Using Enquiry-Based Learning to prepare Students for Group Work: Results of a follow-up evaluation

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This paper reports on the evaluation of a second-year Enquiry-Based Learning (EBL) activity designed to prepare students in the School of Electrical and Electronic Engineering for a group project, known as the Embedded Systems Project [1].

Enquiry-Based Learning is a student-centred, collaborative approach to learning, which allows the student to investigate discipline knowledge, whilst developing personal, professional and other transferable skills. It has been applied successfully in many contexts; there are many examples in the University of Manchester and more specifically in this particular School. However, this example of EBL has received very mixed reactions from students and staff, ranging from the very enthusiastic to extremely negative. As a response to these reactions the EBL activity has been adapted for each of the three years of its delivery.

Previously, the rationale, development and evaluation of its first implementation have been presented [2], and more recently its development over three cycles delivery has been described [3]. An action research methodology [4] has been employed to investigate this activity through its successive implementations, and to inform its development. These evaluations have focused on the delivery and the perceptions of the students and staff during the activity.

This paper focuses on the effectiveness of the EBL activity as perceived by the students and staff engaged with the embedded systems group project, which takes place in the second semester. Supervisors of the Embedded Systems Project, many of whom were engaged in the delivery of the EBL activity in the first semester, were interviewed regarding their perceptions of how the activity influenced students as they began to engage with the project. The students were approached in their laboratory sessions, towards the beginning of the project, to solicit their experiences and perceptions of how the preparatory activity has influenced their behaviour. These two perspectives were triangulated.

It was found that students are developing the required generic and discipline-specific skills to aid them in the Embedded Systems Project. However, not all students are engaging sufficiently with the activity, owing in part to its being under credited. Suggestions for improving the activity are also made.

I. INTRODUCTION

A survey of employers, conducted by the Institute of Electrical Engineers (IEE, now the Institution of Engineering and Technology, IET) [5], highlighted a mismatch between the skills required by electronic engineers and the skills that graduates possessed. This finding is in line with those of similar studies and engineering educational reviews in both America and Australia [6]. These studies emphasise a lack of teamwork and communication skills. There has been debate about the most appropriate method of embedding these skills into the engineering curricula, whether Problem-Based Learning (PBL) or project-based learning approaches are more suitable [6][7]. This paper describes a development where these approaches are used to complement each other. PBL is used to provide a structured approach and framework to prepare students for project-based learning.

A. Background

This development takes place against a background of increased interest in Enquiry-Based Learning (EBL) of which PBL and project-based learning are examples [8].

The University of Manchester was awarded a CETL (Centre of Excellence in Teaching and Learning) by HEFCE (Higher Education Funding Council for England). CEEBL (Centre for Excellence in Enquiry-Based Learning) [9] supports a number of projects across the University.

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The University of Manchester has worked in collaboration with University College London and the University of Bristol on the implementation of PBL into electrical engineering degree programmes [10]. In Manchester, PBL has been introduced into the areas of VLSI design [11], Optoelectronics [12] and Robotics [13].

The School of Electrical and Electronic Engineering at the University of Manchester offers five related degree programmes: Electrical and Electronic Engineering (EEE); Electronic Systems Engineering (ESE); Mechatronic Engineering (MTE); Computing and Communications Systems Engineering (CCSE); and Computer Systems Engineering (CSE), as 3 year BEng or 4 year MEng degrees. These programmes have a common first year, specialised second year through core units and further specialisation in the third and fourth years through core and optional units. The current second year consists of 132 students, divided into 24 tutorial groups of 5-6 students from a mix of degree programmes.

B. *Rationale*

The stimulus for the present exercise arose from experience gained in a practical team project that the school has recently introduced into the second year of its programmes. Known as the Embedded Systems Project (ESP), this ran for the first time in the 2004-05 session, after having been piloted in the MTE programme in the previous year [1]. The ESP represents a 10 credit unit of continually assessed project-based learning.

In the ESP students work in teams of typically 4-5 throughout Semester 2 on the design and implementation of a microcontroller based product. Each programme had a different project, reflecting the specialities of that programme:

- EEE students worked on a model of a 11kV ring circuit;
- MTE students designed and constructed a robot buggy;
- CCSE students looked at data transfer between two microcontroller boards, initially over wires then over a radio link;
- CSE and ESE students implemented a weather recording station with pressure sensors, liquid crystal display and FPGA (field-programmable gate array) controller.

All of these projects have substantial hardware and software components.

To prepare students for this, a 1 credit team-based activity was accommodated into the first semester of the tutorial system [2]. It provides an opportunity for students to develop and practise their teamwork, project and presentation skills in the supportive environment of the tutorial before employing them in the higher stakes environment of the team-project. It was anticipated that they would be able to engage with the team-project more effectively and earlier as a result of this preparation. Consequently, this activity was modelled on the team-project, reflecting its subject matter and its assessment, but the level of activity was proportionately smaller.

Students were asked to design a sensor system, based on the microcontroller processor board that they would use in the team-project, to capture the temperature profile of a commercial decorative tile kiln. This was seen as a suitably authentic task that employed electronic engineering in the context of providing a service to another industrial process. The project involved:

1. planning the project tasks over the semester;
2. choosing a temperature sensor;
3. designing a circuit to interface between the temperature sensor and their microcontroller board;
4. considering the practical implementation issues of the system;
5. making a group presentation of the previous activity.

Tutorial groups met weekly over weeks 3-8 of the first semester to discuss progress on the project. The groups were expected to meet independently between tutorials. The transferable skills were supported by a series of lectures and student guides [14], specifically covering teamwork, project planning, searching for information and group presentation. Student contribution was continuously assessed at the tutorials and the presentation was assessed.

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II. METHODOLOGY

Previous evaluation of this project has focused on the delivery of the activity and students' responses to this [3]. This paper focuses on the effectiveness of the activity: as perceived by the students and staff engaged with the second semester group project.

A qualitative approach was taken, in order to capture the variety of staff and student perspectives and insights into the interaction. In both the staff and student interviews, the context of the enquiry was established: to what extent have the Second-Year Tutorials prepared students for the Embedded Systems Project. Once established, open, goal-free [15] questioning was employed to avoid steering the responses to our preconceived ideas. In addition, the direction that the interviewees took the interview and opinions that they expressed were valued, giving permission to both affirming and dissenting opinions.

There were a number of reasons for adopting this approach. Universities have currently established many evaluative systems. Both staff and students feel both time-pressured and over-evaluated, with students for example being asked to complete an evaluation form at the end of every module. The nature and purpose of these evaluations often emphasise quality assurance, asking students to rate the quality of teaching. There are alternative purposes to evaluation which are often lost through this more managerial process, those of development, examining how to improve an activity, and the understanding of what is happening in an activity [16]. As a consequence, the response rates to many self-reporting instruments, regardless of their purpose, can be low. Further, the purposes of this evaluation are to understand the attitudes and perceptions that both staff and students are bringing to and taking away from this exercise, and to probe the reasons behind their valuing the activity, not just record the value itself. Consequently, detailed and rich data is required to fulfil these purposes. It was also felt that a direct, personal approach in their work context would more likely produce positive engagement with the evaluation process, bringing the evaluation process to the participants, rather than putting an onus on the participants to fill-in a separate form or turn up to another location. A high level of engagement in the evaluation process is important in ensuring that a representative cross-section of opinions is being reported.

The timing of this evaluation was set towards the beginning of the second semester, allowing both supervisors and students an opportunity to settle into the process of the Embedded Systems Project, but early enough for the first semester Second-Year Tutorial activity to be still relatively fresh in their minds. It was also early enough for them to still be responding to start-up processes of establishing a project team and planning their project.

Embedded Systems Project supervisors, many of whom were engaged in the delivery of the first semester tutorial activity, were invited to be interviewed regarding their perceptions of how the activity influenced students as they began to engage with the project. The students were approached in their laboratory sessions, towards the beginning of the project, to solicit their experiences and perceptions of how the preparatory activity had influenced their behaviour. Views from both these perspectives were triangulated.

III. EVALUATION

A. *Students*

Two laboratory sessions were visited, covering all the projects and degree programmes. Over the two laboratories 23 students, from the potential 132 students of the year, were present, representing about 13 of the 32 groups. All students that were present were approached and all agreed to discuss their experiences. However, the depth and detail of the responses was variable as well as the nature of the responses. Table I summarises the reactions to the Second-Year Tutorial system with indicative comments. Which category the comments appear in Table I reflect whether or not there were qualifications to the initial reaction during the rest of the interview. The letters indicate the student or group that made the comment, where students in a group spoke to me independently a separate letter is given, where they spoke as a group, the number in parenthesis indicates the number in that group.

This is a small sample of the total cohort and one that probably represents the more engaged students, and the data was not collected in the form of a poll or survey. However, it is worth noting that the general reaction from these students was that the Second-Year Tutorial system did prepare them for the Embedded Systems Project: 10/23 without any qualification, and 18/23 with some qualification, only 5/23 were neutral or negative. Inevitably, this paper will focus on some of the negative reactions in detail in order to

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understand them and explore how the activity could be improved, but it should be kept in mind that the overall response was positive.

TABLE I. SUMMARY OF STUDENT REACTIONS TO THE SECOND-YEAR TUTORIAL SYSTEM

Reaction	Comment	Student or Group	Total
Positive	Very useful and important	A	10
	Glad that I did it	B	
	Guess so … Yes, directly beneficial	J	
	Able to start much faster	N	
	Yes, … it gives you an idea of how you will be working in the ESP … Very positive	O(3)	
	Knew what to expect … start a bit quicker … easier to get into the swing	Q(2)	
	Helpful … quite helpful	R	
Mostly Positive	It was a bit different … but it was a nice project … a gentle introduction to the ESP	F, G	8
	Quite useful … a useful thing to have.	H(3)	
	It was helpful, it showed me my strengths and weakness … Good practice	K	
	Yes, … pretty useful … quite good.	P	
	It helped with …	M	
Neutral	Moderate: not very good but not very bad	I	1
Mostly Negative	No it didn't help	D	3
	… just a distraction	E	
	It was OK – quite interesting, not particularly useful preparation	L	
Negative	It did not help, in theory it was useful but … I didn't enjoy it at all but I am enjoying the ESP	C	1

Table II summarises the positive and negative aspects the students perceived of the Second-Year Tutorial system. The positive aspects tend to describe the skills and benefits gained, whereas the negative aspects focus on what was wrong with the Second-Year Tutorials. The comments are grouped by emerging themes, with some illustrative quotations included, the *themes*, indicated by italics, are ordered in descending number of references to them (in parenthesis).

The balance of comments is towards the positive (53 to 31), but there are a number of critical comments to address.

As anticipated, the professional and transferable skills associated with *teamwork* (19), *project* planning and management (15), *presentation* (8) and *communication* (4) were mentioned. Some students reported that it had been the first opportunity that they had had to *work in a team* (3) or deliver a *presentation* (1). This triangulates well with the intended learning outcomes of the Second-Year Tutorials and the skills that the students reported that they were developing from the evaluation of its delivery [2][3]. It is reassuring that the students are reporting that they are finding the development of these skills useful for the Embedded Systems Project. There is also evidence that the Second-Year Tutorials are preparing students for the Embedded Systems Project by giving them an insight into *what it would be like* (4) and in some cases this enabled them to *start the project faster* (3). The experience also provided student K with a *personal insight* into his *strengths and weaknesses*, which has informed the way he has approached the Embedded Systems Project, specifically by focusing on programming rather than sourcing equipment.

The types of lessons that the students have been learning are based very much on their experience and the practice of project work, rather than declarative knowledge. For example, student B described that he *'learnt that other people are good at different things and how to work together on the project'*. In respect to communication, other students (H) mentioned the level of explanation required to ensure that people understood what was required for a task and how important it was *to keep up-to-date* (K) on how tasks were progressing.

The emphasis of the Second-Year Tutorials is on the professional and transferable skills described above and the emphasis of the Embedded Systems Project is on the technical skills of developing an embedded system. However, the technical contents and the transferable skills do not work in isolation. The Second-Year Tutorials use a technical problem as a vehicle to develop the transferable skills and the Embedded Systems Project uses the team-project as a vehicle for the technical content. In fact both technical and transferable skills are being developed in both; the difference is really a matter of emphasis rather than absolute distinction. It is one of the strengths and efficiencies of EBL that generic skills and technical content are being developed in tandem as part of an integrated process.

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TABLE II. SUMMARY OF STUDENTS' POSITIVE AND NEGATIVE ASPECTS OF THE SECOND-YEAR TUTORIAL SYSTEM

Aspects	***Theme***	**Students or Groups**	**Total**	**Comments/Sub-themes**	**Students or Groups**
Positive	*Teamwork*	A, B, E, F, G, H(3), I, J, L, N, O(3), P, Q(2), R	(19)	First experience of doing teamwork	A, B, P
				Managing a team Organising a team to get things get tasks done Learning how to interact as a team	A
				Learnt that other people are good at different things and how to work together on the project	B
	Project	F, G, H (3), I, M, N, O(3), P, Q(2)	(15)	Project Plan Dividing the tasks Gantt Chart Management Deadlines Milestones	H, I, N, O, P, Q N, O, R M, N O H I
	Presentations or Demonstrations	D, F, G, H(3), M, R	(8)	First presentation	R
	Start faster and Insight into the ESP	N, O(3), Q(2)	(6)	Start a bit quicker … easier to get into the swing	Q
				It gives you an idea of how you would be working	O
				Knew what to expect	Q
	Communication	H(3) K	(4)	We learnt a lesson about communication – there were language problems and people not understanding the task, we learnt that more explanation was required.	H(3)
				It taught me that communication was key. It is important to keep up-to-date. I naturally finish quickly, so I need to find out what to do to help others to finish their tasks and catch up on their own.	K
	Hardware	A B R	(3)	Researching components for hardware, understanding if the component would be useful and whether the project could proceed.	A
				Using the simulator properly for the design of a circuit	B
				Looking at temperature sensors was very useful, there was a strong overlap with the weather-station project where we had to look for a sensor. Also developing a filtering and amplification circuit overlapped with the ESP project.	R
	Resources and Information	F, G	(2)	… but there were some useful resources: introduction, lecturers, diagrams and photographs, information on the temperature …	F, G
	Personal Insight	K	(1)	It showed my strengths and weaknesses. I found that trying to look for sensors was more difficult than expected, now I am focusing on programming	K
Negative	*No practical component*	E, F, G, H(3), I	(7)	It would be better to build and test a circuit with the micro-controller	I
	Complexity	E, F, G, 0(3)	(6)	The contents and quantity of the SYT and ESP are very different. In the SYT you just had to look up some information and do an easy calculation, it was a trivial problem, in the ESP you are designing a complex system, writing programs and building hardware, if it was more similar, e.g. building, testing and programming a system it would be much more useful.	E
	Programming	D, E, F, G	(4)	No, other subjects were a better preparation, for example Micro-computer Engineering II is built around programming in C	D
	Time/Credit	C K M P	(4)	… too much time for little credit so people were not as willing to engage. It was hard to get other people involved. It was more obvious who was contributing in the ESP than the SYT so the same people did all the work for the SYT. The ESP contributions are weighted so it is fairer. Despite the SYT employing a similar assessment model, since the ESP was worth more credit, tutors and students were more motivated to ensure that it worked.	C
	Resources and Information	F, G, I	(3)	There was some old stuff on the R: drive with conflicting information. There was confusion on the recommended companies.	F, G
				Not enough information	I
	Technical Content	F, G	(2)	… but I felt that their was a lack of technical content, we floundered with the whole research part …	F, G
	Teamwork	C, D	(2)	I am sceptical about group project work in an individual degree. It is hard to teach yourself to be a team player if you are not one already. I would prefer all of the degree to be individual measures of what you have put into it.	C
	Competing Workload	K	(1)	The first semester was very busy for me with 7 modules and a leadership module, in the second semester there was only 5 modules.	K
	Feedback	C	(1)	Generally, not getting enough support through feedback (summative marks and comments) this year	C

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This is exemplified here by three of the students describing in detail the skills and tasks associated with the hardware aspects of the project: *researching components* (A); *using the simulator for circuit design* (B); *looking at temperature sensors* (R) and *developing a filtering and amplification circuit* (R). These skills are very specific and highly contextualised both in the discipline, electronic engineering, and in the project itself. Other disciplines have research elements; however, they would not have to interpret component datasheets, a specific task influenced by the nature of the components under consideration. The other tasks are specifically associated with electronic engineering and do not have direct analogues in other disciplines. However, developing skills in these areas is valued highly by the students as part of the process of becoming electronic engineers. In fact for these students it was these discipline specific skills that they described first, before the teamwork and project planning and management skills.

The authenticity of the project and the associated tasks is important. For example, the student that described using the circuit simulator (B) had been introduced to it and used it in the first year. However, he felt that this was the first time that he was using it *'properly'* to design *'a real circuit'*. This illustrates the process of moving from 'knowing about' something to 'knowing how to do' something, which requires a much deeper engagement with the tools and the technical knowledge. This is facilitated by an authentic task.

From these discipline specific tasks, more generic skills are also being developed. Researching electronic components will develop skills and teach lessons that can be applied to researching other things. Learning to use a specific circuit simulator will prepare the ground for learning to use other circuit simulators, or more generally how to approach learning to use other technical software applications and tools in future.

Many of the criticisms of the Second-Year Tutorials can be summarised in that it did not go far enough: many would have preferred to see a *practical component* (7); some felt that the problem was *'trivial'* in comparison to the *complexity* of the Embedded Systems Project (6). For some students this was seen as a problem (3) and for others it was merely an observation (3). One student wanted to see a *programming* element included as well (E), whilst others felt that the *programming* modules were a better preparation (3). However, two of these (F, G) felt that the two approaches, programming modules and Second-Year Tutorials, were complementary; whereas the other felt that the Second-Year Tutorials were redundant (E). Some felt that the task lacked *technical content* (2).

So some students would like the task to be more challenging and taken to a more complete stage of a working, programmed system. However, this needs to be balanced with the other major criticism of the Second-Year Tutorials that students felt that it was under rewarded (4) in an already busy schedule (K). Currently it is worth 1 credit, yet students felt that they had put in at least double the effort, over 20 hours, into the activity. Student C captured how this undervaluing of the activity has a detrimental effect on the teamwork: *'… too much time for little credit so people were not as willing to engage'*.

In summary, the majority of students recognise the value of the Second-Year Tutorials as a preparation for the Embedded Systems Project, developing both transferable and discipline-specific skills. However, there are demands for it to be a more challenging and complete project: the building, testing and programming of a complex system. In addition, more reward should be given to the activity in accordance with the time commitment required to complete it.

B. Supervisors

There are 16 members of staff, supervising 32 groups of 4-5 students. In general, each supervisor is responsible for two groups of students. Of these 10 agreed to be interviewed. All but one supervisor (S3) had previously been a second-year tutor and had some recollection of what was involved in the tutorial activity.

Despite agreeing to be interviewed not all of the supervisors were comfortable with the process. One supervisor (S5) thought that it was too early in the project to report on their students' progress. Other supervisors simply observed that it was relatively early in the semester. She also felt that the students would not be open in their opinions about the project to their supervisors, since they were involved in the assessment process, and that it would be better to talk to the second year tutors instead. Another supervisor (S3) felt that he could not comment on whether his students were behaving any differently because of the Second-Year Tutorials, since *'I cannot provide an objective metric on how well it has impacted and how it has gone'*. The *'anecdotal'* nature of the evidence and difficulty of drawing any firm conclusions from very partial experience and information was recognised and commented on by several of the other supervisors. For example: *'there is no control group, it is hard to say'* (S9) and *'but can't generalise it may be only two groups'* (S7). The other supervisors interviewed were more comfortable with the request.

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Table III summarises the supervisors' reactions to the effect of the Second-Year Tutorials. As with the student reactions, the category indicates whether the initial reaction was qualified elsewhere in the interview or not. The balance of the supervisors' reactions is towards the positive, 6 positive to 4 neutral and negative. However, the number and nature of qualifications and negative responses is a cause for concern.

TABLE III. SUMMARY OF SUPERVISOR REACTIONS TO THE SECOND-YEAR TUTORIAL SYSTEM

Reaction	Comment	Supervisor	Total
Positive	It is invaluable for them … the group-project work they do in the SYT, this work, the material that you generated, I think is very good; it helps a lot.	S1	2
	A quantum step change in behaviour	S2	
Mostly Positive	Worth doing but needs to be related more to ESP	S4	4
	Good idea but needs candy or stick	S6	
	Good idea but not chunky enough to engage	S7	
	No control group … good thing to do before the ESP, it probably works	S9	
Neutral	*[No direct comment – offered balanced review of students – assume neutral]*	S8	1
Mostly Negative	The SYT has receive a lot of flack this year	S3	2
	The students don't like it [SYT] they fall out amongst themselves over it.	S10	
Negative	*[No comment, but tutor group was vocally critical in a previous year – assume negative]*	S5	1

Table IV summarises the comments of the supervisors about the impact on the Second-Year Tutorials, grouped by emerging theme. It is a similar format to the student comments; the *themes* are indicated by italics, grouped into *positive* and *negative* aspects, the negative aspects are divided into comments about the *students' performance* and comments about the *Second Year Tutorials.* The themes are placed in descending order of the number of supervisors that referred to that theme (in parenthesis). An additional category of *possible improvements* to the Second-Year Tutorials has been added.

The discussions with the supervisors were rich and diverse, often drawing on multiple experiences and perspectives, for example: feedback from their students; the performance of their students both past and present; their experiences as second-year tutors; other teaching experiences including PBL, EBL and other project work at undergraduate and masters level. It is difficult to do justice to all the discussions here.

Many supervisors identified that their students had benefited from the Second-Year Tutorials through developing skills associated with *teamwork* (7), *project planning* (5) and *presentation* (3) in-line with what the students have reported above and previous evaluations [2][3]. However, sometimes these comments were phrased in general terms or in terms of *'ideally'* or *'in principle'* (S9), rather than being categorical statements.

One supervisor (S3) particularly picked out the *searching for sensors*, identified by some of the students (A):

> *It is interesting that you ask them to look for a temperature sensor. This year in the MTE project we have asked them to identify a sensor for their robot to use to follow a white-line on the floor: this is something that they seemed to have done well at.*

reinforcing the idea that contextualised discipline-specific skills were being developed.

There was, however, some *'disappointment'* in the students' performance, particularly in the development of the Gantt chart, which they thought was *'naïve'* (3) and the initial level of *engagement* and activity of some groups (S7). These are clearly two aspects that the Second-Year Tutorials were seeking to address, but in these cases it was not addressing them successfully.

Concern was expressed about the amount of *credit* associated with the Second-Year Tutorials (5). It was felt that this could undermine the seriousness with which students engaged with the activity and especially when it was not proportionate with the time commitment. There was concern that a consequence of the Second-Year Tutorials not being taken seriously was: '*there is a danger that if they shrug off a project failure in the SYT they may go on to a project failure in the ESP'* (S7). A supervisor, who had had the only Second-Year Tutorial group not to engage in the process at all this year, expressed it: *'…it needs the candy or stick to get them to engage. My [SYT] group decided very early that they were not going to engage'*. A counterpoint to the call for credit was made by the supervisor who had not been a second-year tutor (S3): '*you don't need credit to make people do it: if it is interesting and useful it helps'*.

There was a degree of criticism about how it was implemented. It was suggested that (S3):

> *It is difficult to force through change with a large number of staff who are not subject experts and who are very busy, so they have no chance to learn a new area. It needs dynamic and strong leadership at the professorial level to 'bang heads together'.*

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TABLE IV. SUMMARY OF SUPERVISORS' POSITIVE AND NEGATIVE ASPECTS OF THE SECOND-YEAR TUTORIAL SYSTEM

Aspects	***Theme***	**Supervisors**	**Total**	**Comments/Sub-themes**	**Supervisor**
Positive	*Teamwork*	S1, S2, S4, S6, S7, S8, S9	(7)	It is the single biggest issue in the ESP, getting them working well in as a group	S1
				The groups are very well organised, e-mailing me minutes every week	S2
				The SYT presentation that I attended, the group presented very well. Two of the students in my current groups presented came from the group. They are clearly using skills that they had developed in the SYT.	S6
				The groups are at ease with themselves at the beginning – No team-working issues. Teams are happy, but would probably be happy anyway.	S8
				In principle it helps with the teamwork.	S9
	Gantt Chart and Planning	S1, S2, S4, S7, S8	(5)	Especially in confidence to set up the Gantt Chart.	S1
				The students are very organised … they have their Gantt Chart pinned to their lab bench.	S2
				Breaking tasks down	S7
				They are good at the inputs and outputs of the project and knowing the requirements, this is perhaps what you would expect with the type of students they are …	S8
	Presentation	S4, S7, S10	(3)	They are always nervous but they get used to it through practice	S4
	Student Views	S1	(1)	I always ask in the 2nd semester if what you did in the 1st semester was useful – They all said 'Yes' without exception	S1
Negative – Student Performance	*Naïve Gantt Chart*	S7, S8, S9	(3)	Both groups produced naïve Gantt charts – the students claim that 'We haven't done this before!' so it hasn't sank in, they didn't take it seriously enough … The Gantt chart was trivial with no risks and no milestones. They are not picking it up	S7
				I was disappointed in the planning, it was very naïve: no resource planning, allocating tasks against people; no critical path or understanding of a critical task	S8
				… not really developed … not really planned	S9
	Engagement	S7	(1)	Last year my groups had a better start. This year it has been a cold start: No log books; No minutes; They had not read the handbook …	S7
Negative – Second-Year Tutorials	*Credit*	S3, S4, S6, S7, S10	(5)	Not enough	S4, S6
				Not enough marks or time to take it seriously	S7
				They felt it wasn't rewarded enough – a previous year opted out from doing it completely … it needs more credit.	S10
				Neither staff nor students are comfortable with a split module	S3
				You don't need credit to make people do it: if it is interesting and useful it helps.	S3
	Implementation	S3, S6	(2)	It is difficult to force through change with a large number of staff who are not subject experts and who are very busy, so they have no chance to learn a new area. It needs dynamic and strong leadership at the professorial level to 'bang heads together'.	S3
				Tutors not trained for soft skills … they need some more guidance on how to approach the second semester. We are a bit fuzzy about what students should get out of it.	S6
	Motivation	S6	(1)	… it needs the candy or stick to get them to engage. My [SYT] group decided very early that they were not going to engage.	S6
	Project Failure	S7	(1)	There is a danger that if they shrug off a project failure in the SYT they may go on to a project failure in the ESP.	S7
Possible Improvements	*Project Risks*	S7, S8	(2)	One activity might be to put them into the situation of a failing project. How do they know what has happened? Use this to demonstrate the risks and get them to see this as important. Emphasise the problems that can occur.	S7
				Project Risk Analysis: What could go wrong? What mitigation can be made to improve the reliability of the project? This would be a very useful skill. … use a better than average Gantt Chart with these components incorporated as a model for students.	S8
	Link	S4, S6	(2)	Students don't see it as related to the ESP, they don't always make the connection … maybe more clarification	S4
				Make ESP start in the first semester, with the project planning and some mini-reports to drive it.	S6
	Testing	S1	(1)	Provide an Amplifier Circuit and get them to test to see if it works	S1
	Practical and Open Ended	S9	(1)	Personally, I would prefer to do something practical and more difficult to motivate them. Competition would help to provide an incentive. Give them a very open-ended problem so that they can express their creativity.	S9
	Individual Tasks	S10	(1)	Need to have lots of individual tasks … more discrete tasks for the students to assign to each other and work on separately.	S10

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A related concern was that the tutors were *'not trained for the soft skills'* and *'… a bit fuzzy about what the students should be getting out of …'* the activity (S6), suggesting that perhaps the tutors needed more support in delivering the Second-Year Tutorials.

During the discussions, several supervisors suggested ways in which the Second-Year Tutorials might be improved. Two of the supervisors (S7, S8) who were concerned with the naivety of the Gantt charts suggested that it would be useful to emphasise project risk. Each suggested slightly different approaches: an exercise of asking students to save a failing project (S7); or providing a model Gantt chart with project risk management built in (S8). The original Second-Year Tutorials had an exercise of students correcting a flawed project plan from a failing project. It subsequently moved to students designing their own project plans. A similar device could be employed to introduce project risk management and the tutorial activity.

Another suggestion was to strengthen the link between the two activities. There are already a lot of overlaps designed in, but students do not always see the connections. It may be helpful to clarify them (S4). A way of making the links even stronger would be to make the Second-Year Tutorial activity the start of the Embedded Systems Project, possibly the planning stage (S6). This suggestion would have a number of practical difficulties, but more importantly students would lose the opportunity of having a 'dry-run' at a small project and the chance to work with a completely different set of students.

An element that one supervisor (S1) thought was missing was practice analysing and testing circuits. He suggested having a sample amplifier circuit constructed with errors, for students to test and to try to repair.

Another supervisor (S9) outlined his ideal project:

If it ain't broke don't fix it and this ain't broke. But if I could design an ideal project … personally, I would prefer to do something practical and more difficult to motivate them. Competition would help to provide an incentive. Give them a very open-ended problem so that they can express their creativity.

One supervisor (S10), drawing on his experience designing and facilitating PBL in engineering [17], felt that both the Second-Year Tutorials and the Embedded Systems Project would benefit from having more tasks for individual students to get their teeth into and work on independently. However, this might interfere with the teamwork and project planning and management learning outcomes of these activities.

Drawing these comments together, supervisors were generally in favour of the Second-Year Tutorials, though some with qualifications. The development of *teamwork*, *project planning* and *presentation* skills was recognised, though sometimes identified in the ideal rather than the actual. One supervisor identified the more disciplinary specific skill of *searching for a sensor* as being developed. Some supervisors were still concerned with the naivety of the Gantt charts and the engagement of some groups at the beginning of the project, suggesting that not all the intended learning was taking place for all students. This was linked by some to the Second-Year Tutorials not been considered important enough to be taken seriously by the students. One component of this was the amount of time and credit allocated to it. Another component to the importance being placed on the activity is the attitude and confidence that tutors bring to the activity. It was suggested that this may be undermined by the activity not being sufficiently championed, bringing all the tutors along with it, or tutors feeling unsure of the soft skills being developed and requiring more guidance.

IV. CONCLUSIONS

The majority of supervisors and students reported that the Second-Year Tutorials had helped students develop teamwork, project planning and management skills that prepared students for the Embedded Systems Project. Some students reported that it helped them to know what to expect in the Embedded Systems Project and enabled them to start faster. This is in accordance with aims and objectives of the Second-Year Tutorials. In addition, there is evidence of the development of discipline-specific technical skills, such as using a circuit simulator and researching electronic components such as sensors, which are valued by both staff and students and will be useful in the Embedded Systems Project and in the future. This emphasises the importance of the authenticity of the project and the tasks involved for learning how to be an electronic engineer.

There were concerns from some of the supervisors that some of the students were presenting naïve Gantt charts, with little understanding of project planning and project risk management. Also, some groups were still not approaching the project with the required level of engagement. Clearly, not all the appropriate lessons were being learned by all the students.

Both students and supervisors expressed concern about the amount of credit, 1 credit, associated with the Second-Year Tutorials proportionate to the amount of time that it required to complete, at least 20 hours of

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commitment. This was seen as potentially undermining the activity, since it was more difficult to engage students. However, the point is well made that the activity should also be interesting and beneficial to ensure engagement, with the links to the Embedded Systems Project well clarified.

It was suggested that the Second-Year Tutorials would be enhanced if the idea of project risk management could be included in the early stages and a more open-ended problem could be addressed, leading to a more complete solution, including hardware prototyping, testing and programming. An element of competition would provide an additional incentive. This would inevitably be a larger activity, requiring appropriate credit. However, this would be a more engaging and rewarding activity for the students and also develop more of the technical discipline specific skills required to become an electronic engineer.

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