Curiosity Based Learning
Impact Study in 1st Year Electronics Undergraduates

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Abstract—There have been a number of reports over recent years on alternative approaches to teaching that concentrate on encouraging the student to take the initiative. These include but are not limited to problem-based, studio-based, inquiry-based and curiosity-based learning. The purpose of this focused study into curiosity-based learning (CBL) within a small class of first year engineering undergraduates is to develop an understanding of the way such an auto-didactic approach may affect or impact the way students achieve the required learning outcomes. By including CBL phases within the learning outcomes of a business management module, experienced teachers can motivate students to gather, analyse and present data without recourse to more established teaching methodologies. This ‘light touch’ approach may encourage students to adopt CBL methods autonomously in future, enhancing personal and collaborative group studies, improving effective communication and their willingness to challenge conventional wisdom and generally improving a student’s ‘softer’ skills. This paper describes the module, its objectives, previous literature on the topic and the research methodology used before discussing findings and implications. The main findings are that the module has enhanced student motivation, has had a significant impact on student Venturing Self-Efficacy and a positive impact on student awareness of the importance of management to their future careers.

Keywords: Curiosity Based Learning, Auto-didacticism, Impact, Engineering Management, Transferable Skills.

I. INTRODUCTION

Curiosity Based Learning (CBL) is one of a number of similar methodologies that teachers can use to stimulate self-reliance or the willingness to learn in their students. This study looks at a small cohort of 1st year undergraduate students taking Electronic Engineering with Business Management. Using a mix of conventional teaching methodologies and CBL, the teacher guides students as needed, injects appropriate, timely additional knowledge and encourages more interactive classroom debates in student cohorts that are new to the higher education (HE) learning environment. The student groups are expected to self-organise and research the topic ready for presenting back to the class as part of formative assessment. The study attempts to determine if there is any net beneficial gain to potential electronics engineers in attaining and developing the skills to use such research and business management knowledge. Three student groups were asked to reverse engineer separate commercially available products. They looked at the design, packaging, components, physical aspects, quality and build to determine how the product could actually be made and subsequently sold to achieve a profit.

The paper will present analysis of pre-module and post-module questionnaire data as well as through a structured interview with the student cohort and draws on previous similar studies and literature to help position and evaluate the effectiveness of such methodologies.

II. EXISTING LITERATURE

Current literature on CBL refers to similar pedagogical methodologies such as constructivism or experiential learning and to related approaches such as Enquiry-Based (EBL), Problem-Based (PBL) and Studio-Based Learning (SBL), which tend to be pre-scripted and highly controlled. This latter view is supported by Hmelo-Silver et al [1] disagreeing with Kirschner et al [2] who assert that unguided teaching strategies are not as effective as traditional guided methods.

For the sake of clarity this paper will be limited to literature that discusses CBL style approaches within the last 20 years and to teaching that relates to adults who arguably approach learning from a perspective of experience. Tough [3] followed up a US study in Canada where a key finding was that adults are self-directed in their learning. For the purposes of this study we will define adults as those people who are attending a HE course in the United Kingdom, usually aged 18 or over.

A. Curiosity and teaching – guided versus unguided

Curiosity can be defined as “an eager desire to know” [4] or to learn, here we can extend that to a desire to learn about an object to gain skills and use them to show achievement of learning outcomes. Given this definition it can be argued that the CBL method spans the epistemological continuum if it is assumed that the ends of such a continuum are objectivism (knowledge exists that reflects the real world – the desire to learn) and subjectivism (knowledge is based on previous experiences – the outcomes of a desire to learn). A researcher
who uses their curiosity to explore a topic and arrive at conclusions can be said to be exhibiting an ‘Active Learning’ behaviour, actively seeking out existing or discovering new knowledge rather than passively soaking up knowledge from a recognised source. This last point recognises that the act of being curious may span the whole epistemological continuum but the use of a CBL methodology concentrates on discovery as a discrete activity, this being an auto-didactic approach tending towards the subjectivist end of the continuum.

Constructivist teaching methods can be grouped largely into a ‘guided’ or ‘semi-guided’ category even though they tend to be teacher centric, it is the teacher who guides the learner in the direction required. These curricula are designed to achieve learning outcomes through teacher delivered material with the passive involvement of students in the main. The Boyer Commission [5] suggests that a student centric paradigm be developed where research-based learning (semi-guided) should be the normal delivery method. However, as Healey [6] asserts, “…Accompanying these changes it would be essential that systematic research into the impacts of the introduction of inquiry-based learning is undertaken.” Indeed Khun [7] says that the outcomes from successfully implemented EBL style methodologies lead the student to “…become equipped to take charge of their own learning, choosing the questions they wish to investigate and seeking and finding answers to them.” Assuming that such learning takes place within an educational framework, how do teachers ensure the appropriate learning outcomes are achieved if students are completely free to choose what, when and how to investigate topic areas? What skills do students need to carry out effective inquiry?

Cennam et al [8] examined the use of SBL to solve design problems and suggested that instruction and facilitation is key to helping students experiment and communicate their results effectively – a semi-guided approach supporting Boyer [5]. However, SBL is designed to explore specific pre-set aspects of the curriculum with defined outputs, determined by following the process and is thus more controlled than CBL which encourages students to explore the topic area, gather appropriate evidence and arrive at their own solutions. The student is free to research their ‘curiosity’ in their own preferred way thus the use and availability of appropriate resources is likely to be a factor.

It is important to have a baseline from which to measure results, a view supported by Wallace [9] who says that clearly set out aims and outcomes need to be measurable. Previously Barell [10] suggested curricular objectives to be written such as to stimulate the curiosity of the student. The degree of self-direction afforded to the student will be the main determinant of how prescriptive the curriculum design has to be. It is difficult to see how an entirely self-directed methodology would work, especially in first year students, without close monitoring, evaluation of the module and assessment.

Van Berkel [11] discusses commonly used management techniques, making the tutor available ‘on demand’ possibly via on-line facilities. This is interesting as it assumes all students will a) turn up and b) engage with the self-directed learning approach. The approach could generate freeloaders and would almost certainly need considerable policing. CBL tends to overcome some of these aspects by adopting a minimised hybrid approach with some short teacher delivered learning, as required, to ‘inform’ the student’s ability to research using their own preferred methodologies.

B. A Continuum – Guided to Unguided Learning

Given the above it may be useful at this stage to compare guided methods with more modern and emergent methods. It seems appropriate to use a model showing the continuum of teaching methodologies. Figure 1 shows a continuum from typically Guided to Unguided teaching methodologies with a range of example methods of delivery. The skills needed by teachers and students within each delivery method ranges from pure listening to active research and dissemination.

<table>
<thead>
<tr>
<th>Methods of Delivery</th>
<th>Teacher Centred</th>
<th>Teacher/Learner Hybrid</th>
<th>Learner Centred</th>
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<td>Pure Lecture</td>
<td>Lab</td>
<td>Seminar</td>
<td>Pure research</td>
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<td>Q&amp;A Sessions</td>
<td>Discussion</td>
<td>Conference</td>
<td>Group working</td>
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<td>Instructions</td>
<td>AV Delivery</td>
<td>Examination</td>
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<td>Coaching</td>
<td>Role Play</td>
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Fig 1 – Teaching Strategies Continuum (adapted from [12, p.92])

Binson [13, p.17] studied CBL and suggested that when comparing Curiosity and Inquiry based learning there are some key unique aspects to CBL making it a more linear reflective process rather than the circular reflective model.

1) Common
   a) Student centered;
   b) Instructor as a facilitator;
   c) Investigative and explorative; and
   d) Requires an interactive group.

2) Unique
   a) Activities designed to make the students aware of their initial self-limiting baseline of curiosity;
   b) Activities designed to increase the student’s self-awareness of the importance of curiosity;
   c) Activities designed to increase the student’s level of curiosity;
   d) Experience with multimodal methods of representing and defending ones research findings; and
   e) Experience with a model method of research that can be generalized for later use with any subject.
C. Skills development

Much has been written on skills development in education [7, 11, 14] stating the importance of research and communication skills in particular but that development of those skills needs to be facilitated such that students and teachers alike stay on track to achieve objectives and learning outcomes. The need for improved learning and inquiry skills in all learners is clear but especially in first year learners due to their differing academic backgrounds and learning styles. The issue is whether this ultimately leads to students developing surface knowledge and skills in research or that it goes further and develops an intellectual capability for critical analysis of disparate data to arrive at valid conclusions and thus embed this ability for future use – deep learning. The methodology of experiential or activity based learning is widely recognised as being more effective than passive learning [15] but there are concerns expressed regarding group and individual working. CBL is more suited to group learning but the basics of group working raise their own problems including the link back to facilitation. Indeed the element of reciprocity in CBL style teaching is expressed by a number of authors [5] [16] and the need for students and teachers alike to learn from each other increases the depth of CBL activity implying another skill needed to be mastered by students is the ability to transfer their own research based learning to others. Much of modern teaching methodology sets great store in group-based or collaborative working [17], whether this is best suited to a semi-guided or a truly auto-didactic approach is debatable. Several cited studies [15] have shown improvements over time in academic achievement using a CBL approach compared to students who have not been exposed at an early stage in HE to CBL techniques. However, the assumption is that students possess basic problem solving skills and are competent self-starters [18].

D. Effectiveness of auto-didactic approaches

It may be argued that self-education techniques rely heavily on students to take the initiative, implying possession of certain skills or behaviours. Issues encountered by students using PBL [19] include the use of “…mini-lecturing, dysfunctional group dynamics, completing cases too quickly, superficial research, frustration with tutors who lack content expertise, and lack of support for PBL.” Many self-directed methods of learning will encounter such issues, especially as it is difficult for teachers to ‘let go’ altogether and allow students to master the required techniques. Solomon [20] takes a number of views on auto-didactism and argues that it becomes more relevant within science topics or pure research areas. It may be easier to allow researchers to choose the topic area that appeals most to them rather than imposing a specific topic but students, on a course of learning, are a different matter and will inevitably need some guidance, some form of structure. Brew [17] argues that a new model of the relationship between teaching and research is needed for this style of learning generating communities of practice that both research, teach and learn at the same time.

Deignan [21] describes the processes involved in using EBL (p.13) asserting that it “…produces independent learners with transferable skills….is collaborative and valuable, but also demanding…” thus requiring a shift in attitude from both lecturers and students from lecture-based to facilitative. This implies that such methodologies should be embraced whole-heartedly (by re-training teachers) or not at all!

The role of the teacher may evolve to become a mentor or guide, suggesting avenues of investigation, stimulating the minds of students, encouraging students’ self-motivation, steering along a route that may result in the demonstration of society wide agreed learning outcomes. This is not a truly auto-didactic paradigm but one of minimally guided learning, more aligned to a CBL approach than either the prescribed learning from PBL, SBL, EBL or the more traditional teacher-centred teaching and learning methodologies.

E. Learning & thinking style effects

CBL style methods use facilitation and interactions between students and teachers could depend on their psychological states of mind. Berne’s Transactional Analysis theory [22] could be used to explain some of these interactions in which teachers and students adopt one of three ego states, relevant to the situation in which they find themselves. These are briefly described for a CBL methodology as a) Parent ego state – advising, facilitating, b) Adult ego state – researching, self-determining or c) child ego state – listening, questioning. Interestingly this gives rise to a changed state of the relative power relationships between students and teachers because either the student or the teacher could adopt any of these ego states dependent upon the specific datum being discussed.

F. Key Issues from the Literature Review

There is disagreement within academic circles as to the effectiveness of guided versus unguided teaching and learning methodologies [1], 2].

Adults are self-directed in their learning [3] with the skills needed for CBL unclear and any linkage between ability to carry out research and possession of the skills for appropriate reporting of the results are tenuous [7], [14].

The need for close monitoring of learners, especially in their early years of using CBL methodologies is clear [9], [11].

The ability to operate as either a teacher or learner and for learners to benefit at all stages of their academic careers is greater in a CBL style paradigm but it means that teachers may need to undergo further training in guidance and mentoring skills [15], [17], [21].

III. Methodology

This research has used a combination of quantitative and qualitative data in a mixed research methodology to gain as much value as possible from a small sample population (N=14). Two researchers separately analysed the data and
compared their views to add a small measure of triangulation to the research. This has tended to limit the validity somewhat but added reliability and completeness.

The chosen method was for the target population to complete pre and post module Questionnaires (available upon request) that were produced to test opinions before any training took place and immediately after the taught elements were completed. Apart from the initial questions to determine personal details such as schooling, background or age, the questionnaires contained the same questions, generating comparative quantitative data analysed using SPSS software. The output was considered using statistical measures for any significant changes between pre and post questionnaire responses and output in the form of tables and charts.

To enrich the depth of understanding, quantitative output was further analysed using the qualitative data captured through interview with each of the respondents. Evidence is drawn from this semi-structured interview about personal feelings towards the module and how it has affected their opinions of electronic engineers. Semi-structured interviews have been used due to students’ lack of availability for a focus group that may have elicited more data more efficiently [23]. Direct contact with interviewees allowed for more reliable responses whilst allowing for any difficult concepts to be clarified.

Ethical aspects that may be contentious have been dealt with by ensuring questionnaires were completed anonymously, by offering the option of a nil response should the respondent be uncomfortable with any question in either questionnaire or subsequent interview. Interviews were carried out in private and captured data has been anonymised within the report thus respecting each respondent’s personal opinions [24]. All collected data is stored securely in a locked room.

The avoidance of cohort bias or pure coincidence is limited within this iteration of the study. To help alleviate such issues a broad range of assessment of learning outcomes for the cohort has included the use of video recordings of group based presentations, individual assignments and a reflective practice report to identify which aspects of the required learning have been embedded more successfully and are thus more likely to lead to skills that are transferable to the workplace.

IV. FINDINGS

14 responses were received, 1 was removed as an outlier, 10 male and three female respondents were included in the final quantitative analysis. Results from this study show post teaching data for perception and ability to be far more normally distributed than pre-teaching data. The paired samples statistics tests support a general rise in the direction of perception of students from pre to post module data. Paired sample results also show a large rise in venturing self-efficacy (VSE). Further analysis has been carried out to verify early findings and by removing one set of highly skewed data from the quantitative analysis the early findings are still valid except for moving what was previously a significant statistic for VSE just back into the normal range.

The vast majority of respondents (5.77%) had little or no prior experience of teaching on the 8 business topics covered in the module and just over 10% claimed to understand the topics quite well with 0.96% claiming they fully understood the topics. This spread was represented in both male and female populations. When considering aspects of management and the respondents’ perception of how important each might be for electronics engineers, in designing and developing products and in relation to business profitability the level of agreement with the importance of such knowledge rose from just over 85% (pre-module) to 91% (post-module). In fact the post module perception of disagreement with the importance swung from over 11.11% to 0.43%. Neutrals however rose from 3.42% to 8.55% suggesting some had not moved far!

Key skills findings indicate a very polarized view with student views on the importance of certain business and managerial key skills for electronics graduates showing just over 90% in agreement pre module and just under 90% post module. The pre responses showed 7.69% in strong disagreement with 2.2% neutral and the post responses showed 2.2% in mild disagreement with 8.79% neutral.

Looking at entrepreneurial intent and general self-efficacy both showed a slight fall using paired sample means. The same test for opinion of key skills, knowledge of profitability, knowledge of design and development and knowledge of management aspects showed modest rises. Paired sample means test for venturing self-efficacy (VSE) however showed a large mean rise although high to start it rose from 6 to 6.8 (max 7). Looking at the paired samples test of these same criteria did not identify any statistical significance although VSE was close to being significant in a 2-tailed test at 0.078.

V. ANALYSIS AND DISCUSSION

The fact that the majority of respondents came in with little or no prior business knowledge or experience makes the findings above fairly predictable given that all learning outcomes were achieved. However, it is interesting to note looking to the skew factor only one prior topic came out highly skewed – prior understanding of legal aspects the other seven showed a relatively even rate of skew. The data were analysed to see if the male/female split made any difference but this was not found to be the case. The pre-module data tended to be more highly skewed than the post-module data where only the odd topic showed greater than ±1. The category for perception of the importance of design and production showed only one post-module result to be highly skewed but on further analysis this was due to a shift of perception of one respondent from the Strongly Disagree state to the Agree state and thus not unusual. A similar trend is seen in the key skills perception elements and this seems to indicate the teaching methodology is actually having a positive effect even though not coming through as statistically significant. An interesting result to
emerge from the VSE post-module section was when the question ‘The idea of helping a company to enter really new markets is exciting’ showed slightly skewed data seeming to indicate the respondents becoming more cautious rather than more confident with their newly found knowledge. This is reflected more generally as the paired sample means showed more caution perhaps than was expected and is further backed up for entrepreneurial intent with a strong correlation between pre and post test output showing no real difference in student perceptions for EI. On VSE however some mixed results with a fairly high correlation but at 0.78 for 2 tailed test the result is tending towards a significant rise in attitude.

The teaching in this module was a blended design with some outline explanation of topics being covered and facilitation of group based investigative work. The interview stage brought out some interesting aspects from the student’s perspective not obvious from the quantitative data. The fact that all students enjoyed the module and most of them particularly enjoyed using presentations to explain their collective learning seems to support the use of the CBL technique. On the other hand one final comment from a respondent indicated the need for longer presentations as the time taken to research and prepare was disproportionate to the actual presentation time. One respondent enjoyed the module because they were able to “…open up real products and see circuits that someone else has built, investigate them and build a business usage based on the module content.” The use of open discussions both in class and in their groups was cited as building up their knowledge, experience and confidence levels. Indeed it backs up Fosnot’s arguments [25, p.ix] who asserts that:

“…Learning from a constructivist perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and discrepant new insights, constructing new representations and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through cooperative activity, discourse and debate.”

Constructivism uses an active role by individual learners in constructing knowledge and an equally active role from teachers in ensuring the guidance on offer is suitable and sufficient – a point brought out by two of the respondents who would have liked more guidance. One respondent felt it was confusing at first, especially the financial aspects and said “We had to work back from real life product to the theory but now if I think about profit and loss or cash-flow then I relate it to the real world.” This underpins the experiential aspects and the need to investigate, formulate your own understanding and communicate effectively your output. Thinking outside of the normal convention cropped up several times in answer to why the respondents liked the module, one respondent stated that “The module taught me to think in a broad way, think outside the box. For example at the beginning I was trying to know exactly what we are ‘supposed’ to be saying in the presentations but eventually I realized that this is the wrong approach to it. I don’t need to cover specific points and there is no right or wrong answer – I liked that.”

The methodology was quickly accepted by the cohort as their only real dislike concerned a seeming lack of direction and the normal tensions as groups form and self-organise. The group work aspect was brought out several times when asked about any specific difficulties as was the lack of data regarding the products being researched. This may have been due to a lack of experience in team working situations or in generic research techniques. However, all teams did overcome their difficulties and submitted work of a fairly high standard. The final part of the assessment for this module required the individuals to complete the team based research and write up a business plan, reflect on the whole process and complete a reflective report. This data may inform a future full paper on the topic.

The final question asked whether the module had changed their thinking about the role of an electronics engineer, 11 said yes and 3 said no. Of those who said yes, virtually all of them said they had been unaware of the complexities involved in engineering and the links to commercial aspects. The role of an engineer was described as “…needing to be a complete discipline.” One respondent said “Thought it was all circuits, programming, maths, hands on stuff but I now value the need to appreciate the wider picture such as marketing and finance.” Another similar response “…thought engineers just sat and did work like programming and designing but now think they need more skills and more knowledge, especially about business.”

Khun [7] indicates that evidence of student behaviour when engaging in inquiry tasks is scarce; an aspect that this study has attempted to address by including data on a student’s learning and thinking styles pre and post module completion. For the purposes of this study into first year electronics engineering students we have utilised the VAK questionnaire adapted from [26] for learning styles and Gregorc’s [27] thinking styles questionnaires. No real significance has been found between pre and post module responses in these areas. This may be due to the temporal stability of the data with 9 weeks between pre and post module questionnaire completion.

Tables and graphs will be included in the Powerpoint slide presentation to conference and will be available upon request.

VI. CONCLUSIONS AND RECOMMENDATIONS

Whilst the first iteration of this study may not be conclusive, it does provide a baseline against which to continue this approach with each incoming first year cohort to gain a longer-term view of the impact of the teaching methodology. There is also the opportunity to follow these cohorts through their University studies carrying out occasional interviews and combining this study data with quantitative results from their other subject studies to chart their progress. The data obtained can then be used as a baseline to compare with the achievements of students not introduced to CBL at an early
stage. This may identify evidence of deviation from the average result demographic or indeed an increase in the level of transferable skills for CBL based learners. Furthermore, it may be interesting to determine the influence of web based resources on the students’ ability to carry out the research and thus achieve the required learning outcomes. One further interesting dynamic that may emerge concerns the staff to student relationship - would an entirely new paradigm emerge given a full program of CBL style teaching and learning. Also, the shift in employability of newly qualified students may be an indicator as to the effect of introducing a significant amount of transferable skill into an emergent work force.

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