"IT'S NOT FOR LAZY STUDENTS LIKE ME…"

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ABSTRACT

This paper details development of problem-based learning in the Department of Electronic and Electrical Engineering at UCL, including opportunities and challenges in implementation experienced as the 'pitfalls of the pilot' with regard to issues in student support and the complexity of the tutor's role.

KEYWORDS

Problem-based learning, curriculum development, innovation, student motivation, digital communications

INTRODUCTION

UCL is participating in an externally funded collaborative project along with the University of Bristol and UMIST, to introduce problem-based learning (PBL) into electronic engineering degrees. The idea for the project arose when research by an Institution of Electrical Engineers Industry Course Working Party[1] reported a growing dissatisfaction amongst employers with graduates' professional skills. By analysing employer requirements and researching alternatives, problem-based learning appeared to offer a good way forward to make the electronic engineering curriculum more applicable to both students and industry[2]. Staff with growing concerns about students' under-preparedness for higher education – manifested in increasingly surface approaches to learning[3] – also supported the move towards more student-centred forms of learning and teaching. Specific experience from the first-year undergraduate electronics laboratory suggested that the traditional prescriptive approach to laboratory classes resulted in students with poor practical skills and difficulties in relating the experiments to material covered in lecture courses. Because much laboratory work falls within the category of problem solving, it was thought that this would be a good area within which to develop a more student-centred learning environment to support the introduction of PBL into the broader curriculum.

The project plan calls for the introduction of PBL into the third year of the undergraduate BEng and MEng programmes, giving rise to issues of student preparation after two years of a conventional curriculum. Recognition of the scale of change required from traditional teaching to PBL resulted in a two-year development phase and the first fully-fledged PBL units begin in September 2004. This paper reports on the development process to date and uses data from the first pilot study in the "Communication Systems II" module at UCL to illustrate key issues in the design and use of such student-centred curricula.

THE DEVELOPMENT PROCESS

Curriculum

Biggs'[4] theory of constructive alignment has proved a useful tool in conceptualising the PBL curriculum in terms of identifying scope and assessment. The model of curriculum development used in planning for the introduction of PBL – identifying core knowledge and skills and using these to formulate aims and objectives – prompted a review of pre-requisite and concurrent course units to identify areas of overlap or omission. This wide view of the Electronic Engineering with Communications Engineering programme informed the goals and content of the new PBL curriculum, which focuses on four key technical areas: radio propagation; sampling, quantisation and TDM; digital signalling and modulation; and optical communications systems. The disciplinary content is supplemented by three 'key skills' sets: searching and evaluating the literature base; effective use and analysis of datasheets; and understanding and using specification documents to demonstrate good engineering design practice.

Once the core syllabus was defined in this way, trigger material[2] was outlined and thought was given to activities that would engage the students in learning about the core areas. This approach presented a challenge to the traditional problem writing strategies used by academics in tutorial classes or problem sheets. The very nature of PBL suggests that problems should be fairly open, particularly in the later stages of the course, rather than focused questions looking to probe very specific issues in the syllabus. These open questions, which allow the students to explore different and potentially creative solutions[5], are not in themselves difficult to write. However, there are issues involved in designing these questions to challenge the students sufficiently whilst still covering the curriculum. For undergraduate electronic engineering education, it is common to introduce students to physical systems that operate within fixed parameters. To allow students to explore more realistic and 'messy' scenarios, finding example problems poses difficulties in a way that does not exist in, for instance, medical education or the social sciences where PBL is more prevalent. Not only do academics have to be aware of over-direction, variance for re-use also becomes an issue.

One possible outcome of moving away from highly focused questions is that problems will undergo a shift to almost research project level questions. These will require far too much work and do not offer a ‘fair’ challenge to the students. Whilst the research skills needed for PBL are to be valued and encouraged, there is also a need to balance these, especially in the early days, with supported and structured learning experiences that bridge the divide between conventional, didactic teaching and the independent learning we aim to encourage[6].

Of greatest concern, then, is the need to design problems that will cover the breadth of topics in a particular area of the curriculum. One of the strengths of PBL is the requirement for students to move away from a surface approach to learning and have greater depth. Any design-type question will require much greater understanding by the student of the constituent parts of the design[5]. However, how can we make sure that all of the components we want to be covered will be involved in the design? What if we would like different types of design to be considered?

Two schools of thought present themselves, with our favoured solution being half-way between the two. The PBL purist view leans towards accepting that not all the material will be covered, as those taking this view tend to value the less tangible skills and attitudes PBL encourages and accept that students rarely learn 100% of traditional course material. The Traditionalists suggest that ‘covering’ the whole syllabus in some form is vital otherwise the course will be ‘dumbed down’. Our view, albeit in part for pragmatic reasons, is that not every item that would be presented in a lecture course will be covered by all students. However, we identify topics where a range of solutions must be investigated. We then carefully specify problems that include design options and iterative stages to allow students to be led gently towards required designs or areas of the syllabus.

It is desirable to get ‘Traditionalists’ to critique the intended syllabus, particularly the omitted topics, regarding their perceived importance, and effort needs to be made to persuade sceptical colleagues of the benefits of a PBL approach. Proceeding without this support leads to tensions in expectations and potential problems in valuing the outcomes of PBL modules.

As the first cohort to experience PBL will be in their third year, which carries considerable weighting towards their final degree classification, thought needed to be given to timing and weighting of the problems. From an educational development perspective, the idea of introducing PBL to the third year of a degree course was considered unwise. A period of enculturation into the hierarchical nature of the discipline, however, has shown the importance of the tools and methods acquired in the conventional part of the curriculum to support the students in this more independent learning phase. The pilot study, referred to in more depth below, has shown that students rely heavily on what they have been taught, and can learn to use this wisely as they acquire more autonomy.

The first problem the students will encounter is thus a short, self-contained scenario that emphasises the first key skill set and which also includes diverse induction activities to smooth the transition from conventional teaching to autonomous learning. The thinking behind the inclusion of this mini-problem has since been borne out by the difficulties the students encountered in the first pilot (see below).

Assessment

It was clear from the outset that an alternative means of assessment to the traditional written exam would be needed for the PBL students. The very purpose of PBL is to develop some of the intangible attributes of 'good learning' that cannot be measured through objective testing[7]. Following the constructive alignment approach[4] it made sense to assess the students entirely through the products of their work on each of the problem areas set. It is not uncommon for students to experience their learning as stand-alone chunks of information and fail to make linkages between topics, let alone modules; arguably a problem that may have been exacerbated by modularisation. The introduction of assessment by portfolio is aimed at addressing both of these issues.

The students will produce a portfolio at the end of the course which contains two distinct sections: the first will be the notes, reports, specifications and presentations prepared in the course of the academic task of finding solutions to the problems that have been set. These will be group efforts, and will account for 50% of the marks. The second aspect will be an individual narrative within which each student, guided by some key prompts, will describe and evaluate the process of learning and problem-solving, and may also include reflection on group work and ideas for improved performance in the future. 50% of the marks will be awarded for the individual contribution to encourage such reflection on both content and process[8] to consolidate the students' learning. This approach to assessment is not widely used in electronic engineering although softer disciplines use it with great success. Arguably, the hierarchical nature of the discipline tends to mark particular stages and expectations in the learning process which have always been rewarded. Convincing disciplinary colleagues of the benefits of developing wider, softer, less tangible but ultimately more useful skills, knowledge and attributes remains an ongoing challenge; in light of this the assessment scheme now includes a mandatory viva to test disciplinary knowledge. We are often aware that students do not display knowledge of the entire syllabus in their examination scripts. However, it is tempting to view the introduction of PBL as a vehicle by which students cover not only the full syllabus, but develop wider attributes too.

The Pilot Study

The pilot study reported here took place in September 2003. All third year students who had taken Communication Systems II in the previous year were invited to participate in the pilot for a nominal payment, and a small group recruited to return a week early from the summer vacation. No selection took place, but the volunteers included male and female, home and overseas students, and the full ability range. Below we detail the critical issues from the pilot study: how the students find it difficult to identify good problem solving strategies and employ critical thinking and reading skills; and the difficulties of the facilitator role.

A pilot problem was developed that extended some of the material already encountered by the students on the Communication Systems II module. The framework within which the problem was specified should have been familiar to the students, though the material was not. The problem was constructed so that it should have been possible to solve it within a week, which was the time allocated for the pilot study. The students were expected to work together on the pilot problem, and to present their findings at the end of the week. After a brief introduction to PBL, they were given the following scenario:

> "You have been asked to design a wireless digital communications system to link two buildings that are 100m apart. It has been suggested that to avoid licensing issues the system should operate in the ISM band (2.4GHz).
>
> The following specification needs to be met:
> - Bit rate = 50Mbit/s
> - Maximum bandwidth 50 MHz
> - Bit Error Rate >10^{-4}
> - Maximum Transmit Power = 0dBm
> - Receiver antenna Gain = 3dB
> - Receiver amplifier gain = 20dB (operating at room temp 27^{O}C), with an ideal noise figure and thermal noise dominant
>
> Some engineers have suggested the following transmitter designs to form this system. Please evaluate the feasibility of these systems to meet this specification.
>
> You will need to give a short presentation to explain what the suggested systems are, how they work, and whether they meet the requirements presented."

PLEASE INSERT FIGURE 1 HERE

Four data gathering points were scheduled into the pilot study: firstly, comments and observations from the facilitation sessions; secondly, student journals; thirdly, a post-study questionnaire (based on an instrument devised by colleagues at Bristol for their own pilot study) and finally, post-study interviews. After setting the problem, the first facilitation meeting was timetabled for later the same afternoon. At this feedback session, it was immediately apparent that the students had not appreciated the nature of the problem set: their lack of critical reading skills led them to suppose they were working on an analogue system, possibly because the conventional Communications System II module currently focuses in this area. Although they correctly identified key concepts as required by the specification, it was clear that the process of problem-solving presented difficulties. As one of the students confessed in interview, *"we've done Comms II before, we looked at the question and it feels as if we know the answer, it is familiar to us so that's the problem, we tried to second-guess the problem…"* Rather than take a measured approach, the students had focused immediately on the familiar aspect of the problem, the circuit schematics, and had not considered the bigger picture.

It was clear from their questionnaire responses that they felt a great deal of uncertainty in tackling the problem: all of the students felt more direction should have been given and, as one student wrote: *"Do the PBL thing step by step because this way of learning is quite new to us, especially since we've* *been spoon-fed by teachers and lecturers for years."* Closely related to this issue of uncertainty, the students also struggled to locate and manage information to support their attempts at solving the problem. As one student noted in his journal, *"normally we had lecture notes together with problem sheets, we knew the answers to the problems must be in the notes… It is relatively harder to find the relevant information from the library or the internet."*

Whilst the above focuses on real problems the students encountered in such a dramatic change, by the end of the pilot they were all positive about PBL as an approach to learning. As one student noted in his journal, *"I agree PBL is indeed more interesting…"* However, in the final feedback session, when asked if they would recommend PBL, this same student came up with the comment that forms the title of this paper: "It's not for lazy students like me." An appreciation of PBL as an interesting approach to learning does not, it seems, equate to an appreciation of taking responsibility for one's learning.

A final issue to emerge from the pilot study concerns not the students, but staff. Observation of the facilitation sessions illustrated how difficult it is for lecturing staff not to fall foul of their more usual information-giving role[6]. As the students continued to focus in on the micro-detail of the problem, the lecturer found it frustrating not to intervene. Exploratory questioning also proved difficult: the students were not yet competent at following the path of the questioning, fostering a temptation to ask more and more leading questions to elicit the students' knowledge base.

DISCUSSION

Our most compelling observation from the pilot study is the students' inability to tackle a problem. Our small group appeared to have little grasp of the scale of the problem, and rapidly concentrated on the micro-detail of the brief. When asked in interview what, if anything, given the problem again, he would do differently, one of the students replied '*Everything*'. He admitted that no real brainstorming or teamwork had occurred, even though these were elements of a PBL approach the students had identified themselves in the induction activity. The lack of problem-solving strategies raises issues about the best way to prepare students for PBL, and the difficulties of implementing it in a stand-alone module in year three. In refining the curriculum following the pilot study, the first problem – although tightly defined – has now been extended from one week to two, to allow for a range of induction activities to take place in context.

The second revelation from the pilot was the lack of critical reading and thinking skills. The students came to the first facilitation meeting with suggestions for an analogue solution, having mis-read the brief. They also declared the task to be vague: our surmise is that this might be related to the different presentation of the problem from the more usual problem sheets, and also perhaps the use of unfamiliar language – "evaluate the feasibility" – rather than the more common "state", "derive" or "explain". In both the final facilitation meeting and later, in interview, this issue was explored further. The students' belief that they could 'guess' – a word that came up several times in interview – based on their existing knowledge demonstrates how quickly they focused on the familiar parts of the problem without taking the wider context into account. A second assumption also came to light: we had provided them with two modulation systems to investigate, and they quite quickly dismissed one of them. This led them to assume that the second system must work and a lot of time was spent on proving it. It is clear that students are overly-dependent on lecturer-supplied information and are not encouraged to critique such perspectives.

In developing the PBL approach and trigger material, we thought at length about the processes – for students – of such a module. Figure 2 (below) illustrates how we imagined the student groups might act.

PLEASE INSERT FIGURE 2 HERE

Our observations during the pilot allowed us to reflect on actual student processes, rather than this idealised model. Figure 3 (below) represents the stages the students appeared to go through.

PLEASE INSERT FIGURE 3 HERE

The uncertainty the students felt in trying to tackle the problem is likely to have its roots in the difficult transition from a very conventionally taught programme to the unstructured nature of PBL. In questionnaires and interview responses, the students were adamant that lecturing staff should provide clear guidance and direction at the time of presenting the problem scenario. This attitude goes against the grain of a true PBL approach, where the students learn to be self-sufficient in defining their own objectives and approaches. It should be noted, however, that the timing of the pilot study might have had an impact on some of the student behaviour. The participants had returned a week early from the long summer break and so were not yet back in the habit of regular study. They also did not have the benefit of other structured learning activities going on around them. We also used one of the more challenging problems for the pilot, to test the scope of support that may be necessary. Without the benefit of prior tasks of this nature, it may be that the problem set was too overwhelming for the students to develop confidence in their problem solving strategies. As one student commented in the post-pilot interviews, "*the problem with this PBL is we were not certain with the answers or information we found, so I think meetings with the lecturer should be done as often as possible, so that we know that we are on the right track."* Even by the end of the experience, they had limited confidence in their ability to become independent learners.

An important element of the transition from conventionally taught courses to PBL is the responsibility placed on students to define their own objectives and to seek out the information they need to produce workable solutions. There were conflicting views amongst the students on this issue, from the successful information seekers, using the internet and library wisely, to another who seemed overwhelmed by the amount of information available and ill equipped to make a judgement of its value. When asked if he thought he was successful at finding the information he needed, he replied *"no. I wasn't at all because I have no confidence in the way that I should go round to it. When I'm not confident then I wouldn't know when this finding is correct or not, or relevant or not."* His information searching for the problem stretched no further than a set of first year notes. He found nothing of use on the internet, although his colleagues were more realistic, using the internet successfully for their first-level information needs. We aim to avoid the information overload scenario by populating an online repository with a range of resources related to communications systems. These will have keywords attached, so that students will have access to a range of quality assured resources via a concept level keyword search facility. This will be supplemented by an online information skills tutorial incorporated into the induction activities; it is hoped that this approach will also support students at the start of their third year projects.

So far, this paper has focused mainly on the issues to be addressed to support student learning. However, from the pilot, it became clear that academic staff development will also be important. Despite extensive experience in small group tutorials, lecturing staff involved in the pilot found the facilitation sessions difficult to manage. It could be argued that staff willing to adopt a PBL approach are inherently student-centred in their orientation. This makes the need to stand back and allow the students to find their own direction (including making their own mistakes) very difficult.

With little literature available on PBL in the physical sciences, developing judgement in intervention strategies and new forms of assessment are going to be interesting challenges. Arguably, during the pilot study, the students did a lot of learning, but their final solution was partial. Clearly there is a tension in a PBL approach between valuing creative, correctly functioning solutions and non-working alternatives that display a great deal of learning.

ISSUES IN IMPLEMENTATION

For Students

From the pilot study, several issues were identified as key to the successful implementation of PBL, such as:

- Students' perception of a lack of support
- Students' need for more detailed guidance
- A need to persuade students that there is not 'one right answer'
- Supporting students' problem-solving and information-seeking skills development

The major concern amongst students in the pilot study was the lack of direction provided by teaching staff. These concerns need to be addressed during induction, which will involve a range of activities aimed to reduce reliance on lecturer input. We will supplement these activities with appropriate support materials and frequent feedback.

For Staff

Arguably, teaching staff can find the transition from their conventional role to a facilitative approach equally difficult. Issues for staff encountered during the pilot study included:

- Developing a ‘hands-off’ approach
- The temptation to over-specify problems
- Developing good judgement over intervention strategies
- Developing more broad-based assessment criteria

Observation of the facilitation sessions during the pilot week illustrated how testing it is for lecturers to refrain from their more usual information-giving role. This also occurs at the trigger writing stage as staff are tempted to include overly-prescriptive detail in the problem scenarios.

This disjuncture for staff is further complicated by the difficulties of preparation: giving students autonomy of approach to complex problems means uncertainty for staff too. This is particularly acute in terms of intervention, as students partially articulate their problem-solving strategies. Frequently, the most powerful learning occurs as a result of initially following a wrong path; at what point, then, should lecturers intervene?

Likewise for the assessment problem. One surmise here is that a different view needs to be taken on assessment criteria, with a balance to be struck between process and solution. Again, there is little to guide us in this area and a deal of resistance from those who feel that PBL students should be measured conventionally to assure standards.

CONCLUDING REMARKS

At the outset of the PBL development, we were keen not to underestimate the scale of change necessary, and the pilot study has confirmed the range of issues and level of detail inherent in this kind of curriculum development. Although a range of educational development tools and models have been used, and proved useful, in the development, the pilot study has amply illustrated the gulf between the theory and practice of problem-based learning. The 'pitfalls of the pilot' have been discussed in this paper with specific issues relating to the adjustment of both staff and student perspectives highlighted. We remain convinced that a PBL approach has much to offer both students and staff as a motivating learning experience, and we look forward to using the lessons learned from the first pilot to inform future developments.

Caption Text

Figure 1: The pilot study problem scenario

Figure 2: An idealised problem-solving process

Figure 3: An illustration of the pilot study students' actual problem-solving process

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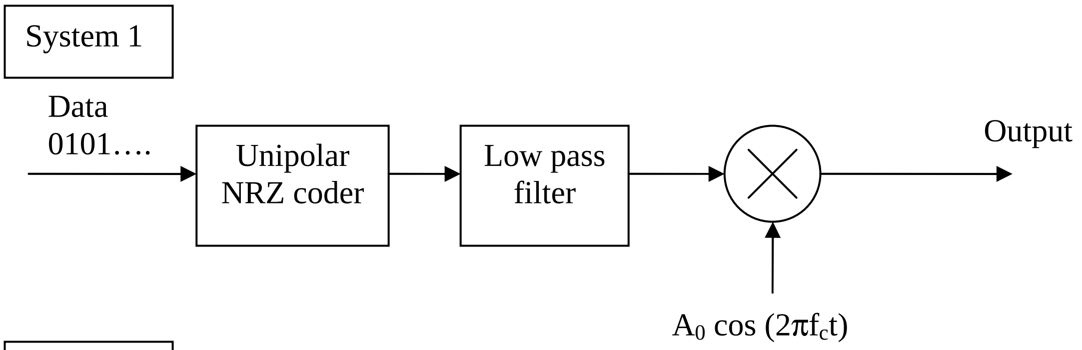
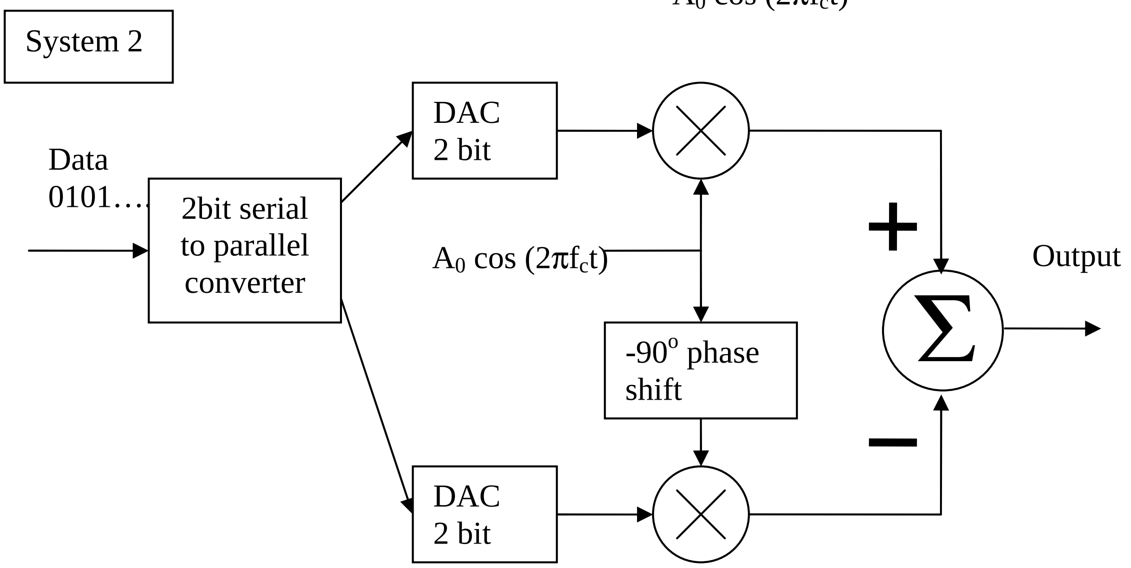
Figure 1

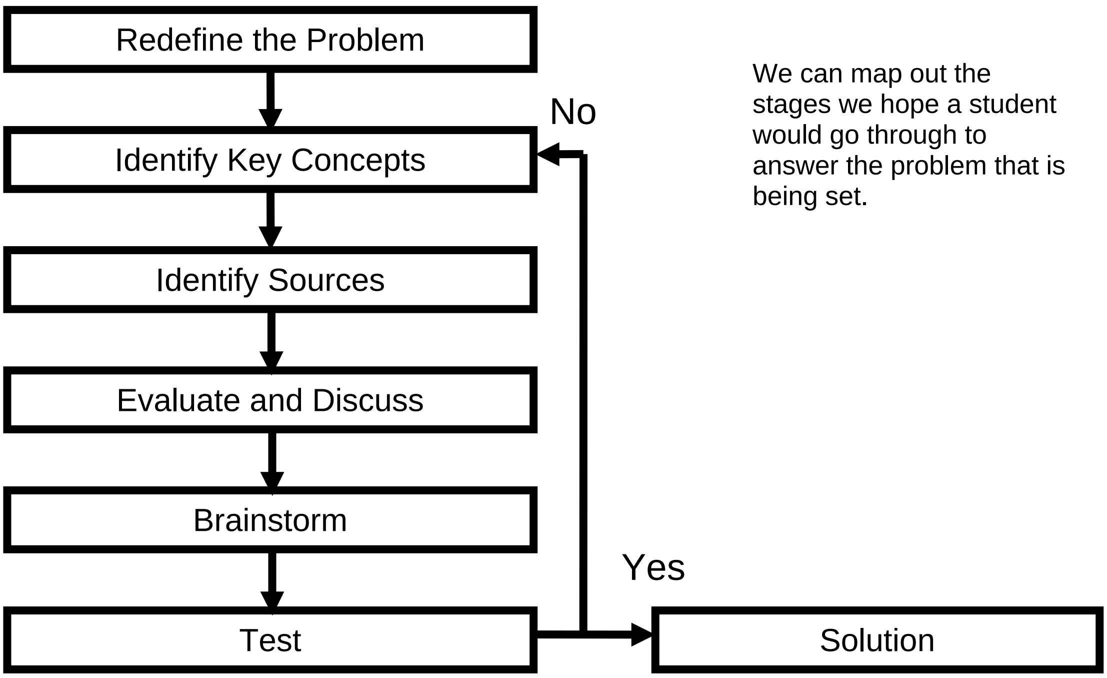


System 1
Data
0101….
Unipolar
NRZ coder
Low pass
filter
Output
A_0 cos ($2\pi f_c t$)



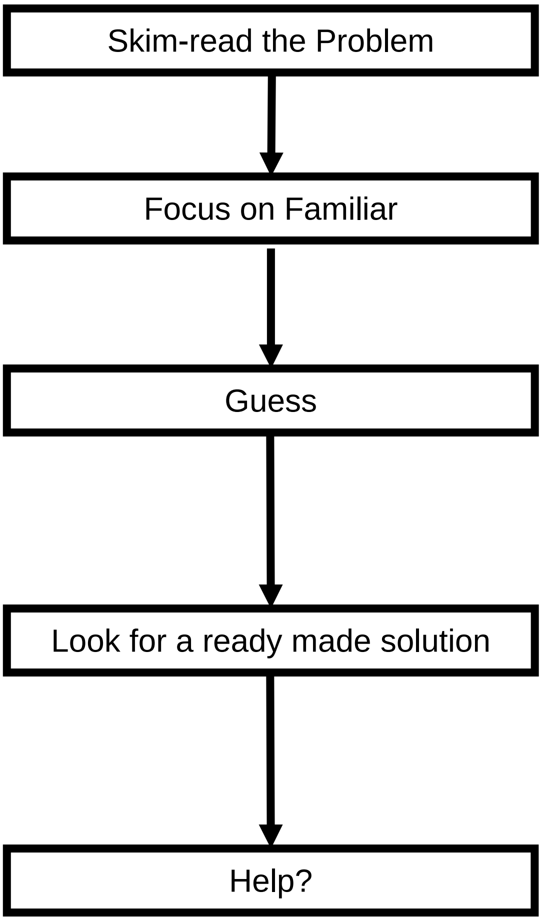
System 2
Data
0101….
2bit serial
to parallel
converter
DAC
2 bit
A_0 cos ($2\pi f_c t$)
-90^o phase
shift
DAC
2 bit
+
–
Σ
Output

Figure 2



We can map out the stages we hope a student would go through to answer the problem that is being set.

Figure 3



The students at first misread the question and started to look for an ***Analogue System*** solution, despite the question specifically saying a ***Digital System***

"We looked at the question and it feels as if we know the answer, it is familiar to us so that's the problem, we tried to second-guess the problem…"

"...usually in coursework, there's problems, but they ask you for specific things... we have problems with this being wide open."

Evidence of student research found in the library