A New Approach to Training and Software: Good Instruction vs. Good Software

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ABSTRACT

In this computer age, CAS, Computer Assisted Software, is common, available, and used in both University teaching and Industry Training. The purpose of this talk is to address a new approach to assessing CAS usefulness. The typical approach, both in the University and Industry settings is, "Does it work?" "What are the 'before and after' scores and are they significant?" This approach is flawed for three reasons: I) INSTRUCTION vs. SOFTWARE: We already have a rich literature on good instruction that is supported by before-after analysis. This instructional literature should be both sufficient and necessary to evaluate software. II) SOFTWARE OMISSIONS: If the software is lacking an important instructional feature the current attitude is to wait for the next software version before implementing; contrastively, we advocate concurrent supplementation of the software with necessary instructional aids. III) CONTRADICTORY STATISTICAL RESULTS: The over-emphasis on software necessarily leads to contradictory statistical results on efficacy since the important driver of instructional methodology is typically lacking from the experiments. As time permits, examples are given from several disciplines using the four pillars of good instructional pedagogy advocated by Hendel in a recent book.

Keywords: computer assisted, self-efficacy, attribution theory, structured curriculum, goal setting, superior pedagogy,

1. GOALS

The purpose of this paper is to discuss the challenges, enhancements, and successes of using software in a course covering the material of the Society of Actuary (SOA), Financial Mathematics (FM), preliminary examination course [14]. *Although a specific software is examined, the paper presents general goals for success with software.*

1.1. The University and Software. The software introduced is the relatively new Adapt-in-Class (AiC) (Section 5). The university setting is Towson University (TU) a Center of Actuarial Excellence (CAE) school (Section 4).

1.2. A New Approach to Computer Assistance (CA): This paper offers a novel approach to assessing CA. The traditional approach to assessing CA is using a before-after study: Two classes with students with similar attributes are offered identical instruction except that one class additionally has CA. If the identical assessment of the two classes shows a statistically significant performance difference for the CA-class, we can conclude that the CA is effective.

For several reasons, this approach has flaws. These flaws are discussed in Section 3. The approach of this paper is to assess the CA by assessing the instructional method of teaching. If the instructional method of teaching is superior and the CA fits into this method then the CA is effective; if the CA does not fit into the instructional method, or, if the instructional method is unsound, then the CA is not effective. A discussion of sound and superior instructional methods, with clear operational criteria to evaluate the methods, is presented in Section 2.

1.3. Exploratory Nature of this Study. This study is exploratory. There are several reasons for the exploratory nature of this study:

i) Finding 2 Classes to Treat: It is not possible to strictly identify two cohorts (classes) of students, one using the software and one not using the software, since the students universally study from the software whether the instructor uses the software or not. This universal usage by the students is a qualitative assessment of the software, but not sufficient to fully justify its use.
ii) Obtaining Metrics: An important metric in assessing software used in an actuarial course is the number of students who, after taking the course, can successfully complete the Society of Actuary (SOA) Financial Mathematics (FM) examination. This examination is given in February, April, June, August, October and December of each year. However, students pass on a rolling basis, some immediately, and some after a year or two. This makes obtaining counts difficult.
iii) Successful failures: Some students drop the course the first time they take it, then retake it (and in fact pass the SOA examination). Such students create complications in creating metrics since they are simultaneously successes and failures.
iv) How the CA is Used: The instructor, based on the principles in this paper, has changed *how* the software is used. These changes are discussed later in the paper. Obviously, however, if the method of using the software changes, then assessment of the CA must be delayed until the method is stabilized.

2: PEDAGOGY

This section examines criteria for good pedagogy. These criteria are used to assess both instruction and use of CA.

2.1 The Four Pillars of Superior Pedagogy. In a recent book [19], Hendel proposes four attributes, or pillars, that every good pedagogy must exhibit:

- Executive Function: Using multiple modalities of presentation and multiple-parameter explanations [17].
- Goal-Setting Theory: The breakup of complex tasks into a

sequence of simpler tasks, each clear, well-defined, specific, challenging, and achievable short term [20,29,30].

- Attribution Theory: The perception by students that success is dependent on their own efforts [38].
- Self-Efficacy: The belief of students that with their current skill sets they can achieve the desired course goals [4].

These four pillars are consistent with, and supplement, other definitions of pedagogic challenge such as those of Bloom [8], Anderson [3], Van-Hiele (for geometry) [35], Gagne [15], Marzano [31] and Webb [36, 37]. These four pillars also incorporate several decades of research on goal-setting theory [29, 30] as well as the importance of student self-efficacy for educational success [4].

The four pillars of pedagogy are also consistent with the requirements of pedagogic excellence addressed on a national level for K-12 by the Process Standards of the National Council of Teachers of Mathematics (NCTM) [33], as well as the Standards of Mathematical Practice (SMP) proposed by the Common Core State Standards for Mathematics (CCSSM) [13].

2.2 Stages for CA Success. Using this theory of pedagogy, Figure 1 describes critical attributes required for any CA to be successful. Heuristically, Figure 1 states that a CA is successful, that is, statistically increases performance, if it possesses the following important three attributes:

- *Structured Curriculum* (SC), a clear taxonomic structure of modules and submodules with each submodule presenting specific learning objectives (SLO), focusing on a single skill that is clearly defined, specific, challenging, and achievable short-time, and with each module defining a unifying characteristic of all its submodules [5,6,7].
- *Sufficient Problems* for each submodule
- *Levels of Problem Difficulty*.

We now explain how each of these three attributes mirror superior pedagogy.

- The *Executive Function* pillar of pedagogy requires using multi-parameter instruction simultaneously involving several areas of the brain. SC is multi-dimensional since each submodule is governed by the multiple parameters of the high-level curriculum topic and the submodules unified by this module; the collection of submodules exposes similarities and contrasts in the main topic.
- The most important driver of the pedagogy pillar, *Self-Efficacy*, the belief of the student that with their current skills and sufficient effort they can achieve a certain outcome, is performance mastery that comes from practice [4, 19]. This is afforded by a large question bank.
- The *goal-setting* pedagogy pillar requires skills that can be developed by clearly defined, specific, challenging tasks, achievable short time. This is afforded by *levels of difficulty*. Certain CA use flash-cards, hints, and explanations of errors. This is an added feature consistent with *goal-setting* which shows that performance is enhanced when feedback is present [27, 28, 39, 40].
- Because the CA is a machine, it is objective. A student mastering an easy difficulty level knows that (s)he achieved this through their own merit. Such a student is more motivated to advance to further levels. This corresponds to the *attribution* pillar of pedagogy which states that pedagogy is best when attribution is based on work and effort [38].

Computer Assistance (CA)+Structured Curriculum (SC)

- *Structured Curriculum - Question Banks*
- *Graduated levels of problem difficulty*
- *Performance mastery through adequate practice*
- *Solutions providing feedback on problems*
- *Success attributed to effort; Increased self-efficacy*
- *Loop back to SC - Question Banks* (1st bullet)

Figure 1: Stages achieving pedagogic mastery through CA.

3: COMPUTER ASSISTED SOFWARE

3.1 CA Assessment. As indicated in Section 1.2, the position of this paper is that a 1) sufficient and 2) necessary condition for CA to be effective is that it supports a superior instructional pedagogy. However, examining the literature exposes arguments for rejecting both necessity and sufficiency.

1. Sufficiency: Besides supporting a superior pedagogy, CA efficacy depends on other factors such as i) teacher's attitude towards computers, ii) professional development (training) opportunities, and iii) barriers to computer use [23].

2. Necessity: The position that support of a superior instructional pedagogy is necessary for CA efficacy seems to contradict a rich literature using before-after studies demonstrating CA efficacy without reference to instructional method. These before-after studies examine performance in two cohorts of students one using CA and one not using CA. A statistically significant performance difference, demonstrates CA efficacy (see the critique in [2] against this argument).

The purpose of this section is to examine the necessity and sufficiency arguments against the literature. We will show that:

1. The literature reveals contradictory results on CA efficacy. This paper argues that contradictory results are explained by the missing variable of instructional method.

2. Good attitude, training, and lack of barriers are parameters that affect additional CA efficacy.

Before presenting the literature, we note several reasons for rejecting the before-after method of assessing CA:

- Operationally: it would be difficult to create two student groups one of which learns with CA and one which learns without it. Students come to the university to earn a degree. They ask professors and fellow students, "What works?" They are told that CA affords them adequate practice. Thus, students naturally want to use CA. It would in fact be unethical, for purposes of a study, to deprive a group of students from what everyone else is using to attain success.

- Pedagogically: a before-after t-test (or ANOVA) can at most prove that something in the CA is pedagogically useful. It does not identify what in the CA is pedagogically useful. In fact, a major point of this article is that AiC will not lead to success, by itself, but does lead to success as part of a correct pedagogy. Since the literature shows that SC by itself improves grades, it is expected that a SC-based CA is similar.

- Assessing instruction vs. CA: This article goes one step further beyond exploring SC in CA. This article argues that we should not judge CA itself by statistical tests but rather judge the instructional methods that the CA supports by statistical tests. If the instruction is good and the CA supports that instruction, then the CA is good. That the four educational pillars of pedagogy improve pedagogy has been justified elsewhere [5, 6, 7, 19]. We are merely using the CA as a vehicle to implement good pedagogy.

We now present selected studies from the literature.

Hunter's Doctoral Thesis. Hunter in her doctoral thesis [24] compares the two treatments of CA and SC. She finds that univariate and multivariate analyses revealed *no* statistically significant instructional type effects on mathematics achievement or attitude towards mathematics.

Such a result is consistent with this paper's approach. CA *by itself* should not be expected to increase pedagogy; contrastively, CA when built on an SC, should at least have the same effect as SC without CA. Hunter's study emphasizes that the proper focus on pedagogical success is not on CA by itself, but on whether the CA enhances pedagogy.

Hudson's book. Hudson [23] illustrates the type of analysis advocated by Figure 1. Hudson, besides discussing the success of CA, presents a variety of learning theories.

Hudson further includes other very relevant variables which however are not discussed in this paper. Hudson discusses issues such as i) teacher's attitude towards computers, ii) professional development (training) opportunities, and iii) barriers to computer use. Future studies along the line of this paper would benefit from inclusion of these variables.

Qualitative Benefits of CA. Several authors [9, 11, 26] suggest the following benefits to use of CA in the classroom:
- Active engagement in the learning process
- Multimedia instruction
- When and where students can learn
- Learning at one's own pace
- Receiving immediate and accurate feedback.

We immediately see that multimedia instruction (involving several parts of the mind) and immediate feedback (a component of goal setting) are two important components of the four pillars of education mentioned in Section 2.

A Metastudy of 40 studies. We close this section with an examination of a meta-study on the time-honored *before-after* method. Amir and Basol [2] conduct a meta-study of CA, based on 40 CA studies. Overall, CA does increase performance.

However, the underlying studies do not, in every case, identify all the variables enumerated in Figure 1: i) SC, ii) question bank size, iii) attribution theory and iv) feedback loops.

This meta-study correctly notes some results are positive and some are negative. The position of this paper is that both positive and negative studies of CA should carefully document the presence or absence of the theoretical pedagogical prerequisites needed for instructional success. The prediction of this paper is that the presence of pedagogic variables, not always included in studies, should lead to uniform results.

4: TOWSON UNIVERSITY (TU)

4.1 **The University**. Towson University, a public university located in Towson, Maryland in the United States, has evolved into a four-year degree-granting institution consisting of eight colleges with over 22,000 students enrolled. The university provides more than 60 majors and 75 graduate programs. There is a 17:1 student-faculty ratio. 78% of full-time faculty hold the highest degree in their field. TU is ranked 10th in U.S. News' Top Public Schools-Regional Universities (North) [34].

In 2002, Towson University was named a Center of Academic Excellence in Information Assurance Education by the National Security Agency. Towson University maintains strong partnerships with public and private organizations providing unique opportunities for research, internships and jobs [12].

4.2 The Mathematics Department. Initially, the Mathematics Department at TU served the education goal of the University. In the 1960s, the two concentrations in mathematics were Pure Mathematics and Secondary Education. However, by the 1990s the Mathematics Department offered Applied Mathematics, Actuarial Science Mathematics, and Applied Mathematics and Computing. The Department also offers master's degree programs in Applied and Industrial Mathematics, and Mathematics Education [32].

4.3 Center of Actuarial Excellence [10]. In 2013, TU was named a Center of Actuarial Excellence, CAE, a designation conferred by the SOA. There are currently under 30 CAE schools worldwide. The Centers of Actuarial Excellence (CAE) program allows universities and colleges with outstanding actuarial programs the opportunity to be recognized for that achievement and to compete for special SOA grants.

The CAE program was designed to meet the following objectives:
- Strengthen the position of the academic branch of the profession
- Enhance actuarial research and intellectual capital development
- Encourage universities to play an integral role in advancing actuarial knowledge
- Build connections between the profession and top-tier actuarial programs and faculty.

Because of its CAE designation and its strong ties to industry, TU is in a unique position to assist its actuarial science and risk management majors in obtaining internships and jobs.

4.4 **Summary**. Today, the TU Mathematics Department offers an Actuarial and Risk Management concentration. It has several faculty members devoted to teaching actuarial mathematics, several of whom have attained the highest possible actuarial degree. Several dozen mathematics majors belong to the actuarial and risk management concentration. In addition to actuarial course work, TU provides research opportunities to students, hosts job fairs, and supports an internship program.

Passing the preliminary SOA examinations is an important prerequisite for the continuing success of the Actuarial and Risk Management concentration. The next few sections will discuss the introduction of CA into the FM actuarial course.

5. ADAPT in CLASS

5.1 **ADAPT Software [1]**. Adaptive Dynamic Actuarial

Practice Tests (ADAPT) is an online problem and testing software designed to adapt to the student's current level. ADAPT generates varied questions from a large database and allows students to take questions on given topics at several levels of difficulty.

The ADAPT concept was invented by the Northwestern College actuarial science program, led by Dr. Timothy Huffman and assisted by Dr. Graham Lemke. Dr. Huffman uses ADAPT as part of his teaching curriculum.

ADAPT offers many types of computer assistance including:

i) An online study manual
ii) An online library
iii) An outline question bank of about 1500 questions with graded difficulty,
iv) Complete worked-out solutions to all problems, and
v) Video-lecture solutions to many problems.

The ADAPT quizzes and examinations are created as follows:

- The student selects modules from the SC
- The student selects a range of difficulty levels
- The student selects a quiz size (number of questions).

The student then takes the quiz. ADAPT scores the quiz. After taking the quiz, the solutions to each problem are available to the student. ADAPT will also provide a student with his or her earned level which reflects all examinations and quizzes taken to date. The student's quiz/examination history is stored in ADAPT. The student can review quizzes taken on specific topics and at specific levels of difficulty and chart progress.

5.2 The Stages of Figure 1 Applied to ADAPT. The position of this paper is that CA by itself does not improve performance. Rather the CA must serve a pedagogically sound curriculum and possess the prerequisites listed in Figure 1. A review of the stages of Figure 1 shows the following:

- The Society of Actuaries produces detailed syllabi for the material on each examination [14]. The SOA syllabi are *structured curriculum* (SC). The ADAPT question bank is taxonomized using the SOA SC syllabus.
- The ADAPT question bank has adequate size (1500+ problems). This allows sufficient practice for *performance mastery* both generally and on individual topics.
- The ADAPT question bank provides *immediate feedback* by presenting solutions for each problem.
- Additionally, ADAPT creates an online community allowing more *feedback* as well as professional staff who respond to inquiries.
- CA is ideal from an *attribution theory* viewpoint. Software is objective and not subject to prejudice. Because the ADAPT questions have a graduated level of difficulty, success cannot be attributed to luck or chance. It follows, that the ADAPT software is ideal for creating an environment where success is attributed to work and effort.
- ADAPT questions have *graduated difficulty*. The educational theory of goal setting, one of the four pillars of pedagogy, teaches that intermediate goals must be specific but challenging. By using a graduated level of difficulty, students can quickly identify when the problems they are doing are too simple and when they are too hard.
- The graduated difficulty allows candidates to self-assess readiness for SOA examinations. To pass the SOA exam, students must master questions at the 5.5 difficulty level. This capacity for self-assessment increases *self-efficacy* since students are confident that with their current skills they can pass a difficult SOA FM exam.

5.3 **Summary of Features of Interest in ADAPT**. Thus, although ADAPT offers many features, according to Section 2, the following features are those that are critical to achieving classroom success:

- The *structured curriculum* of the SOA and the consequent ADAPT taxonomy of questions based on the SOA SC
- The large question bank of about 1500 problems allowing an achievement of *performance mastery* which in turn increases *self-efficacy* the belief of the student that with their current skill-level they can answer questions of specified difficulty
- The *graduated difficulty* of problems facilitating adequate *goal setting* and *attribution theory* since students perceive their success or failure at a given level based on their work and effort
- Worked out solutions affording *feedback.*

5.4 **ADAPT in Class (AiC)**. Originally, ADAPT was used as a supplement to classroom material. In the last few years, about 20 universities have started to use ADAPT as part of the classroom experience. ADAPT responded by creating a new product, **AiC**, Adapt in Class. The AiC has all the features of ADAPT.

Additionally, the instructor can create class quizzes. The students take the quizzes and the instructor instantly receives all student scores as well as summary statistics on each student and question. The AiC quizzes have the following properties (note the similarity to ADAPT generated quizzes described in Section 5.1):

- The instructor selects modules from the SC
- The instructor selects a range of difficulty levels
- The instructor selects a quiz size (number of questions)
- The instructor can arrange for:
    - Immediate feedback, that is, solutions after each problem
    - Delayed feedback, that is, solutions after the entire quiz is done
- The instructor can select questions (from specific modules and specific levels of difficulty) either:
    - Randomly (each student gets questions from the same module and same range of difficulties, but the questions may differ from student to student)
    - Custom-based (the instructor selects the same question for all students; each question meets the instructor's criteria of module specificity and difficulty range).

Sections 7 and 8 discuss introduction of AiC in the Fall 2017 semester of the Theory of Interest course at TU.

6. LEVEL OF PROBLEM DIFFICUTY

Several times in this paper, reference has been made to problem difficulty or problem level. This section clarifies through the following illustrative example what problem level measures:

- Consider the module of pricing level annuities, that is annuities which every year pay a fixed (level) amount of $*X*. Finding the price for such an annuity involves plugging numbers into a formula. Such a problem would probably be at a simple or easy level, say 0-3.

- Now consider an integrated problem, that is a problem that integrates two Financial Mathematics modules. Suppose the annuity pays \$X at the end of years 1 through 10 but then increases payments by \$10 in years 11 through 20. So, it pays \$X+10 for the 11th year, \$X+20 for the 12th year, etc. Pricing this annuity requires *simultaneous* use of techniques from two modules, level annuities and increasing annuities. Thus, its difficulty level might be level 4.
- Now consider the same problem, \$X per year for years 1 through 10 and payments increasing by \$10 per year for years 11 through 20. Suppose the period of payment is changed to monthly payments. In other words, payments of X/12 are made monthly for years 1 through 10; payments of \$(X+10)/12 are made monthly for year 11, payments of \$(X+20)/12 are made monthly for year 12, etc. Such a problem might be at level 5 and be at the level of difficulty of a typical problem on the SOA examination.
- To emphasize how the problem difficulty was raised, note that three distinct FM modules were used: (i) level annuities, ii) increasing annuities, iii) payment periods different from interest periods.
- The problem statement can be completed by i) giving the price of this annuity and requesting calculation of \$X, or by, ii) giving the value of \$X and asking for calculation of the price. In either case, the annual effective rate of interest would also have to be given. The student might have to adjust the annual effective rate to a monthly rate.

Passing from a one-module problem to an integrated problem can be a significant *jump.* The psychological literature indicates that for problem solutions requiring integration of just two modules, task difficulty and solution time increase *even* if each of the integrated tasks are easy. The reason for this increase in difficulty is because integration requires use of executive function, while contrastively, a single-skill problem requires no executive function [16, 19].

7. AiC, THE FIRST SEMESTER

In consultation with the director of the actuarial program at TU, the author made the decision to try AiC in class.

How software should be used was discussed in previous sections. Software-supplemented instruction should ideally i) use an SC with ii) clear, specific goals, achievable in a short time, with iii) adequate problems for mastery, and iv) provide immediate feedback.

This section discusses challenges and problems with using the software and how they were overcome. Of special interest to instructors using CA is the idea of *supplementing* the software with instructional materials remedying software deficiencies. The section concludes by indicating specifically how the good features of AiC, discussed in previous sections, were used.

7.1 **Cost Challenges**. AiC costs money. It is well known that costs for college course textbooks can be expensive. An example of concerns for student expenditures is found in The Higher Education Opportunity Act [21] which requires the University to inform students at the time of enrollment what textbooks and supplemental materials are required and/or recommended for a course.

This problem of cost was dealt with by: i) Exempting students from purchasing a textbook; ii) Requiring purchase of AiC; iii) Providing a complete set of notes online [18].

The net effect was to *replace* textbook cost with software cost without depriving students of textbook resources. The cost of the AiC is comparable (but slightly higher) to textbook cost. Furthermore, TU has a software reimbursement policy: When a TU student passes either the Probability or the Financial Mathematics examination, they can receive a scholarship covering part of the cost of the ADAPT software.

Therefore, overall, students did not perceive the required purchase of AiC as a cost burden.

7.2 **Software Deficiencies**. Because software was grading the problems, students never received feedback on the *form* of their solutions. For example, a satisfactory solution, *independent* of the problem, should reflect use of the *rule of four* [22]:

- Geometric: A geometric timeline exhibiting all cashflows and interest rates
- Formal: A basic *Equation of Value* unifying all components of the problem
- Computational: Calculator time-value lines compactly summarizing certain special calculations which can be done swiftly on the special calculators used in class
- Algebra: A formal algebra component.

This important rule illustrates use of an *executive function* approach to instruction, *executive function* being one of the four pillars of pedagogy presented in Section 2 [19].

To remedy this deficiency, students were required to hand in one problem from the electronic homework given every class day and graded by computer. Since students already new the correct answer to this submitted homework problem, they were not graded on answer correctness but rather they were graded on the solution *form.* More specifically, each homework was required to use the *rule of four* to achieve full credit.

Thus, when a student physically turns in homework, it is examined for *form*, that is, for the presence of all four major problem-solving areas. For example, a correct solution that does not have a timeline (geometric representation) has poor *form* and would receive 75% if it has the other three components of the *rule of four*. Similarly, a correct solution that does not indicate skillful use of the Calculator TimeValue lines but uses the other three components of the *rule of four* would also receive a 75%. The aggregate grade on *form homework* reflects the student's use of the four components of the *rule of four*. The final homework grade for the course is an average of the *form homework* and the *electronically graded AiC quizzes.*

Historically, this instructor had always taught with one handed-in homework problem. The advantage of this approach is that students are exposed to the *rule of four* as a class goal; the deficiency in this approach, is that only one homework problem was given, it being too burdensome to grade multiple problems for each class student for form. The first semester that AiC was used, no handed-in homework was used; rather, students were assigned multiple homework problems which were graded electronically. However, the lack of feedback on solution form hurt many students as seen on class examination scores. The theme of this paper is that CA is part of the instruction, not a substitute for it; consequently, the instructor decided not to accept this deficiency and wait for more developed versions of the software. Therefore, in the 2nd semester the course was taught, AiC was used and the deficiency of solution form was remedied by requiring students to hand in one homework which was graded on form. The expected resulting improvement in student performance was immediately seen.

7.3 **Good AiC Feature:** The good features that a CA should have are presented in Section 2; Section 5 shows that AiC possess these features. In this remaining subsection, we lightly review these good features with an emphasis on implementation.

- Structured Curriculum (SC)**:** Meta-studies have shown that SC *by itself, as an instructional method* (without necessarily using CA), significantly improves performance [5, 6, 7]. The Society of Actuaries provides a detailed SC for the Financial Mathematics Course [14] with 11 distinct modules each with a few submodules of very specific skills. Both the online notes [18] as well as ADAPT [1] use the SOA structured curriculum [14] to teach and pose problems.

  In a 15 two-days a week semester, on average, two class days are devoted to each of the 11 SOA modules, during which ADAPT problems from the relevant module are presented.

- Problem Difficulty: There have been students who have taken the FM course, received grades of *A*, and then failed the SOA FM examination because the question-difficulty level of the SOA FM examination was higher than the question-difficulty level of the problems done in class. AiC provides a unique opportunity to remedy this by offering graduated levels of question difficulty.

  The SOA FM examination corresponds to ADAPT level 5.5. However, many textbooks problems are at difficulty level 0-3. Accordingly:
  - The first few weeks of the course, level 0-3 problems were used (to accommodate the difficulty level that students are used to)
  - After the first few weeks, levels were gradually increased to levels 4-6.
  - The instructor used to routinely do occasional level 7 and 8 problems but has since abandoned this practice as it overchallenges the students who are struggling to obtain a sense of what is a reasonable level of difficulty. On occasion, harder problems are done, particularly when the instructor uses solution methods lowering the difficulty of the problems.

- Problem Focus and Hints: Homework problems were selected by the instructor. Each problem illustrated some key point or technique connected with that syllabus topic. For each problem in class and for each homework problem, a one-phrase description of the focus of that problem was given. For example, for the illustrative problem presented in Section 6, the following focus might be stated: "*level, increasing*, with *deferrals* and *conversions*." Students found these high-level hints very useful both for learning and for achieving success in homework.

- Random vs Specific Problem Selection**:** AiC allows an instructor, when creating a quiz, to use random selection of questions by the software. Random selection of questions is a design feature which prevents cheating and gives credibility to assessment.

  However, the goals of using AiC in the classroom were both instruction and assessment. Consequently, this instructor exclusively created homework quizzes with custom-made specific problem selection. The goal was to select problems, which besides covering certain syllabus topics also emphasized certain key points and nuances of these topics. As discussed in the previous bullet, this selection process was made more transparent using hints and focus statements for each assigned problem.

4 Pillars of Education	**Item of CA assessment**	**Present in AiC?**	**Comments**
Executive Function (EF)	Structured Curriculum	Yes	
EF	Rule of 4	No	Supplement CA with *form* HW
EF	Multiple Media	Yes	Written solutions, videos, etc.
Goal Setting	Graduated difficulty	Yes	Students can start at level 0 and work their way up
Goal Setting	Immediate Feedback	Yes	Solutions to all problems
Goal Setting	Remedy a particular deficiency	Yes	Any module can be practiced till mastery
Attribution Theory (AT)	Effort vs. luck	Yes	
Self-efficacy	Self-paced self-management	Yes	Oral reports, by students, of interest in AiC
	Performance on SOA exam		A metric difficult to implement because i) there is no cohort of students not using AiC; ii) students pass the SOA exam at different points after taking the course including, sometimes, after failing the exam.
	Performance in Class		This is a poor metric since initial student performance varies

Table 1: Evaluation of AiC using the 4 pillars of pedagogy [19].

8. ASSESSMENT

Previous sections discussed various means of assessing AiC. Table 1 summarizes several possible approaches of assessing use of AiC. The fundamental idea underlying all these assessment methods is to assess AiC by the extent to which it facilitates the four pillars of good pedagogy. Adequate statistical justification of the four pillars exists in the literature [19]; a CA that facilitates these pillars will enhance pedagogy.

9. CONCLUSION

This paper has explored the use of computer assistance (CA) in instruction. It argues that the criteria for assessing CA are pedagogical, not statistical. CA is pedagogically useful if it helps implement i) structured curriculum, ii) proper goal setting, iii) attribution based on effort, and iv) self-efficacy, by providing adequate practice to achieve mastery. These ideas should prove useful to other instructors in other subject domains.

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