources agree/disagree? Are the strengths and weaknesses of the study acknowledged? Does the discussion refer back to points raised in the lit review? Are there flaws in the claims or argument? What does this text add to the body of knowledge? (This could be in terms of theory, data and/or practical application) What else needs to be done? What relationship does it bear to other works in the field? What is missing/not stated? So what? What are the implications of the work for the subject/discipline?

Table 2 Critical thinking descriptors and guidelines based on Bloom's Taxonomy

Category	Descriptor	Guidelines
Knowledge	**Describe/list/report** information It also includes methods and results in a scientific report.	*What* is it about? At the start, you may need to **define** terms in the title, or restate the title in your own words. *What* information do you need to include? Sources should be referenced. *What* does it mean? You may need to rephrase some of it in your own words; **describe** and **clarify** the material. *Who* did the work? *When* and *where* did it happen?
Comprehension	**Explain** in your own words what the information means, in order to demonstrate that you understand it; **Justify** what you are doing. Your writing should be *clear* and *comprehensible*.	*How* does that work? *Why* does that happen? *Why* am I doing it this way?
Application	Make **generalisations** based on theories or concepts relevant to your field. Relate **theory to practice**.	Apply theories to practical situations. *What if*? Solve mathematical problems. Construct charts and graphs. Demonstrate correct usage of a procedure. Use **examples** and **analogies** to illustrate your explanations.
Analysis	**Identify salient points** **Break up** the material into logical 'chunks' and **Reorganise** these to fit your plan of work.	**Identify** (and justify?) key topics, issues, arguments/problems or assumptions that need addressing to answer the question. Perhaps you need to establish and justify a framework of analysis (e.g. criteria of evaluation). ? **Categorise, sequence and link** the material together in a *logical* and *coherent* format; planning your work is key. In what order will you present your material? Sequence the material into a logical narrative. What is the connection between one paragraph and the next? Each paragraph should end with an idea or fact that forms the subject of the next; link them together so that the writing

		flows from one item to the next. *So what??*
Evaluation	**Explore and examine** the information that you are presenting in order to form a **judgement** about the *value and/or merit* of the material or its *limitations*.	*What* does the material or do the results mean and how is it relevant to the topic? **Explain** (interpret) and make an **objective judgement** based on evidence about the merit and/or value of the material; can it be believed; is it useful? **Analyse the argument** if there is one. *How* do the results or claims from one or more sources stack up? **Compare and contrast** different sources. Are they in agreement or not? Does one piece of evidence support another? If not, why might that be? Try and think of possible reasons by **weighing the evidence**. Are the methods sound? Look for bias or errors. Are the assumptions valid or are there gaps in the argument? What are the limitations of the work? Are the results accurate and precise? Is the interpretation/reasoning logical?
Synthesis	**Integrate** information that you have found and decide *what* can be **concluded** from analysis of the data/information. **Consider** it in the wider context. **Plan or propose** where to go from here.	What are the key conclusions/outcomes of your work? This is **new knowledge/ideas** that you have identified or formulated as a result of evaluating and integrating material from different sources. Is there a balance of evidence in favour of one outcome? Does any further work/research need doing to support your inferences or conclusions? What next? Can you **hypothesise** about what might/should be done? So what? What are the wider implications of these conclusions? How does it fit in to the wider body of knowledge? Are you able to make **predictions** about the implications or consequences of what you have written? Do you need to formulate a plan or new proposal?

Example of critical writing for an essay: *Ebola: a disaster waiting to happen?*

INTRODUCTION

Set the scene with information relating to the title, defining and clarifying terms.

***What** is Ebola?*
***When**, **where** and **how** was it first discovered, and by whom?*
***What is the issue/problem that you have identified** to address in this essay (e.g. virulence and transmission versus effective treatment – does this mean that it is a disaster waiting to happen?)*

MAIN BODY

What main topics will you cover?
Address the questions: What? Who? When? How? Why? (Reference your sources)
***Scientific**: structure, replication, transmission, virulence, treatments, prevention, outbreaks.*
***Other**: Political influence, WHO, education, impact of culture*

For each point/aspect (in a new paragraph):
Start by stating the particular aspect, issue or problem the paragraph will tackle (topic sentence).
Then develop the body sentences as follows

- **Report** facts, information or issues and define/ clarify any terms.
- **Describe** and explain what it means in your own words.
- **Develop** this by citing one or more sources, and evaluating the supporting evidence; is it reliable/valid, what are the limitations, what were the assumptions, was the methodology sound (e.g. sample size big enough)?
- **Compare** different sources to see if they agree or disagree, and try and think about why that might be. What did they do that was similar/different?
- **Illustrate** your work with figures where appropriate and examples from other diseases where appropriate (e.*g. bird 'flu*), and/or refer to models, theories or rules that underpin your material where appropriate.

Finish with a conclusion sentence, linking back to the main topic (relevance) or making a transition to the next aspect.

CONCLUSIONS

What can you conclude overall?
Draw together the key points from the main body.
Does the evidence overall suggest that it was a disaster waiting to happen?
Given the mode of replication, and transmission, and the lack of effective treatments, it could be a disaster waiting to happen. This is compounded by mis-information, lack of political motivation to admit that there was an outbreak, lack of education about the virus, cultural beliefs and behaviours.

Does any further work/research need doing to support your inferences or conclusions?
So what? What are the wider implications of these conclusions?
Further work on new treatments; better education of populations; better communication at all levels.

How to assess critical thinking: Two methods using descriptors and rubrics

Peter Facione and Noreen Facione have developed a four-level Holistic Critical Thinking Scoring Rubric to assess critical thinking skills.

Below are the criteria for level 4, the highest level.

Consistently does all or almost all of the following*:*

Accurately interprets evidence, statements, graphics, questions, etc.
Identifies the salient arguments (reasons and claims) pros and cons.
Thoughtfully analyzes and evaluates major alternative points of view.
Draws warranted, judicious, non-fallacious conclusions.
Justifies key results and procedures, explains assumptions and reasons.
Fair-mindedly follows where evidence and reasons lead.

Elaina Bleifield and the Paulus CT Group have also developed four-level Critical Thinking Scoring Rubrics to assess critical thinking skills.

Below are the rubrics for level 4, the highest level. You can see that they also map onto the Bloom's categories.

CATEGORY ONE: KNOWLEDGE AND COMPREHENSION (understanding the basics)

4—The work consistently demonstrates clear, accurate, detailed and comprehensive understanding of the relevant facts / data / theories/ terms as well as the ability to organize the information for application, presentation, documentation, and/or further examination.

CATEGORY TWO: APPLICATION AND ANALYSIS (attaining the concept)

4—The work demonstrates confident ability to work with the key concepts / information / process / theory -- applying or extending them to a wide variety of new problems or contexts, making predictions, recognizing hidden meanings, drawing inferences, analyzing patterns and component parts, communicating insightful contrasts and comparisons.

CATEGORY THREE: SYNTHESIZING AND EVALUATING (going beyond the given)

4—The work demonstrates surprising/insightful ability to take ideas / theories / processes / principles further into new territory, broader generalizations, hidden meanings and implications as well – as well as to assess discriminatively the value, credibility and power of these ideas (etc.) in order to decide on well-considered choices and opinions.

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Appendix 3: Online employability survey

Opening message (same as in email)

> Dear final year student,
>
> Your final year project should be an experience that helps you gain/hone skills desired by employers.
>
> To find out to which extent your project has made you more employable, please complete our anonymous survey. The survey comprises a list of skills for which you will self-determine your level of competence BEFORE and AFTER the project completion, and one open text question.
>
> Once the questionnaire is completed, you can enter our prize draw. There are four prizes, each worth £25 of Love2shop vouchers. The results will be announced on Wednesday 13/05 at 10 am. Good luck!

Employability skills audit after completion of your final year undergraduate project.

Degree programme?
Degree with placement year?
Type of final year project?

Complete this skills audit below. Rate on a scale of 1-4 [4 being the highest] your level before and after your project work.

No evidence of competence in this area (never done it)	Evidence of competence in some elements associated with this area (done it once or twice)	Evidence of competence in most elements associated with this area (done it several times, competent)	Evidence of competence in all elements associated with this area (wealth of varied experience, skilled)
1	**2**	**3**	**4**

Communication skills (personal skills)	Where you might have done it	Score start	Score now
Formal written communication skills	Project report (or Portfolio)		
Writing for different audiences	EDU/ELP resource, Portfolio pieces		
'Everyday/routine' written communication skills	eMails to supervisor or other interested parties		
Formal oral communication (Formal public speaking)	Tutorial talk, presentation to research group		
'Everyday/routine' oral communication skills	Discussing/formulating ideas with supervisor and colleagues		
Capacity to express difficult opinion in a tactful manner	Giving feedback to a colleague; trying to resolve differences with colleagues/supervisor		
Negotiation skills	Trying to reach an agreement over an issue by stating and supporting your case		
Networking skills	Forming working relationships with colleagues/new people		

Research skills	Where you might have done it	**Score start**	**Score now**
Research skills: ability to find a wide range of information	Researching literature or other resources related to your project		
Technical skills: experimental or IT	Conducting everyday project work		
Analytical skills (formal): ability to handle data appropriately (text or numbers) and present key features	Looking at and sorting out data that you have collected, and present it so that it can be understood		
Critical thinking: ability to understand and evaluate information/data to determine its merit/value/worth	Thinking about what data or information means, possibly in relation to other work; comparing one set of data with another		
Drawing conclusions	Summarising information into a series of key take home messages		

Project Management skills	Where you might have done it	Score start	Score now
Time management/task management	Planning of routine tasks and milestones/deadlines		
Organisation: ability to generate realistic and clear action plans	Planning your project overall as well as routine tasks		
Output: ability to produce deliverables to a high standard and on time	Generating experimental data, EDU materials (lessons, games etc), ELP resource, final report		
Leadership: ability to take charge and set an agenda or put a plan into action	Being in charge of a class		
Practical problem solving: ability to find practical and common sense solutions	Logical ways of approaching project and any problems that encountered		
Creative problem solving: ability to find 'out of the box' solutions	Novel (unusual) ways of approaching project work and any problems that are encountered		
Reflection and Reviewing: ability to reflect on and monitor progress, and regularly update plan accordingly	Completing lab book (e or other), before and after meeting with supervisor or attending training workshops, reflective part of the SMP portfolio,		

Personal skills	How you might have shown it	Score start	Score now
Professionalism, commitment and reliability	By being adequately prepared before a task/meeting; committed to the work; punctual, organised, enthusiastic, reliable.		
Collaboration: ability to work effectively with other people where appropriate	By working with others on the whole project or part of it, or liaising/negotiating with others as appropriate.		
Independence: ability to work on a task with minimal training or supervision	By being ready to have a go/getting on with work, making sure any training is recorded adequately to be independent later, finding information for yourself when necessary.		
Resourcefulness/initiative	By being proactive in seeking information from various sources and coming up with ideas/solutions to problems.		
Perseverance/tenacity	By sticking with project when things don't go quite to plan. By finding a way through a problem.		
Confidence	Through your interactions with staff/colleagues/peers and your approach to the project –becoming more assertive/professional as you progressed		

Other questions:

- We are aiming to launch interdisciplinary projects in the near future where, for example, a student from the education Faculty will work with an EDU student to produce class activities, or a student from the computer science Faculty will work with an ELP or bio-informatic project student to produce their resources. Do you think this is a good idea and would it have appealed to you personally? [free text]

Appendix 4: Slides for presentation entitled “Projects with the ‘e’ factor”

Student Projects with the 'E' Factor

Maggy Fostier & Carol Wakeford
Faculty of Life Sciences
University of Manchester

Email contacts: maggy.fostier@manchester.ac.uk, carol.wakeford@manchester.ac.uk

7 types of FYP

- Lab/Field; Biomodelling; Bioinformatics; LAB
- History of Science, Technology and Medicine
- Enterprise Projects; BUS
- Science Communication
  - Science Media Projects; SMP
  - eLearning Projects; ELP
  - Education Projects; EDU

Create & evaluate a resource: lesson, practical, problem-based tutorial activity, resources for flipped lectures

Current Model

one student – one supervisor for all except BUS; 6 students – one supervisor

Semester 5	Semester 6
Bioscience Literature Review Project Proposal Begin preliminary project work Supporting Seminars	Project work Project report *Supervisor is first marker + moderator* *Core assessment criteria including critical thinking*

Interdisciplinary Projects: rationale

- Employers use multidisciplinary teams
- Final year projects/dissertations are good opportunities for cross-discipline projects
- The benefits:
  - sharing expertise/interest and making the output better
  - increasing employability by honing new skills through a unique experience

What do we mean by interdisciplinary projects?

Projects where the "*learners draw on two or more disciplines in order to advance understanding of a subject or problem that extends beyond the scope of any single discipline*." (Graham et al, 2014)

Collaboration *"can be described along a continuum delimited at the one end by informal communication and exchanges and, at the other, the homogeneous integration of disciplinary components"* (Gnaur et al., 2012).

Project approach

Development of **assessment criteria** for interdisciplinary projects.

Validation of current assessment criteria by staff from two Schools using semi-quantitative analysis of reports for **critical thinking**, using NVivo 10 software for text analysis.

Employability audit to determine student perceptions of the **added value** provided by final year projects, and to identify **skills gaps**

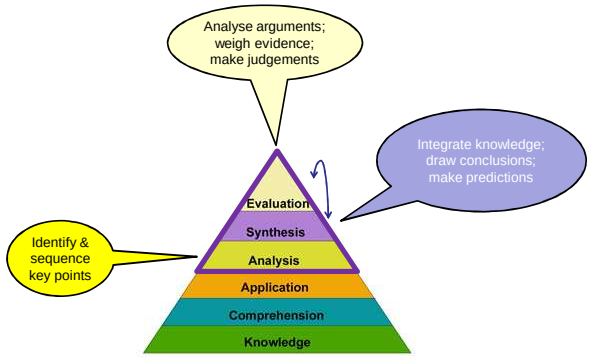
Design of a **model for interdisciplinary projects**

NVivo Text analysis for Critical Thinking based on Bloom

Analysis of Critical Thinking

- Compared % critical thinking (CT) in upper second (2:1) and first class (1:0) reports across different types of project using NVivo 10 software
- 30 reports (Introduction & Discussion sections); 6 each from LAB, EDU, ELP, SMP, BUS
- Descriptors based on Bloom's taxonomy (adapted from Hughes, 2014)
- Analysis performed by 2 RAs, one from Bioscience; one form Education

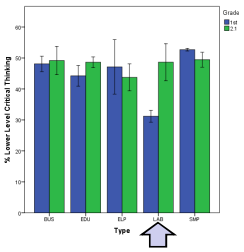
Critical Thinking descriptors

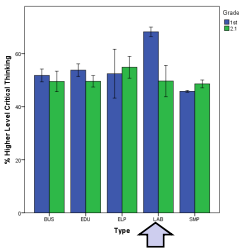


Lower vs higher order skills

Lower order skills
(knowledge, comprehension, application)

Higher order skills
(analysis, evaluation, synthesis))





Proportionally more lower order skills in 2:1 lab reports, and proportionally more higher order skills in first (1:0) class lab reports; NO difference in other types of report

Why no difference in CT?

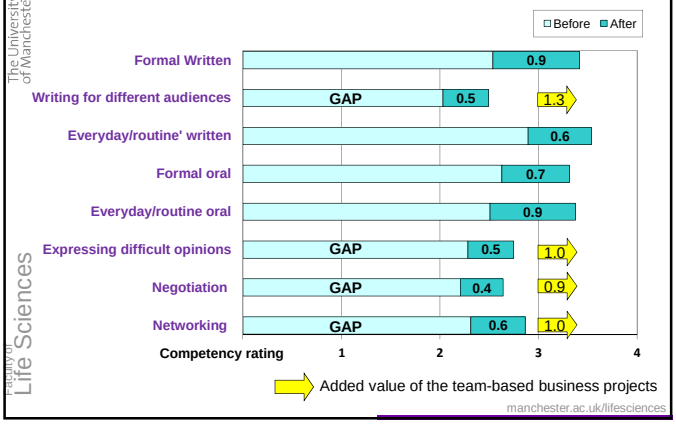
- Actual classification was dependent on additional factors (only analysed intro/discussion)?
- Methodology based on Bloom more suited to lab reports (descriptors more appropriate)?
- Bioscience supervisors may not be able to discriminate so accurately between 2:1 & 1:0 in non-lab reports?
- Sample size too small?

Employability audit

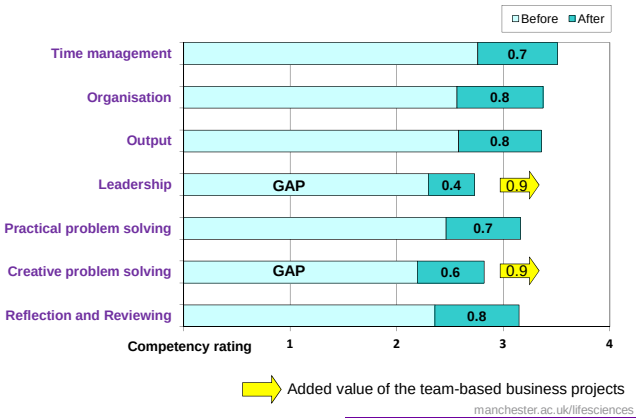
Employability audit analysis

- 67 respondents including 42 LAB, 3 EDU, 6 ELP, 4 SMP, 4 BUS.
- Perceived level of competency rated [Likert 1-4] 'before' and 'after' on 26 skills grouped in four sets: **Communication, Research, Project management, Personal**. (Harvey, 2001; Maxwell et al., 2007).
- The mean 'before' & 'after' scores and their differences were calculated. Skills gaps were defined by mean 'after' scores ≤ 3
- Analysis using Wilcoxon signed rank test. For all skills the difference between before and after is highly sig P<0.0001

Communication skills



Project management skills



Added value for each project

Total skills gained per student

N=	67	3	6	42	4	45	40	27
total mean score/ maximum possible score x 100	Total	EDU	ELP	BUS	SMP	LAB	Non IE	IE
Before score (%)	63	56	59	62	67	62	59	66
After score (%)	81	71	81	86	85	81	80	82
Difference (%)	18	15	22	24	18	18	21	15

Where are the gaps?

- Parity amongst projects
- All skills improved for all projects on average
- Gaps identified mostly in team working types of skills – could be addressed by interdisciplinary projects
- EDU showed most skills gaps but sample size small – to be repeated.

Projects with the 'E' Factor

Enhanced

- **E**mployability
- Student **e**xperience – novel opportunity
- **E**ngagement – favoured by collaboration
- **E**xcitement – new and interesting projects
- **E**ffect – better quality output and more rigorous research

Launch in 2015-16 with 4 projects between bioscience and education

Examples of potential collaborative inquiries between Bioscience and Education students

- What are the language barriers to learning biology?
- An investigation into the effects of culture shock on international students in FLS at the University of Manchester
- How does the use of analogy/metaphor in the biology classroom influence learning?
- What are the common misconceptions about biology (at school level or HE) and how might these be overcome?
- How do bioscience and education students use social media for learning?

Your turn

- Can you think of an idea for an interdisciplinary project between us and you?
- (Bioscience + ??)

- Jot it on a post-it and leave it for us!

Thanks to….

- Our 2 RAs Chrissy Stanley and Diane Harris for their patience, perseverance and good humour!
- The Centre for Higher Education, Research, Innovation and Learning, University of Manchester for funding this work
- Colleagues in the School of Education for their cooperation and continuing support

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