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# A New Implementation of Keller Plan Teaching for an Undergraduate Electronic Engineering Course

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## BACKGROUND

Keller plan teaching is a method of self-paced personalised instruction pioneered half a century ago. It is ideally suited to the STEM fields and others which involve hierarchical knowledge development and are conducive to valid and reliable staged testing. In the '60s and '70s Keller plan teaching (Keller 1968 & Keller 1974) was proved to be more effective although more expensive to implement than standard course delivery methods. A Keller plan approach using the advantages of new technology was devised and given to first year Electronic Engineering undergraduates at La Trobe University. The learning results were compared directly to previous years' intakes (which had taken the course presented using standard techniques) and the results are presented in this paper.

## PURPOSE

We sought the answer to the following question: by using the well-established principles of the Keller plan method in combination with the utilisation of newly available IT and casual tutoring staff, is it possible to obtain better learning outcomes at a comparable cost to standard teaching practice?

## DESIGN/METHOD

In the first year of operation no lectures were given, tutor-supervised laboratory-based learning being implemented instead. In the second year of the program, one lecture per week was given to allow conceptually difficult topics to be discussed efficiently with a larger group. Students were required to pass as many of the ten basic sequential module tests as possible and there was an optional eleventh module. At the end of the course the students were also given a similar exam to that used in years when standard teaching practice was employed. This was an attempt to have a direct comparison of exam performance with previous years' intakes. The Keller plan module and exam marks, and the exam marks from the two previous years' standard course, were analysed to determine learning outcomes. An independently designed and administered student satisfaction and quality assurance survey was used to establish students' impressions and measure levels of satisfaction and compare those with measures obtained when the course was delivered using standard techniques.

## RESULTS

Students were more engaged, had a lower dropout rate and felt that they were grasping principles more easily than when taught using standard techniques. Exam results were similar in the first year of the program, but showed a clear improvement in the second year even though the average ATAR entry score for these new students was lower than it had been the previous year.

## CONCLUSIONS

Implementation of Keller plan style courses is now much more practical than it used to be due to the availability of new IT offering flexibility in material presentation and the possibility to track student effort and results. The question posed by this study is answered in the affirmative; it is now possible to achieve better learning outcomes at a comparable cost to standard teaching practice, the on-going Keller plan cost being expected to be about 30% greater than a standard approach.

## KEYWORDS
Self-paced learning, Keller plan, Personalised System of Instruction.

# BACKGROUND

Keller Plan Teaching (KPT) was developed by academics in the late 60's based largely upon the ideas of Fred Keller, an inspirational psychologist and academic. KPT (Keller and Sherman 1974) is an example of individualised teaching and a great deal of research was conducted in this area following Keller's seminal paper "Goodbye teacher" (1968). This research showed conclusively that KPT produced better student outcomes than traditional methods. For example, Kulik et al. (1974) examined several published studies in their paper *"*The Keller Plan in Science Teaching*"* and concluded that: *"*final examination performance in Keller sections always equals, and usually exceeds, performance in lecture sessions" and that "In every published report , students rate the Keller plan much more favourably than teaching by lecture". Five years later Kulik et al., in their paper *"*A meta-analysis of outcome studies of Keller's personalized system of instruction*",* also say the method "produces superior student achievement, less variation in achievement, and higher student ratings in college courses, but does not affect course withdrawal or student study time in these courses."

The core features of KPT are that:

1/ it is self-paced;

2/ has very well defined learning objectives;

3/ that these learning objects are demonstrably met at a high level of mastery as the student progresses through the course.

Being self-paced means that no student is disadvantaged due to the lecturer having moved faster than the student's ability to follow. When the pace is set by the lecturer it must be set to cover all of the material within the course time limit. If the course standard is high, this inevitably means that weaker students will not be able to keep up. Without having gained mastery of the earlier foundation elements of the course the weaker students will gain little from the material presented later in the course. The lecturer can choose to 'dumb down' the course for the sake of the weaker students but this means the top students will receive less benefit. The broader the spread of abilities in the class, the worse this situation becomes. Self-paced learning, on the other hand, does not unfairly penalise either weak or strong students in this way. A distinct disadvantage of self-paced learning is that, previously, it has been difficult to implement due to the requirement to create a great deal of high quality written or recorded course material. It has also been difficult to track and assess many students at widely different stages of the same course. These disadvantages can now be overcome relatively easily with new IT technology.

As has been mentioned, the research strongly suggests that the Keller plan approach to teaching at tertiary level produces better student outcomes than the traditional lecture based methods in use at the time (and which are still largely relied upon in most institutions). Several authors mention the potentially higher cost of implementing KPT (for example, Stice & Hereford (1973)). Several studies report the significant grade profile changes, skewed towards a much higher proportion of high grades, which result from Keller plan courses (e.g., Tyree (1997)). KPT has remained in the background with few universities adopting its methods probably for reasons of expense and unease with the departure from the familiar normal distribution of grades. Perhaps its time has now come for the reasons outlined below:

(1) Governments now demand that an increasing proportion of school leavers study at university so the tendency is for average academic attainment levels of new entrants to be lower than was previously the case. Entrants with very high levels of academic ability are still present so there is now a much broader level of capability within the student cohort. Lecture based courses, which proceed at a fixed rate through the curriculum, are now much less suitable since the weaker students can quickly get left behind leaving them little chance of meeting their potential.

(2) Changing student work patterns and the impact of IT in high schools have increased the divide between secondary and tertiary approaches to education. Standard lecture/tutorial/laboratory teaching techniques at tertiary level have not kept pace with improved high school teaching practices.

(3) There is now much greater availability and ease of use of electronic methods for material presentation, testing and marking. The cost of implementing these methods is also continually reducing.

(4) Students now appear much more demanding of constant and detailed feedback about their performance and progress. When compared to one main exam result at the end of the semester, the continual assessment inherent in the Keller plan approach gives the rapid feedback to which students have become accustomed at school and which they still demand.

# DESIGN/METHOD

## Overview

Given the established superiority of the KPT method and the assumption that the principle reason it is not more widely used is the perceived expense (based on outdated experience without the benefit of newly available technology and relatively lower tutorage costs), we wanted to find out if a Keller plan course, designed for first year electronic engineering degree students, could improve learning outcomes without a significant cost increase.

A Keller plan approach using the advantages of new technology was devised and given to first year undergraduates in 2011 and 2012 with learning results compared to both 2009 and 2010 cohorts, who had taken the course when standard techniques were used. In contrast to the standard Keller plan, with this course it was possible to fail the modules yet still pass with a good enough final exam result. Two pass options were implemented so that students and staff would not feel the course assessment was radically different to established practices. In the first year of offering 12% of students passed using this exam result option but, after improvements to the course delivery in the second year, the figure was only 1%.

## Operational Details of the Keller Approach Described in this Study

In the first year of operation, 2011, no lectures were given (other than an introductory lecture in the first week) and in 2012 one lecture per week was delivered to allow conceptually difficult topics to be discussed efficiently with a larger group. This is commensurate with the procedure adopted in many other institutions. Indeed, Keller (1968) himself stated that he intended no lectures be given and later realised that some lectures ought to be included for motivational reasons (based on the written module notes).

Learning in this new Keller plan course was self-paced, it being mandatory to prove ‘mastery’ of each core principle before being allowed to proceed. Mastery is a term that was used by Keller to indicate learning objectives have been fully met but it does not imply that a particularly deep understanding of the subject matter was achieved as the word in current common usage might. Teaching was mostly laboratory based with discovery of principles as opposed to demonstration of principles being the aim since it is well-established that active learning and self discovery are more effective. Tests weighted 9% each were given at ten important milestones, with an eleventh test (before which no additional material was introduced) being worth the final 10%. Students were required to obtain more than 80% for each module test to continue on to the next module. A capable student would pass each of the ten basic modules in sequence and their final Keller plan marks would be based on the grades they achieved on each of the module tests. This is in contrast to Keller’s original premise which demanded that, before progression to the next module, the current module test should be passed with a perfect score. To manage this, Keller had allowed students to defend a wrong answer on a test through argument with their “proctors” (tutors). To simplify the running of this course we eliminated this system but demanded the still relatively high

pass mark of 80% for each module. As students progressed at different rates it was envisaged that they would end the course having completed different numbers of modules, each with a mark between 80 and 100%. This would lead to the final grade distribution. Students who got a mark lower than 80% in a module were required to repeat the test (many different tests for the same module having been prepared). The mark recorded after a repeat test was passed was limited to 80% in fairness to those students who passed at their first attempt. There was no penalty for failing a test and it could be repeated many times. Tests usually took about an hour to complete although some students took up to three hours, particularly when circuit design, construction and trouble-shooting was involved.

Written material for each of the ten modules contained explanations of electronic principles, worked examples, graded problem sets, practical exercises such as building and testing a circuit and a practice module test. The graded problem sets typically comprised nine sets of five questions per set. However, within these sets students could exhibit mastery and pass quickly to the next set covering another concept. The ten modules contained material covering both introductory analogue and digital electronics concepts. Ten modules were adopted because this number kept each of the similarly sized modules to a manageable size in terms of work load. At the rate of one module a week some students would finish three weeks before the end of semester. Many students working at a slower pace would nevertheless have the additional time they required.

All of the course material was available online. A practice test, available within the modules, was checked by a tutor before students were allowed to progress to the module test. This was an opportunity to identify weaknesses in understanding and helped develop a rapport between tutors and students. The module tests themselves were presented on paper and often involved an experimental activity of relevance to the module. Students completed them under examination conditions and, while the tests were not open book, tutors were instructed to support students should they forget a relevant formula (as long as they could demonstrate an understanding of the concept embodied by the formula).

Students chose one of four three-hour time slots each week which they were required to attend. However, they were made welcome to attend more than one session a week and many students took advantage of this opportunity. A roll was taken at each session to track attendance and allow supporting staff to follow up with students who were not attending regularly. The module test completion records also offered an opportunity to identify student progress and intervene as necessary.

The modules were marked by the tutors and the marking was moderated by the subject coordinator to ensure that marking patterns and methodologies were consistent. Following completion of a module test it would be marked in the presence of the student with immediate feedback being given on the score and problems with wrong answers. Students could sit different versions of each module test as many times as required to pass, however, the majority of students passed at the first attempt. When a student failed a test, they were only permitted to re-sit another test on the same topic after at least 2 days had elapsed to discourage attempts being made without a period of re-learning and reflection. The fact that very few students required more than two attempts to pass at the required level of 80% mastery proves that re-learning and reflection were taking place.

The weekly additional motivational lecture would focus on a key area, such as a circuit solution procedure, explaining it in detail and giving worked examples. The lecture was scheduled for 9AM Tuesdays and the downward attendance trend experienced was similar for this time slot as in previous years when the subject was delivered via three lectures per week plus laboratory classes. No material was presented in these lectures that had not already been adequately covered in the module materials available on-line. Lectures were not recorded but this is planned for the future.

While students were executing their modules tutors would move throughout the laboratory to provide advice and assistance if required. The tutors found it challenging but possible to deal

with the fact that different students were studying different modules simultaneously. Most experimental activities had an element of design to them to foster student engagement. Students responded positively to this opportunity to take a much more active involvement in the work than is generally the case in a class room or learning laboratory setting.

The tutors and students had module guides to help them negotiate the course and, distinct from the way Keller implemented it, from the start of the course the students had access to the material from all of the modules (except the last) so they knew what was coming up. The final (eleventh) module did not introduce any new material and was optional. It presented a challenging problem requiring students to design, build and test a circuit including analogue and digital elements and then write a report outlining their design calculations, description of all circuits and the results of tests and measurements.

### Assessment

At the end of the course the students were given the same type of exam used in years of standard teaching practice with the intention of having a direct comparison of exam performance with previous years' intakes. The attendance and dropout rates, the Keller plan module marks, the standard exam marks of the Keller plan students and the exam marks of the two previous year's intakes were analysed to determine learning outcomes. The feedback from the Keller plan students and the previous two years' cohorts were compared to establish students' impressions and levels of student satisfaction with each type of delivery.

## RESULTS

### Overview

At La Trobe University for many years there has been a robust quality assurance of subjects scheme based on students' perceptions as measured by an end of semester survey designed by the Academic Development Unit (independent of our department). Only the last four years' results were analysed because the survey questions were identical for those years (previous years had slightly different questions). The average response rate for the four years analysed was 65% of enrolled students and the average number of enrolled students was 82. Out of the 20 questions in the survey, ten have been selected for analysis (questions not analysed were those which are not particularly relevant to this subject, e.g., "This subject helps me to improve my writing skills" and less specific questions like "The quality of this subject is…" although significant improvements in the feedback given for these questions were also found). The main lecturer and co-ordinator for this subject was the same person for all four years and many of the casual staff, while not always the same, were from similar backgrounds and at a similar level (i.e. PhD students and sessional lecturers). The number of staff used was similar for all four years although, now the program is established, the actual number of contact hours for the casual staff will be slightly greater and for the lecturer it is expected to be slightly lower than for a standard course. The relative consistency in staff means variations in feedback are most likely due to real differences in the course delivery method rather than to student's opinion of the staff's teaching skills.

To establish a baseline, the results from the previous five years of the standard course were analysed. Again, the lecturer and material in the course and exam/laboratories and marking standard was identical in each of these five years. The dropout rate, those students who failed to complete the course, was also checked.

## Analysis of students' perceptions

In the Tables 1a to 1d below the results of the student surveys are shown. The students answered each survey question with a score of 1 to 5, higher being "better", and the average score is given in the tables. For brevity, the question wording has been compressed to indicate what area the question asked was aiming to evaluate, for example "Assessments are clearly linked to the learning objective" (answer 5 if always, 4 if usually, 3 if sometimes, 2 if rarely and 1 if never) is compressed to "Assessments clearly linked to objectives". The four years evaluated are shown at the top of the four results columns. For all of these results it is noted that, although the conventional course given in 2009 was identical to that given in 2010 it received slightly lower student feed back scores. The reason for this is probably that the class size was large, more than 100. According to La Trobe University, Academic Development Unit, (2005), "classes of more than 100 systematically attract somewhat lower ratings than smaller classes". All years apart from 2009 had class sizes significantly less than 100 so no overall score lowering effect would have been a factor.

**Table 1a: Reaction to material presented & method of learning**

| Question topic | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| | **Standard** | | **Keller** | |
| Interest in subject material | 3.9 | 4.0 | 4.4 | 4.4 |
| Relevance of material | 3.9 | 4.0 | 4.3 | 4.6 |
| Feedback contributes to learning | 3.8 | 4.0 | 4.2 | 4.4 |

Results in Table 1a above show a large improvement in how the students see the material and teaching method. It also shows that the second year of offering improved on the first (2011).

**Table 1b: Self-assessment of students' effort**

| Question topic | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| | **Standard** | | **Keller** | |
| Time & effort invested (by student) | 3.5 | 3.8 | 3.9 | 4.0 |
| Best efforts put in | 3.6 | 3.9 | 3.9 | 4.2 |

Results in Table 1b above show a small improvement in the students' assessment of their own efforts, particularly in the second year of offering (2012). To get students to put more effort in is always the biggest challenge.

**Table 1c: Clarity of learning objectives**

| Question topic | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| | **Standard** | | **Keller** | |
| Learning Objectives clear | 3.9 | 4.1 | 4.0 | 4.2 |
| Assessments clearly linked to objectives | 4.1 | 4.3 | 4.2 | 4.4 |

Results in Table 1c above suggest that the first year's Keller course offering (2011) did not result in the expected improvement in the important goal of clarity of learning objectives. However, the results do tend to support the contention that the situation was remedied in the subsequent year.

**Table 1d: Subject matter content of course**

| Question topic | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| | **Standard** | | **Keller** | |
| Overall challenge of subject | 3.9 | 3.9 | 3.9 | 3.9 |
| Amount learned | 3.8 | 4.0 | 4.2 | 4.0 |
| Value of learned material | 3.8 | 4.0 | 3.9 | 4.1 |

Results in Table 1d above demonstrate that the students do not assess the subject matter content covered (difficulty, amount and value) as consistently and markedly different between Keller plan and standard years. This is reassuring as there was no intention to change these aspects of the course although significant variations are noted in the amount and value feedback figures.

The purpose of the student survey questionnaire has always been to drive enhancement and improvements in the courses though review and analysis of the results. This review has demonstrated that the KPT does improve this unit from the students' perspective.

## Exam/laboratory marks

The percentage of students who passed and students who dropped out and did not take the exam are shown in table 2 below. The remainder failed the exam/laboratory combination and this figure includes any exam re-takes that they may have sat.

**Table 2: History of results for standard course**

| Year: | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| | **Standard** | | | | |
| Pass rate | 70% | 61% | 56% | 62% | 39% |
| Dropout rate | 8% | 11% | 8% | 4% | 15% |

The average pass rate over the five year period was 58% and a general downward trend over time is apparent. The average dropout rate was 9%.

These results will now be compared to the Keller plan final marks shown in Table 3 below. The pass rate is for the combination of final exam mark or the total Keller modules mark since students could fail to complete the modules yet still pass the subject by passing the conventional final exam. However, for most students the final marks were obtained from the completed modules marks.

**Table 3: Results for Keller plan course**

| Year: | 2011 | 2012 |
|---|---|---|
| | **Keller** | |
| Pass rate | 50% | 71% |
| Dropout rate | 14% | 7% |

The exam pass rate on its own was very poor for 2011 and 2012 (37% and 32% respectively). The suspected reason is because there is little incentive for students to try hard at the exam if they have already done well with the Keller modules. In 2012, many students failed to even take the exam though they were likely to have passed judging by their

good module marks. In this case, trying to use the final exam as an objective performance comparison measure with previous years has been a failure. The dropout rate has remained similar in Keller plan years to standard teaching method years.

# DISCUSSION OF RESULTS AND CONCLUSIONS

## Student satisfaction and engagement

Clearly the exercise has shown that students are more satisfied with this new course delivery method and felt they had put in more effort. The staff were also left with the strong impression that the students were more engaged and had better attendance rates and had a higher level of achievement.

The very nature of the Keller approach required students to attend to complete practice and module tests which fostered improved engagement. The design elements in the laboratory activities also stimulated student engagement; strikingly obvious to the staff when compared with student responses in previous years laboratory work which was highly structured.

## Grade outcomes

The grade distribution, markedly different to standard teaching years with a higher proportion of high marks, has not been presented here; it clouds the issue. A different grade distribution is inevitable because to pass Keller by completing 10 modules with at least 80% in each gives a minimum mark of 72%. Many students reaching this level would never have been able to get a similar mark in standard exams, even though they may have been equally knowledgeable. The simpler metric of pass rate is sufficient to demonstrate that there has been an objectively measurable improvement in learning outcomes. In Keller courses the grades tend not to sort students into well nuanced bands of achievement, they simply indicate who has reached the required level. In our course we had added a single optional and more challenging module, the eleventh and final one, to give better students the opportunity to achieve a higher mark. This idea could be extended if a higher level of “ability sorting” is required but that risks a compromise of the advantages of the Keller method which maximises the number of students who reach the required level of mastery of the subject.

The experience has shown that the problem of accommodating the ever broadening abilities of new entrants (or at least the increased variation of enter scores which indicate broader academic attainment levels in prior learning at school) has been successfully dealt with.

The dropout rate has not increased implying the poorer students are still being given a chance to keep up and reach the required standard. The trend of fail rate, which had been worsening, has now been reversed.

## Further work

The experience from the first year of offering the Keller plan has led to us being able to make significant improvements in the second year and further improvements have been identified for subsequent years.

In the second year of running the Keller plan one module was divided into two which gave the students more encouragement and sense of achievement for this area (Thevenin and Norton equivalent circuits and the Principle of Superposition). This was such a clear improvement that it is now proposed to subdivide the course into smaller learning objectives and have more module tests, especially now we have more experience in setting up these tests. However, it should be noted that preliminary work has indicated that if the module size is too small students started memorizing equations and methods in order to pass the modules rather than actually understanding the material. This becomes evident in later modules when students are expected to know, and build on, the learning outcomes of earlier

modules. In addition, the design of each module test needs further honing to ensure they really do test the concepts involved. We also plan to record all of the motivational lectures so students can access and revise them after they have been delivered live. Final exams with no incentive are not a good way of rigorously assessing performance relative to years employing standard teaching. Nevertheless, student engagement with final exams enhances motivation so a marking scheme is needed to give the exam extra weight for those who have passed the Keller modules.

An automatic system to track student progress and send them reminder messages if they are falling behind is required. This was done manually in 2011 and 2012 but should be automated.

This subject was offered to one student studying in external mode in 2012 but the materials, including experimental equipment and components, need to be re-organised for future years when we expect more students to nominate to study externally.

Rough costings indicate that the initial course was a little more than twice as expensive to implement as an on-going standard course. Now that the course has been established it is expected to cost only 30% more than a standard course. In future a detailed tracking of costs is planned to confirm this to be the case.

Implementation of Keller plan style courses is now much more practical than it used to be due to the flexibility in material presentation and ease of tracking of student results given by new IT technology. The question posed by this study is answered definitively in the affirmative; it is now possible to get better learning outcomes at a comparable cost to standard teaching practice by using a Keller plan approach.

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