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A University Project to Produce an Analogue Robot Kit for Schools: Do Customer-based Projects Affect Student Motivation?*

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The study presented in this paper explores the effect of modifying a robot design, build and test project to motivate the students to adopt a deep learning approach. This was achieved by changing the end product to a robot kit, which was used to teach year 9 school pupils about analogue electronics. The results showed that the students were motivated towards a deep learning approach by different factors. In this study, three factors were identified. A second part of the project involved the students teaching year 9 pupils using the robot kits. The indications were that this had a favourable outcome.

INTRODUCTION

IN AN ELECTRONICS COURSE the students attend lectures and undertake projects to apply the knowledge they have acquired. Hopefully, as a consequence, they adopt a more intrinsic interest in the subject and hence take on a deeper learning approach. There is a substantial amount of literature showing the benefits of project-based learning and its positive effects on students approaches to learning [1–4]. Such benefits include time to reflect upon concepts and approaches and a greater opportunity to interact with project supervisors and peers to engage in a more interactive form of learning. This has been shown to increase motivation and interest in the subject material and encourages students to take responsibility for their own learning. However, when assessing electronics projects it becomes apparent that although the students have a strong motivation to produce a working system, they do not appear to see the need to understand in depth the theory behind their designs. Hence, the outputs of many projects are non-optimal designs together with a poor understanding of the subject. The conclusion from this is that the projects do not promote a deep learning approach, as described in the literature [1–4]. Therefore, the aim of this study is to modify an existing electronics project and assess whether the changes promote a stronger link between achievement and the motivation to learn.

In order to achieve this aim, the term 'motivation' in the context of student learning needs clarifying. There have been various studies which for example, describe the difference between extrinsic, intrinsic and achievement motivation [5]. This was investigated using the Approaches and Study Skills Inventory for Students (ASSIST) [6] by Solomonides [7] who concluded that the motivational element extracted from the inventory was strongly affected by the context. Therefore the ASSIST inventory is used in the analysis of this project.

The project chosen for this study was initially a one-week project in which third-year undergraduate students worked in pairs to produce a working analogue robot. This was modified into a two-week project in which the first week was identical to the initial one-week project. The aim of the second week was to produce a single optimised design, which then formed the basis of an analogue robot kit. In an attempt to stimulate further the students' motivation towards a deep learning approach, they were invited to two local secondary schools to teach year 9 pupils about analogue electronics using the kits they had designed.

A secondary aim was to assess the viability of this project for promoting electronics at secondary school level. Thus, a secondary aim was to informally assess the benefits (if any) of school pupils interacting with the students in a project environment.

DESCRIPTION OF PROJECT

The project ran over a dedicated period of two weeks, with 100% supervision available. It was one of six projects on offer and four third-year undergraduate students were involved. The aim was to

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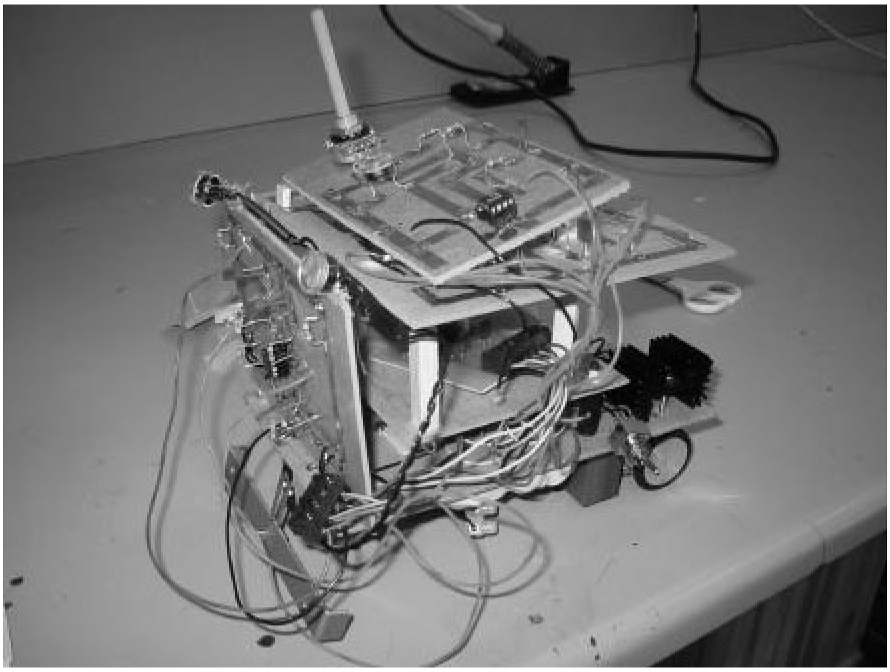

Fig. 1. Light-seeking robot containing circuits produced by secondary school students.

motivate or enthuse the students to understand how the circuits work and to experiment with different designs, rather than just build a working robot. In the first week, the students were required to individually design and build fully functioning light seeking robots using purely analogue electronics, i.e. non-software-based solutions. In the second week, the students were required to pool and simplify their design ideas to produce analogue electronic robot kits for twelve- to thirteen-year olds, based on the light-seeking robots.

The project was assessed in two parts: demonstrating the functionality of the individually designed robots together with circuit diagrams, and demonstrating the kit robot and producing an instruction manual. This exercise contributed to 1.1% of the total marks for the M.Eng. degree course. A final unassessed part of the project consisted of the students helping pupils to learn about electronics using the kits at two local secondary schools. To execute this, two different methods of releasing the information to the schools were used. For the first school the circuits were introduced to the students on a lesson-by-lesson approach. This enabled the teacher to explain the functionality of the individual circuits in detail. The undergraduates then spent two lessons explaining how the circuits were used to create the robot and aiding them in the their construction. In the second school the undergraduates spent a complete day at the school, with the students having no prior experience of the project.

The light-seeking robot

The robot design is based on the behaviour of living creatures. Its main purpose in life is to find light and then sunbathe until it has sufficient energy. It also has a defined behaviour towards other robots; it can either try to push them away or it can simply run away. The second option was chosen for the kit due to its simplicity. A photo of a typical assembled robot is shown in Fig. 1 with the circuit schematic in Fig. 2. It consists of two individually driven motors driving the back two wheels and an undriven caster at the front. The robot steers towards the light by sensing the light intensity at both sides of the robot. The light direction circuitry then stops the motor on the brightest side and switches on the motor on the darkest side. Hence the robot steers towards the light. The light intensity circuit stops both motors when the robot gets near the light. The robots can detect the presence of each other by means of bumpers connected to switches. (In the initial designs, ultrasonic transducers were used. However, the circuits associated with these were considered to be too complicated for schools.) The response of the robot is to swerve backwards and run away. This is done by sending signals to the motors to turn in reverse. One motor does this for one second and the other for three seconds. The result is a turning motion.

The school robot design exercise

The robot kit consisted of a chassis with two bi-directional motors and associated control circuitry to drive the two back wheels. A metal caster was used instead of a front wheel due to its better manoeuvrability. The robots were supplied to the schools with working circuits attached to the chassis circuitry in three modules, the light level detector, light direction detector and the bumper timer circuitry. Thus the robots were fully functional at the beginning of the project. The aim of the project was for the students to learn about and build fully functioning circuits, which could then

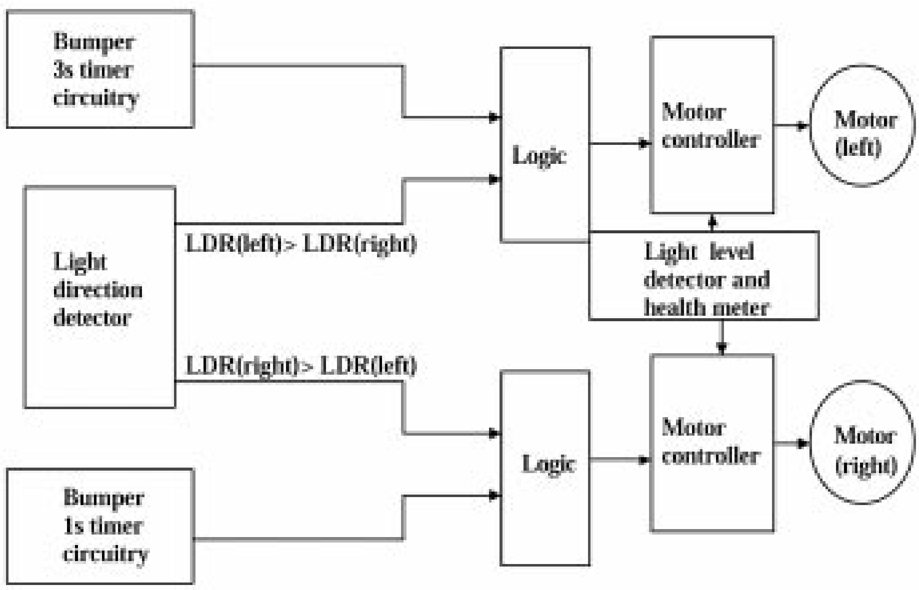

Fig. 2. Circuit schematic of robot.

replace the standard circuit modules on the robot. Therefore, as the project progressed, the robot contained more circuit modules produced by the school pupils. An example of such a circuit module is a light controlled switch. This can be tested totally independently of the robot. When it is working its inputs and outputs can then be connected to the robot to become the light level detector which determines how far away the robot is from the light source when it stops.

METHOD TO EVALUATE STUDENT LEARNING APPROACH

The aim of the method was to assess whether the modified project promoted the students to adopt a deep learning approach. The results are intended to act as a guide to designing project-based learning modules.

In the assessment three methods were employed: interviewing the individual students, the ASSIST inventory and the materials produced by the students (the robot kit and the written report). The interview consisted of asking the students a series of questions about their project aims, expectations, etc. Questions were also asked about a paper design project, which had no end product and customer, that they had carried out earlier in the year to explore any differences. The answers were then put into three motivation categories. The results are shown below.

Category 1: The motivation/ aim was to meet course objectives and obtain high marks

- 'In the robot design I want to get a good grade and produce the robot at the end of it.'

Category 2: The motivation/aim was to produce a working design fit for purpose

- 'We've definitely had an aim of producing a robot for the school kids and within that aim you can go through the 'how you can make it simple as you can and how to get it to work every time' and that has been like a clear aim for this week.'
- 'I'd say, obviously in the robot project we have an end product and you can see you have succeeded or failed within the two weeks whereas that wasn't as clear with the paper project—there was no clear succeeding or fail.'
- 'Then there's the idea of the fact that someone's going to have to use it and I think that's an important aspect.'
- 'I got a working project but it would be nice to get a more permanent type of thing.'
- 'In the robot design I want to get a good grade and produce the robot at the end of it'
- 'And in this [the robot project] if you get it to work then we know it's working.'
- 'You get a robot that worked—definitely the big one.'

Category 3: The motivation/aim is to experiment with and reflect upon different designs and processes

- 'It was probably to find interesting ways to solve the problem. There were a number of different ways we found to make it follow the light and we were looking for the best ways and ways that seemed interesting.'
- 'I think its probably this one: the problem-solving aspect I found quite enjoyable because the last project it was really going through what other people have done before and trying to find the best bits to put in our projects but this one it

Table 1. Results from ASSIST Questionnaire

Deep learning

Factor	Seeking Meaning					Relating ideas					Use of evidence					Interest in ideas					Sum of Totals
Question No	4	17	30	43	Total	11	21	33	46	Total	9	23	36	49	Total	13	26	39	52	Total	max =80
Student 1	3	3	3	3	12	4	4	2	2	12	4	3	3	5	15	4	4	5	4	17	56
Student 2	4	4	4	4	16	4	4	2	3	13	4	2	3	4	13	4	4	3	4	15	57
Student 3	2	2	3	2	9	4	4	2	1	11	4	2	2	4	12	2	2	4	3	11	43
Student 4	4	3	3	2	12	4	2	4	4	14	2	2	2	5	11	3	4	5	4	16	53
Average	3	3	3	3	12.25	4	4	3	3	12.5	3.5	2.3	2.5	4.5	12.75	3.3	3.5	4.3	3.8	14.75	52

Surface learning

Factor	Lack of purpose					Unrelated memorising					Syllabus boundness					Fear of failure					Sum of Totals
Question No	3	16	29	42	Total	6	19	32	45	Total	12	25	38	51	Total	8	22	35	47	Total	max =80
Student 1	2	1	1	1	5	4	2	2	2	10	3	3	5	4	4	1	1	1	4	7	26
Student 2	3	2	2	2	9	2	2	4	2	10	4	4	4	2	14	3	3	2	4	12	45
Student 3	2	1	2	2	7	1	2	4	3	10	4	4	5	5	18	4	1	3	4	12	47
Student 4	2	1	2	2	7	4	2	4	2	12	3	4	3	4	14	3	1	4	2	10	43
Average	2	1	2	2	7	3	2	4	2	10.5	3.5	3.8	4.3	3.8	12.5	2.8	1.5	2.5	3.5	10.25	40

Strategic learning

Factor	Organised study					Time management					Alertness to assessment dema					Achieving					Monitoring effectiveness					Sum of Totals
Question No	1	14	27	40	Total	5	18	31	44	Total	2	15	28	41	Total	10	24	37	50	Total	7	20	34	47	Total	max =100
Student 1	5	3	2	1	11	4	4	1	3	12	4	5	4	4	17	5	3	4	2	14	5	4	5	4	18	61
Student 2	2	2	2	1	7	2	2	2	3	9	4	4	4	4	16	4	3	2	1	10	4	3	4	4	15	50
Student 3	3	5	1	2	11	4	5	5	4	18	4	5	4	4	17	5	5	5	5	20	4	4	4	4	16	71
Student 4	3	2	1	1	7	1	5	1	3	10	2	4	1	3	10	5	5	1	4	15	2	1	2	2	7	42
Average	3	3	2	1	9	3	4	2	3	12.25	3.5	4.5	3.3	3.8	16	4.8	4	3	3	14.75	3.8	3	3.8	3.5	14	44.8

Factor	Supporting understanding					Transmitting information				
Question No	b	c	f	g	Total	a	d	e	h	Total
Student 1	3	4	2	2	11	4	5	3	5	17
Student 2	4	4	4	2	14	4	3	5	4	16
Student 3	2	3	1	4	10	4	5	5	4	18
Student 4	4	5	2	3	14	4	3	3	3	13
Average	3	4	2	3	12.25	4	4	4	4	16

was just a lot of experimentation trying to find the best way to do it.'

- 'Its just fun to watch these things go about all the time.'
- '. . . get a robot to the level that a thirteen-year-old can build it and that was quite challenging really in parts.'
- '[From] the first week you can . . . go away and play with your robot and improve it and see whether you can get it to do what you want it to do.'

The ASSIST inventory consists of a series of statements with which the students rate their agreement on a scale of 1 (disagree) to 5 (agree). Entwistle [6, 8] has already performed the statistical analysis which relates the responses to different factors such as seeking meaning and organised study. These factors can then be related to the different approaches to learning, i.e., surface, strategic and deep learning. The four students were asked to fill in the questionnaire with specific reference to the robot project. The results are shown in Table 1, which shows the results presented in tables related to learning approach. In each table a student's score for a particular question is recorded. The questions are then grouped into subcategories and a total for each subcategory is calculated. The last column shows the sum of all the subcategory totals for each student with the maximum total shown to aid in interpretation of the results. The last row shows the average values for each question, subcategory total and sum of totals.

DISCUSSION

The interview quotes were classified by grouping together common types of statements. Although Table 1 shows a neat classification, it was found that each student did not exhibit just one form of motivation to learn. In fact all four students exhibited the motivation to obtain a working robot. It was interesting that they all exhibited the motivation to reflect upon their designs as well and that the reasons for this were different. For example, one student was particularly motivated to experiment with different design options in the first week:

> 'I think the second week was something that we had to do but wasn't as enjoyable as the first week. In the first week you can kind of go away and play with your robot and improve it and see whether you can get it to do what you want it to do. In the second week [it] was . . . not as enjoyable because you had already done most of the groundwork.'

whereas another was more motivated to do this when the ideas were pooled and he was exposed to other design solutions:

> '. . . how you can make it simple as you can and how to get it to work every time and that has been like a clear aim for this week. The previous week was all about competition and the aim was to beat everyone else.'

However all the students were motivated towards experimentation and reflective design by the fact that they knew it had to be suitable for a thirteen-year-old and therefore the final design had to be simple, easy to understand and reliable.

> 'It was probably to find interesting ways to solve the problem. There were a number of different ways we found to make it follow the light and we were looking for the best ways and ways that . . . seemed interesting and I suppose we wanted to make a design that people would be able to understand 'cos its no good having something that's really complicated . . . people would find it hard to understand and it would be quite counter intuitive'

> 'But at the same time the robot has been . . . a lot more infuriating . . . it has to perfect and working'

The interview evidence comparing the paper design and robot project showed that the students' motivation to learn in the paper design exercise was strongly influenced by the fact that this project carried more marks.

> 'Well the one last term carried more marks for the degree so I put more into that.'

> '[put more effort in to] last term, most definitely . . . mainly 'cos its worth more marks, basically.'

Thus the comparison was not taken any further. However, this line of questioning did reveal that there were different opinions as to whether the robot design did reinforce the lecture material from the analogue electronics course.

> 'It's brought in a lot of the analogue electronics which I'm quite glad because I can actually see where its all been—where all the different circuits where you can actually apply them.'

> (Interviewer) 'Did either of the projects bring your course work into context?'(Student) 'Probably not. This one had a bit of analogue electronics so obviously that was useful.'

> '. . . certainly this one has done because its applying all we've learnt in lectures.'

The ASSIST results corroborated the interview findings in that two of the highest scoring factors were 'Interest in ideas' (14.75/20), and 'Achieving' (14.75/20), which strongly relate to the two categories of motivation all the students exhibited. As expected the strategic element of 'Alertness to assessment demands' was high at 15/20. The questionnaire showed in general that the students in this study had the strongest tendency towards a deep learning approach and were strongly motivated towards achieving, both in the assessment part and obtaining a good quality robot kit.

The final piece of evidence was the robot designs and the written reports. The aim of the final robot kit was to produce circuit designs which would work regardless of component tolerances and non-optimal build quality and to have a minimum number of new concepts to introduce to the school pupils. The students achieved this by pooling and optimising the best individual circuit designs. To achieve the aim of minimising the number of new concepts, they based all of the circuits around a single comparator IC instead of using more complex ICs such as the 555 timer and ultrasonic decoders and frequency controlled oscillators. This reduction in the use of complex ICs resulted in circuits which were more reliable to build and fault find with. The design reports also revealed an in-depth understanding by the students of the circuits they had designed. Again, the evidence points towards the project structure promoting a deep learning approach.

TO ASSESS THE BENEFITS TO SECONDARY SCHOOL STUDENTS

The intention of this part of the project was to pilot a scheme to enthuse twelve and thirteen-year-old pupils to consider studying electronics further: the eventual aim being to increase the number of students studying electronics at university level. The four students who designed the robot kit each took charge of a group of about three pupils. This allowed them time to give specific technical help on the project and for the pupils to ask questions about electronic engineering and university in general. At the end of the project, the pupils tested their robots in a general arena. Other pupils from the school were invited to observe. The pupils showed considerable enthusiasm when it came to demonstrating their robots and most pupils wanted to take them home. The design of the kits meant that all groups had a working robot at all stages of the project. The idea behind this was to increase the confidence of the less able groups. Although, the projects were set up differently at each school and the level of prior knowledge of the pupils differed, both sets of students showed considerable motivation. Evidence to support this included many students working through their break times and personal modifications to the robots' appearances e.g. mice and devil robots. Further details of this project can be found on [9].

The response of the teaching staff was very positive with both schools retaining the circuit designs and an example robot. One school intended to extend the design into an integrated technology project for sixteen year olds, incorporating electronic, material and computer-aided design.

CONCLUSIONS

The results presented indicate that a student's motivation for doing a project is related to his/her learning approach and to the return of the learning task. They further show that the type of motivation can be influenced by the design of the project. This supports existing research [10]. It was found that the project contained aspects which resulted in all the students exhibiting a motivation towards a deep learning approach and provides a useful framework on which to base future projects.

The use of the robot kits by the undergraduate students to teach analogue electronics to year 9 pupils was assessed less formally. However, initial indications revealed a favourable outcome.

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