Application of the Keller Plan to Marine Education in the 21st Century

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The Keller Plan (sometimes called The Personalized System of Instruction or PSI) was developed by Fred Keller and his associates in the mid 1960's as, among other things, an alternative to conventional classroom teaching as had been practiced for thousands of years. Since then, the Keller Plan has received very positive evaluations by students and in well-designed experiments, grades on both quizzes and final exams were "significantly and considerably" higher for Keller Plan participants as compared to students in lecture sections.

At the Marine Institute, our experience with marine education has led us to develop an instructional method very similar to the Keller Plan. This paper will outline the benefits of the Keller Plan and how these benefits are transferable to the current model at the Marine Institute. It will also report on the implementation of the Keller Plan and its favorable reception by current students. Based on the experience so far, it is anticipated that students following this model will enjoy above average success in the government set exams.

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1. Background to the Keller Plan

The Keller Plan (KP), or as it is sometimes called the Personalized System of Instruction (PSI), has been developed and known for almost 50 years. Discussed by Fred S. Keller in his paper "Engineering Personalized Instruction in the Classroom" [1] and then refined and presented in the paper "Good-bye Teacher" [2], the KP was based on his experience in teaching in the Signal Corps during World War II. In that position he noted that the training was highly individualized in spite of large classes and that there was a clear progression for students to follow with a demand for near perfection at every step combined with clear terminal skills. The result of the program was to graduate people with high levels of competency.

He first put the KP into use in a number of universities in the early 60's and during this time formalized the KP as having the following criteria.

1) Self-pacing where the student works through the course at their own pace. The course material is broken into units which present specific related topics.

2) Unit mastery requirement which allows students to only progress if they meet some established criteria demonstrating mastery of the unit.

3) The use of lectures and demonstrations as motivational material, as opposed to delivering critical material.

4) A stress on the written word which in this case actually means a stress on presentation of material in a non-lecture format.

5) The use of proctors which permits repeated testing, tutoring and a personal-social aspect of the education process.

Since first proposed, the KP has undergone remarkably little refinement and the five criteria given above are still at the basis of any KP course, but perhaps altered slightly depending on circumstances.

These criteria can be grouped into two themes; the first allowing students to cover material on their own, the second ensuring mastery of a topic. The self- pacing feature of the program is enabled by having prepared units which are provided to students as they progress. Such units have traditionally been written (as mentioned in criteria 4 above) but can easily include video material or some other computer based format. Lectures are not essential to the course and, when they are given, are usually to emphasize points covered in a unit or to enrich the course through an outside entity such as a guest lecture.

Mastery of a topic is demonstrated by a test or quiz at the end of each unit. If the student achieves a predetermined score on the quiz, they are allowed to proceed to the next unit. Traditionally, mastery scores are quite high and usually above 80% indicating that the student has a strong knowledge of the material before moving on to the next unit. If the student does not achieve the mastery mark they are given some guidance on where they can improve and after reviewing the material they can take the test again.

There is no penalty for having to retake the test and students may have to repeat a module several times. It is rare for a student to make it all the way through a typical course without repeating at least some of the topics. However, each test must be sufficiently different to again test the knowledge of the unit. Another feature of the KP is immediate feedback provided by the proctors who evaluate and return tests usually while a student waits.

2. Advantages of the Keller Plan

The remarkable thing about the KP is the success with which it is met in a variety of course types using varying criteria. This created a fair bit of interest in the method and as Buskist [3] says:

> Because grade distribution in PSI classes fall mostly within the A range and bear little resemblance to those found in traditional teaching formats, teachers and administrators alike have shown interest in empirical based comparisons of PSI and traditional lecture methods.

Taveggia [4] reported that over 350 studies conducted between 1924 and 1965 showed no demonstrable difference between different instructional methods. Methods such as lectures, group discussion, tutorials and educational media such as television were generally equal when evaluated on the results of student performance on final examinations. They then went on to compile research where the KP was evaluated against traditional teaching methods. They found 14 studies between 1969 and 1973 which reported on 28 courses ranging from Cultural Anthropology to Nuclear Engineering. The result was that all 28 favored the KP.

A “meta-analysis” study by Kulik [5] reviewed the KP along with Bloom’s Learning for Mastery [6] method using 103 studies carried out in college level courses. As an aside, Bloom’s Learning for Mastery (proposed in 1968) is another program which emphasizes mastery of a topic before progressing. However, there is a difference in the focus of the two methods; Bloom looked at

mastery in the context of a public school system, as opposed to the KP which has been implemented mainly at the college and university level.

The papers used in the meta-analysis were reviewed prior to being selected and judged suitable for inclusion based on criteria defined by Kulik (such as reporting results from examinations at the end of the course). Of the 103 studies, 96 reported that the mastery approach has a positive effect on performance in examinations.

While this is an impressive statistic, the even more impressive feature is that the average effect size was 0.52. In this case, the effect size is the increase in student scores as measured by standard deviations (i.e. the mastery based courses had scores that were increased on average by 0.52 standard deviations). In more concrete terms this means an increase in final exam scores on average from the 50^{th} percentile to the 70^{th} percentile.

Kulik was also able to create subsets of the 103 studies that looked at other features important for student success. Eighteen of the studies assessed student attitude towards instructional methods and found an overall positive effect size of 0.63. Fourteen of the studies looked at student attitude towards the subject and found a positive effect size of 0.40.

The only area where the KP based courses suffered in comparison to conventional courses was in the area of course completion (there was no data for the Learning for Mastery method available). Here there was a small negative effect size of -0.14, indicating that there was a slightly higher drop-out rate in the KP based courses.

The KP also does better regardless of the evaluation format. Buskist [3] reports that students who take KP courses do better on:

(i) Multiple choice examinations,

(ii) Final examinations,

(iii) Essay examinations,

(iv) Examinations designed to measure recall and

(v) Follow up examinations given several weeks after the end of a course.

Kulik [7] went a step further and did a component analysis of the features of the KP to identify which features of the plan were the most important. He found that frequent quizzing, immediate feedback and requiring a mastery of the material were critical. In addition he found that another feature (not part of Keller's initial plan) which was important was the inclusion of review quizzes given after every 4 or 5 units.

While these studies are somewhat older, recent studies show similar results. For example, in 2012 Mackie [8] looked at the implementation of an electronic engineering course using the KP. He reported that students appear more interested in the subject matter and that the percentage of students passing the course had increased. Although he cautions that the way the KP was implemented means that final grades are not able to be compared, or as he puts it "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".

Interesting and relevant for people engaged in teaching nautical science and marine engineering is that while the KP was initially created for psychology and other social sciences courses, it has been found to be well suited for more technical courses. Grant [9] states that "PSI achieved many of its initial successes in physics, engineering and the sciences".

3. Disadvantages of the Keller Plan

The clear benefits of the KP method of teaching present something of a paradox when compared with the adoption of KP courses. It would be logical to conclude that since it is a demonstrably better instructional process the adoption would be high and increasing where as the opposite is true; the adoption is actually low and decreasing. Why this is so is interesting and has been commented on by several authors.

Many cite the cost incurred for the traditional KP based course as one of the impediments to integration. This cost represents an investment by the faculty involved in setting up the course in addition to a dollar cost since it requires a number of proctors to run which is generally a paid position given to an upper year student.

The investment by faculty setting up a KP based course is significant and is more than either a distance delivery type course or a lecture based course. As Herzberg [10]says "The Keller Plan is a complex system and a good deal of commitment to it is necessary to implement and maintain it in its full form. Such commitment does not come without cost…" The starting point of the development is the creation (or organization and clarification if already created) of learning objectives for the course. The learning objectives must be grouped into appropriate units and then material can be developed which cover the learning objectives. Also, for every unit, multiple tests must be made so that students can have multiple attempts. All of this must be done before the course begins since it can be reasonably assumed that some students will work through the material very quickly.

There is also a cost due to the use of proctors who interact with the students after every unit to assess their quiz results and recommend remedial action. These are paid positions, but a sufficient number must be available to give students fast feedback. Herzberg [10] claims that in the 25 years he has run a KP based course he has employed 267 proctors.

However, if cost was the only restriction funds could probably be found; after all in laboratory courses it is common to have upper year students or full time staff assigned to help out in the laboratory itself. In fact a more serious problems exists in the present "culture" of the traditional educational institute. The lecture format has a number of beneficial features. It creates a structure and platform for the instructor to discuss their topic of expertise. It also imposes a convenient time frame for the institute which can have all courses run the same length with precise start and stop dates. In fact, the only entity that the lecture based course does not benefit is the student (Buskist [3]). Thus a move to a KP type course would require some flexibility on the part of both the institute and the instructor.

Another impediment to the adoption of the KP is surprising in that it is based on the success of the students. As Buskist [3] says "Many PSI instructors must also contend with colleagues and administrators who complain of too many A's". This is also echoed by Tyree [11] who states that in his KP implementation of a law course, about 80% of the students did well enough to achieve a "high distinction" when guidelines indicate that between 2% and 8% should.

It would be fair to assume that the high marks were due to the criteria that students must achieve a very high mark on each unit in order to progress (and must retake tests until a high mark is achieved).

If these marks were then used as part of the final assessment, it would be logical to assume a skewness towards higher marks. However this is not the case as was discussed previously in this paper since the improvement is also reflected in final examination grades and in post-course examinations. While this may be a real impediment, it is hard to justify since essentially the students are being poorly judged for doing too well.

The one real problem identified is that of student withdrawal. The authors feel that the recent drive towards standardization of education is generally good and necessary, but has created a very structured framework in which classes and consequently students are used to operating. In a KP based course, the student is at the center of the process and drives it. While there are the necessary supports, it is ultimately the student who must review the material and decide when they are ready for a unit quiz. It is easy for a student to think that this week is a busy one and they will catch up next week, but of course the next week is even busier and thus they never catch up. Facing working through a term worth of material in half a term is daunting enough to make even dedicated students withdraw.

The following table summarizes the main impediments to a KP based course along with our assessment of their validity.

Table 1: Impediments to adoption of Keller Plan courses

Impediment	Assessment
Cost	Valid
Cultural Change	Valid in that it will result in a change of culture but if this results in serving students better it should be considered.
Marks too high	Not valid
Student withdrawal	Valid

4. A Sample Course

The authors have been active in the area of distance education and educational technology for several years. Experience gained through previous courses emphasized the advantages of breaking material down into smaller manageable units as well as the benefits of allowing repeat assignments (Tucker [12]). In one notable case (a course dealing with engineering economics), the application of these ideas turned a course which was difficult for students and frustrating for the instructor into one which has become popular and in which students achieve considerable success.

The application of this knowledge resulted in the construction of an applied mechanics course to prepare students to write the Transport Canada Applied Mechanics Exam for watch-keepers (the extension of this course to the exam for Chief's is currently on going). This work has drawn heavily on our experience in teaching distance courses while taking advantage of the most advanced technology we could get our hands on. This section describes how the Applied Mechanics course was initially designed.

A flowchart describing the course is shown in Figure 1. A new learner starts a course and after being given some introductory information about how the course works is given Module 1 to review (in the applied mechanics course the first module is Forces as Vectors). The module consists of a carefully prepared presentation which can best be described as a narrated PowerPoint presentation. Essentially, what the student sees is a series of PowerPoint slides but each one is narrated by the instructor who presents the theory and goes over examples to clarify the points made.

The PowerPoint presentations have been developed based on the learning objectives that comprise the Transport Canada requirements for the applied mechanics course. They also have what we call engagement questions which are simple questions which "pop-up" throughout the presentation and are based on the presented material. They are intended mostly to act as "speed bumps" to fast forwarding through the lectures, forcing students to slow down and ensure they are absorbing the material.

An important part of the process is the support cloud. In a course like this there is a huge amount of potential support which must be in place. Student issues can range from technology problems accessing the course material to lack of (or forgotten) background material. The support cloud is in place to help with anticipated issues and consists of technical support and recommended web based material to help students understand the prerequisite material.

Once the student has completed Module 1, a quiz automatically becomes available. Up to this time the quiz has been hidden but upon completion of the Module, it is now visible and the student can proceed to take it when they feel ready. The quiz is intended as a diagnostic tool and is not used in a prescriptive way. If the student does not achieve the mastery mark (in our case set at 80%) it will not

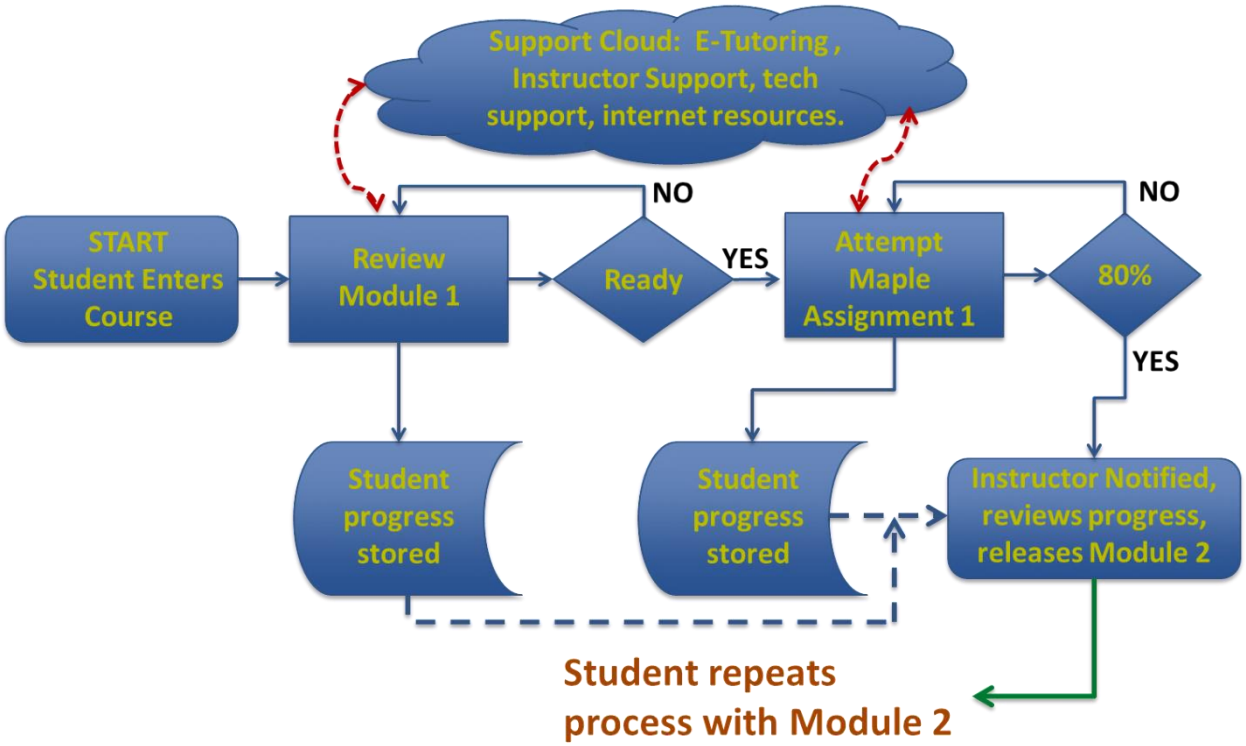

Figure 1: The course flowchart as first developed

reflect poorly on their record. They are expected to make an honest attempt at the assignment. While there is no restriction on the tools the student can use (i.e. notes and texts can be used) the test is timed so the student cannot take too much time looking up solutions.

If the student scores 80% or more, the instructor is notified who can review the work. If the instructor is satisfied with the work they can open up Module 2 and the student continues to progress. If the student does not achieve the 80%, they are forced to review the material before taking another quiz. The quizzes are designed in Maple TA and draw from a collection of appropriate applied mechanics questions. Also, the specific numbers for each question are changed every time (our current rule of thumb is that each question must have at least 100,000 possible permutations).

The Applied Mechanics course has over 30 units but we feel that there is a very large amount of material to be covered in the it. Twenty four units would be more appropriate for a standard length course. This is in line with Williams [13] who recommends 20 to 30 units for a standard course.

Upon completion of all the units, the student is prepared to take the Transport Canada exam. Also, since the students now have access to all the units, they can review as they wish. The online course exams are also open in case the student wishes to practice on certain topics.

5. Bringing a course in line with the Keller Plan

It should be noted that the initial online version of the applied mechanics course was developed without any knowledge of the KP. It was designed based on our experiences and what we found that "worked" and what the technology allowed us to do. In retrospect it fits quite well with the KP. The material is broken into manageable units, the material is not lecture based, and the student is able to progress at their own pace but must show mastery of a topic before progressing. However, after becoming aware of the KP method of teaching the authors were able to make some slight changes to the model to bring it more in line with the traditional KP model. The changes are shown in Figure 2.

Most of the changes have to do with the instructor's role in the course and some of this is enabled by new technology being adopted by the Marine Institute which will integrate results from the Maple TA program directly into the learning management system, D2L. In the previous version of the course, the instructor had to manually release the next module, but now the module becomes visible upon the student obtaining mastery automatically. In a world where education is global and not restricted by a 9:00 to 5:00 workday, the advantage is significant.

The other important change involves the migration of the role of the instructor from someone who releases new material when mastery is achieved to someone who becomes active when a student does not do well. In the previous case the instructor was more active as a manager of the system, but now the instructor, while still maintaining their management role, acts as the traditional proctor (minus the marking of multiple quizzes). They can review all the work up to that point and identify specific problem areas and then recommend remedial action. This specific and unique feedback for each participant is much more inline with the role of the proctor in the traditional KP approach. It also

provides a personal interaction with the student to keep them interested and supported.

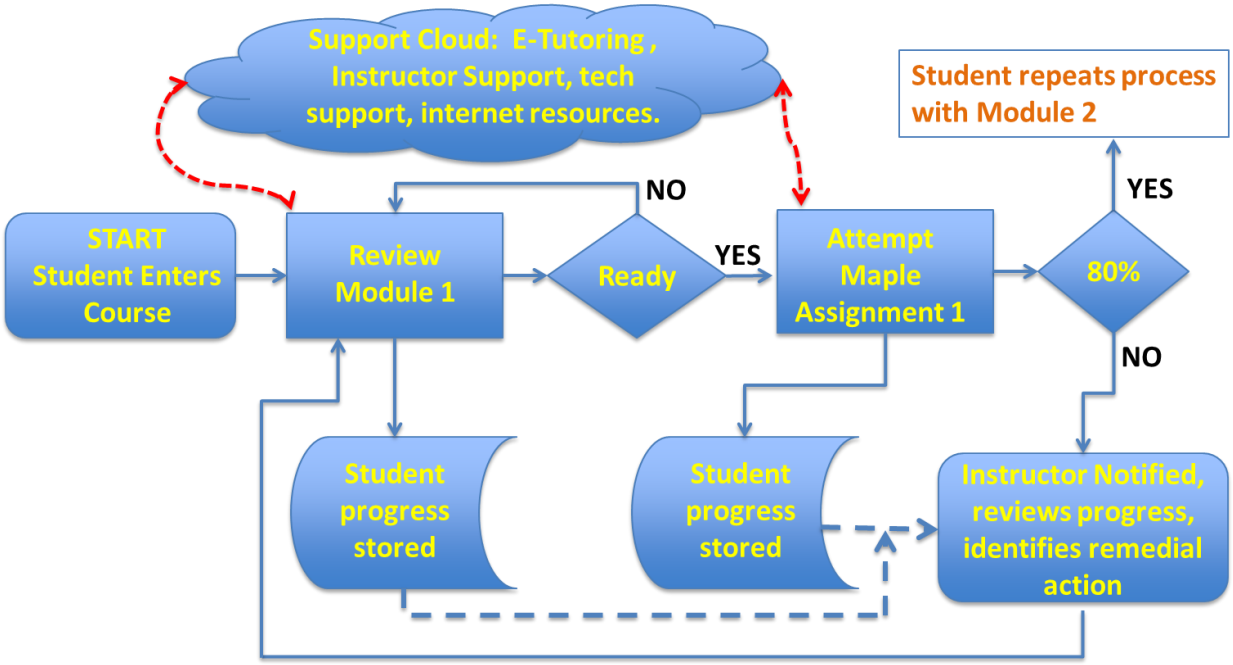

Figure 2: The applied mechanics course with a Keller Plan focus

A new feature, which we are considering adding, is based on Kulik's component analysis. He identified the importance of having reviews after every 4 or 5 units. The material in the Applied Mechanics course is suited to being grouped, although logical groupings may mean that some reviews only cover 2 units. Using the Maple TA quizzing process, such a review would be easy to set up and still provide students with instantaneous feedback.

6. Benefits of the electronic Keller Plan

The authors feel that the redesigned course offers an electronic version of a Keller Plan course. While taking advantage of the benefits offered by the KP method, it addresses the problems outlined in Table 1.

For example, while the cost of developing the applied mechanics course was significant, with the materials in place it becomes relatively easy to administer. To elaborate, to reach this point has taken two faculty members working on and off for two years to develop the necessary material. This includes a basic set of narrated powerpoint slides, a set of quizzes coded in Maple TA, identification of material for the support cloud and even the development of integration software which is currently only available at Memorial University and one other location in the world. This represents an approximate cost of a half man year excluding software development costs. But it should be noted that this course is an unusually large course; approximately 1 ½ regular courses. In addition, it should be noted that this course was created using new tools and techniques and the learning curves in places were somewhat steep.

However with the materials in place, the instructor becomes not only what Keller envisioned when he used the phrase "managers of learning" but also an active and focused participant, dealing with specific student issues when they have trouble with the material. The instructor does not need to correct multiple quizzes, but they do need to review quizzes where students have not done well and come up with specific remedial actions that are individualized for each student. They are there to

explain difficult concepts but do not actively lecture. Essentially, they are there to enable students to learn the material.

The course outlined here is also able to overcome the cultural issues surrounding higher education due to the nature of the intended clients and the instructors interested in the work. Generally, since the course is new in several aspects, the professors interested tend to self-select to be open to formats other than lectures. Also, where the learners are probably active mariners , the timing of the course can be fit around their needs. For example, the current course is given as a preparatory course (one which prepares the mariner to write the Transport Canada examination). As such it does not need to follow the regular scheduling system found at Memorial University.

The issue of students being too successful tends to be an issue where a class result is envisioned to be a normal distribution. In fact since we are preparing our students to write an exam administered by others we expect and hope that a very large percentage are able to pass the set exam. A 100% pass would be a more than acceptable result.

The final issue of students falling behind is a real one but since the students know they will be facing a critical, career dependent examination after completing the course the motivation is high. In addition, the instructor is better able to assess progress with this course than in other KP based courses since the learning management system keeps track time and length of student activity. If an instructor sees that a student has not been active for 2 weeks, they can make reasonable attempts to contact the student and determine if there are specific course related problems.

Parts of the applied mechanics course have been given to students over the last two years. Feedback has so far been very positive. Students feel that the current method has turned a course which was previously feared into a course which they can do. As instructors, the authors feel that the students gain more from this method and are better trained to challenge Transport Canada exams.

7. Conclusions

The authors feel that the course developed follows the KP system which is a demonstrably better instructional method. The course allows students to work at their own pace through complex applied mechanics material, slowed down only when they start to go wrong and need help in certain topics. However it has distinct advantages over the old Keller Plan in that, once in place, the cost to run the course is relatively low while specific targeted instructor student interaction is high.

While the course is good, there are potential improvements which can be made in the future. For example, there is the potential for “branching” in a presentation based on student responses to engagement questions. Thus an initial layer of feedback is in place in the lecture but only becomes available if a problem is exhibited.

While it has been offered in parts to two previous student classes it is expected to run a full KP based course starting this fall. The subsequent experience gained and student feedback will continue to craft the applied mechanics program into a strong course for marine engineers.

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