# AC 2010-2209: DEVELOPMENT OF AN INTELLIGENT REMEDIAL TUTORIAL LEARNING SYSTEM FOR NON-TRADITIONAL AND ADVANCED PLACEMENT STUDENTS

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# Development of an Intelligent Remedial Tutorial Learning System for Non-traditional and Advanced Placement Students


## Abstract

Many four-year degree engineering technology schools have experienced problems in upper level student achievement and retention related to critical skills gaps legacies of non-traditional, advanced placement students such as two-year community college transfer students, formerly active military personnel, and other students matriculating from lower level courses with below average grades. While qualified to enroll in upper level courses by criteria such as individual course grade minimums met and minimum grade point averages achieved, many advanced placement students might not have been introduced to, or perhaps not mastered, specific critical skills necessary for success in upper level courses.

The consequences are several and can be severe: 1) faculty spend an inordinate amount of classroom and mentoring time in upper level courses on remedial rather than advanced skills development; 2) student achievement suffers as the cumulative effects of skills not mastered compounds; 3) retention rates of upper level students are negatively impacted.

This paper describes initial activities and results toward development of an innovative on-line, critical skills, intelligent remedial tutorial learning system intended to serve those students requiring extra-curricular learning support to enable their successful matriculation and retention in upper level courses. This founding work project was internally funded through a university Faculty Innovation Grant award.


## Introduction

Many researchers have investigated the use of web based automated delivery of course content. Web-based training (WBT) and on-line distance education (ODE) systems are an outgrowth of at least two decades of computer-based training (CBT) and intelligent tutor systems (ITS) research and applications. In fact, web-based training (WBT) appears extensively in training programs for businesses, at universities, and in government agencies to provide training for employees in areas such as corporate policies, computer security, and administration processes.

These applications typically present the material in a linear instructional process with embedded periodic testing using multiple-choice questions to provide student assessment and outcome cores of the module. As often applied, this instructional approach can provide useful means for incremental augmentation of knowledge where the initial knowledge of the student is well known, perhaps through a pre-screening process, and the new concepts are likely to be easily understood by the students via a single presentation.

However, the interest here is specifically the situation where students have very different backgrounds and where any number of concepts might require explanation or immediate remedial learning including perhaps multiple perspectives. Students in this knowledge-deficit situation generally benefit from direct interaction with an instructor, such as in the traditional visit to an instructor's office for private one-on-one tutoring. In this personal interaction, the instructor will assess 'in real time' the student's understanding of any number of prerequisite skills and knowledge and will adjust the direction and pace of the meeting, and ideally respond with sensitivity, insight, and accuracy at teach point of assessment during the tutorial session.

The long-term goal of this effort is to create, using interactive software, an effective substitute for the one-on-one, across-the-desk tutorial experience for the advanced placement engineering or engineering technology student needing remedial instruction. The envisioned autonomous intelligent remedial tutorial learning system (IRTLS) would assess the student's understanding and modify the direction and pace of the instruction on a continuous basis, as do effective instructors in the private tutorial session. As opposed to a traditional linear tutorial system, having a predetermined presentation of material and more or less inflexible performance assessment system, as discussed above, the IRTLS instruction would continually adapt to the responses of the student, adding or eliminating content and assessment based on student responses, again as do effective tutors. While clearly being much more complex than the linear approach, a properly designed IRTLS will provide substantially better outcomes for the student requiring predominantly remedial instruction on a path to learning new knowledge.

When complete, the IRTLS will help to facilitate and assure the success of advanced placement students, i.e., students matriculating from 2-year school, continuing their education after military service, or otherwise seeking advanced placement status, in engineering and engineering technology programs nationwide. Feedback from student outcomes can be used to improve continuously advanced placement student preparation through collaborative links and cooperation with 2-year program affiliates with matriculation agreements with the 4-year school.

The authors are preparing proposals to national funding sources to continue development content in expanded topics modules, experiment with artificial intelligence methods for quality and effectiveness of the remedial learning experience, and to refine system quality and effectiveness metrics to project resource and cost estimates to full system design.

The remainder of this paper presents the development of a prototype module to assess the inherent complexity and feasibility of the IRTLS approach. Related non-tutorial efforts and intelligent tutorial system research are introduced. Next presented is the implementation of the authors' prototype IRTLS. These are followed by a discussion of the results and lessons learned, and, finally, conclusions and future research directions.

## Related Work

### Current Means to Encourage Successful 2-year to 4-year Academic Transitions

#### Academic Transition Challenges

The transition from 2-year to 4-year (2+2) engineering or engineering technology curricula, or transitions from another 'non-traditional' starting point, such as military background, career displacement, etc., can be a challenge for students for a variety of factors.

Weak skills proficiency is one kind of challenge. A student might have been exposed to some critical skill area, such as a mathematics skill (e.g., L'Hospital's Rule), an engineering problem-solving technique (e.g., free-body diagrams), or equipment use proficiency (e.g., operating an oscilloscope), but not had extensive practice or not been exposed to engineering applications. These weaknesses or deficiencies can leave a student catching-up rather than keeping-up early in a 300-level course.

Another challenge for the transitioning student is a complete lack of a required skill. In the authors' Electrical Engineering Technology program, many military-trained, non-traditional students have outstanding experience in electronics design and troubleshooting, with training and schooling experience arguably equivalent to an associate's degree, yet have not been exposed to complex number theory, a skill necessary to the analysis of AC circuits at an ABET accredited baccalaureate degree level education.

Assessing Transition Preparedness at the 4-year School

A variety of means are in place at 4-year programs to assess student preparedness, beyond the written record of courses taken and grades received, to facilitate or encourage students to make a successful transition to their +2 courses. Students typically are given course descriptions and prerequisite skills lists to assess and reflect on their preparedness, then either encouraged to narrow their skills gaps on their own or be mentored personally by an advisor.

One common transition-enhancing practice is the use of a placement exam to demonstrate clearly for the student areas and levels of skills weaknesses or 'gaps' they will need to revisit before embarking on their +2 curriculum. The authors know of no coordinated remedial program intended specifically for 2-year transition students and provided by a 4-year school, though these might exist, or have existed, considering the ubiquity and diversity of transition student skills weaknesses or gaps.

Facilitating Transition Success at the 4-Year School

The performance or retention rates of non-traditional students, as a subset, have not been well documented at the authors' Engineering Technology department. Still, anecdotal evidence from EET 300-level course instructor and 2+2 incoming advisor experiences indicated that a portion of students, significant enough to be a problem that required attention and remediation, were entering their +2 years with some academic handicaps. These handicaps, combinations of various levels of diverse critical skills weaknesses and omissions, were leading to unacceptable outcomes, as stated above, including poor student performance leading over time to frustration, disinterest, failed upper level courses, and even dropping out of school. A measurable burden was placed on 300-level instructors (and their traditionally matriculating students) as the few underprepared students required disproportionately large amounts of attention, in class and out of class, for these students to remediate prerequisite skills and learn new material.

Faculty met regularly to discuss program status and continuous improvement in general and a decision was made to address the problems immediately associated with the challenged transfer and non-traditional transfer student. The concept of an on-line, remedial tutorial was discussed and grant monies were sought to begin evaluating the efficacy and practicality of an intelligent remedial tutorial system to encourage and facilitate student transition success and relieve faculty from the extra burden of remedial tutoring.

## Other Approaches to Facilitating Transition Success

### Matriculation Agreements and Curricula Alignment

Not all degree programs or areas of study included in a blanket 2-year and 4-year school matriculation agreement will provide close-coupled, in depth preparedness for students. It is not surprising that not every student transition will be a seamless trajectory of courses and skills development across the two schools. The reasons are many: the community or technical college might not adhere to a common accreditation agency; two-year programs often have a terminal degree philosophy embedded in many of their programs as appropriate to their communities at large; the first 2-year curricula vary across the 4-year school programs; the 2-year school might have matriculation agreements with several independent 4-year schools, each with their own program prerequisites; and other reasons.

Schools do work together at varying levels of cooperation and effectiveness to align course and program skills to assure the preparedness of the transition student. The 4-year school has some influence to expect quantitative and qualitative curricula design and topics inclusion at some or many its 2-year school matriculation affiliates.

However, in general, the task is formidable to have excellent alignment between every 4-year curricula and every 2-year school. Thus, some skills weaknesses and gaps can be improved through cooperative, continuous improvement in curricula alignment.

### Student- or Faculty-led Remedial Tutorials

Another approach to reducing the mismatch of prerequisite skills of transition students simply is to provide scheduled tutorial sessions. These sessions, similar to formal programs commonly offered in math, physics, and English, for example, would be volunteer sessions including either scheduled or ad hoc topics. Faculty could be assigned instruction topics identified in incoming transfer student placement exams. Superior senior or otherwise qualified students could be selected to assist with special topics or general help and support.

The authors have identified problems with the organization and logistic of such a formal program, vis a vis an intelligent on-line tutorial, including

- The variety of levels of skills, and the diversity of skills, of any one or the class of students would present a burdensome task organizing and assigning all the tutorial resources required
- The formal tutorial program does not relieve faculty of the extra burden of remedial tutoring

- The proven superior learning skills of the assigned student tutor do not necessarily correlate to superior teaching skills, especially in a remedial teaching setting
- While the design of an intelligent remedial tutorial is front-loaded, demanding an intense resource effort at first, the digitized sessions have unlimited life expectancy
- An intelligent remedial tutorial presents the opportunity to design a remedial experience devoid of the stigma traditionally associated with remedial programs, providing, for example, anonymous, flexible, highly interactive, self-driven, and 'fun' interface and content

**Existing Intelligent Tutorial Research**

Computer-based intelligent tutorial systems (ITS) have been available at all levels of education, at a wide variety of 'intelligence' levels, with a wide variety of designs that include variations in learner-system interface, overall interactivity, audio and visual sophistication, and other attributes. Early discussions and critiques of ITS methods and outcomes are reported by Shute and Psotka[1], Psotka and Mutter[2], and Merrill[3]. Discussions of theories and applications in modeling tutor, student, and curricula can be found in Siemer and Angilides [4], Tchétagni[5], and Koedinger and Corbett[6, 7].

The US military has made extensive use of 'canned' training tutorials and more recently so-called e-learning programs (remote on-line and web-based training systems) and has been a leading institution of the development of advanced graphics and 'video game' style training systems. See an overview by Ong and Ramachandran.[8]

Extensive pedagogical research in ITS has been conducted to improve learner experience and outcomes. See, for example, Kolb[9], Mayer [10]. Research has identified the special need for interactivity and flexibility in the stand-alone or autonomous tutorial. See discussions in Sims[11,] Kristof and Satran[12], and Kirschener, et al [13]. Murray provided insight in the programming of analogies in remedial tutorials[14].

The design of intelligent remedial tutorial research is a relatively small area of ITS research overall, but has nonetheless received special attention. For research in authoring tools, see Nkambou[15] and Murray[16]. For discussions on web-based systems, see Zhiping, et al[17], and Brusilovsky[18].

In the long run, the authors intend in future research and development to combine ongoing proven pedagogical research results, best practices of working tutorial systems, and results of the proposed application. The goal would be a framework for faculty to develop remedial tutorial systems for in all engineering technology curricula, e.g., electrical, civil, mechanical, etc.

**Initial Grant Implementation Overview**

Short of the long-term research goal outlined above, the immediately practical scope of work of the awarded Faculty Innovation Grant was to launch development of an IRTLS for the Electrical Program of the authors' engineering technology department.

A preliminary review of the literature of research and applied intelligence tutorial systems indicated to the authors that the initial challenge was the need to assess the complexity and ultimate feasibility of the proposed intelligent tutorial approach. Clearly, as the embedded intelligence, that is, the level of interactivity and responsiveness to the student's actions, increases, the more complex and content-robust the learning system will be. This tradeoff between the benefit of intelligence depth and the cost of system complexity was seen as a critical consideration in the design of the envisioned program-comprehensive IRTLS.

The development of appropriate measures of complexity was considered of immediate importance to enable estimations of future tradeoffs between development cost and improved student outcomes and quality evaluation of the tutorial experience. From the perspective of the student, the interactivity or responsiveness of the learning system can be characterized as the frequency of assessments and the alignment or precision of subsequent instruction to the misconception or error. Students using an interactive training or instruction system, be it a new skills training session or perhaps a troubleshooting tool provided with a personal computer, for example, particularly do not want to be misdirected by the program to incorrect or otherwise inappropriate instructions. Nor do students want to read through an instruction set or wait passively through an animated or video display of instructions, for any inordinate length of time.

The authors proposed that after a means to measure and evaluate the tutorial system complexity was developed, a prototype module was needed to assess the efficacy of the proposed metrics, and to evaluate practical development projections in terms of software tool development and instructor labor time. The initial grant scope of work provided a first step toward assessing complexity tradeoffs and practicality of design of an IRTLS.

A prototype development effort was begun to aid in better understanding the potential, limits, and cost tradeoffs and as a guide for future design based on preliminary testing and evaluation of student outcomes and responses.

In the next section, the authors' approach to measure system complexity will be described, followed by a description of one of the prototype modules. Results and lessons learned are included in Section 4. Proposed future research is discussed in Section 5.

## Module Characteristics and Metrics

The authors proposed that the tutorial system complexity, i.e., the desired amount of interactivity and responsiveness, of an IRTLS could be viewed in terms of the number of independent assessments (the responses to student actions) and explanations or instructions (as activated by these assessments). In other words, the authors proposed that a measure of complexity would include the frequency of assessments and usefulness or effectiveness of the system-presented follow on instruction, as perceived by the student.

As an illustration, consider the flow of an autonomous learning system as shown in Figure 3.1. In the two figures, each node is meant to represent an assessment of a response by the student and each branch is an explanation or linear instruction. Figure 3.1a represents a system that is predominantly linear with infrequent assessments. Figure 3.1b represents a very interactive and responsive, i.e., intelligent, system where the instruction is very adaptive and tailored to the student's understanding as assessed by the system in response to the student's actions. The system shown in Figure 3.1a might represent a series of recorded lectures; while the system in Figure 3.1b might represent the experience a student would have working individually with an instructor in a one-on-one tutorial session.

Two metrics were defined: the Linear Instruction Frequency (LIF), i.e., the average time between assessments and redirection; and the Response Assessment Depth (RAD) measure, i.e., the number of branches available after a student response assessment. These two metrics are proposed to provide a measure of the system interactivity or responsiveness, and its effectiveness, as perceived by the student.

The quality of the learning system will be very sensitive to these measures. As the instruction time between assessments decreases or the number of possible and available instruction branches increases, the system complexity increases very rapidly. Thus, while software tools and technology may be available to author very complex remedial learning systems, the content development time may limit the applicability to larger groups of students having various individual preparedness or skills base. The prototype modules designed by the authors and described below are intended to explore the increased development time and assess possible limitations for electrical engineering technology applications.

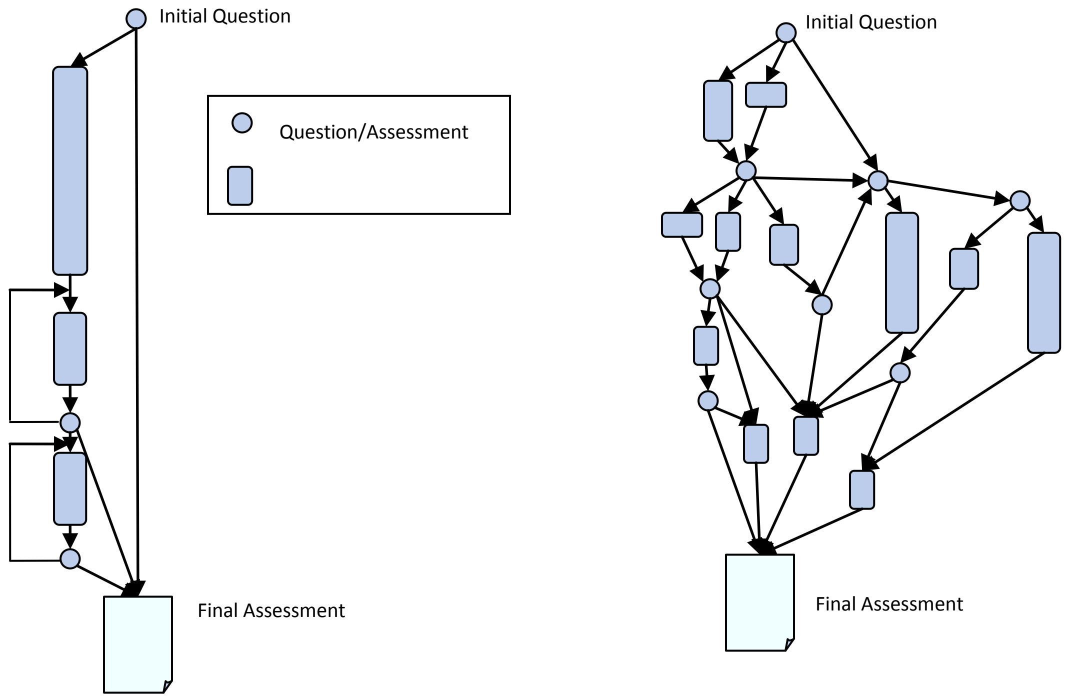
Prototype Module Description

Several commercially available interactive learning system development tools were evaluated for this application. Each of the tools presented some limitations, for example in response feedback loop capability (such as limited nested loops), graphical details, or other encumbering features limiting the richness of the interactive environment meant to mimic the one-on-one, live-instructor tutorial experience. It was rapidly determined that the many limiting features were going to retard development of the Response Assessment Depth in initial prototype

The relatively best tool was selected as a development environment for the prototype. The major effort focused on the content development, i.e., illustrations, graphics, recorded audio interfaces, etc. LIF was maintained at a high level by limiting the prototype session content to only a simple problem task, in this case, DC circuit analysis.

The initial development quickly indicated that robust, exhaustive content development, as might frequently come to play in a one-on-one live tutor session, would be required to attain a learning system with relatively large RAD and LIF measures. Several design criteria were considered to attempt to minimize the rapid growth in complexity while maintaining the quality of interactivity.

For example, high level decisions, such as choosing how to approach a problem or which technique to use were used to free the system from assessment decisions and 'force' the decisions onto the student. The LIF increases with such tactics, as these higher-level questions require less involved branching and flow control logic than questions to diagnose conceptual errors or missing skills from student failed attempts. Still, it is not uncommon for the live instructor to attempt similar tactics with a student, but this is usually a considered decision based on perceptions (active assessments) of student prior demonstrated ability.




a) Linear models relay on longer presentations that are more comprehensive and more sporadic assessments, resulting in few possible paths to mastering the topic

b) Interactive models include many assessment nodes and provide many paths toward mastering the topic.

Figure 3.1: Conceptual models for interactive and linear instruction models.

Another design criterion was to document carefully the learning objectives or specific skills being tested when developing a problem and to maintain a clear understanding of what specific skill was being tested at each assessment. This was important when assigning a new path or direction based on the student response. We attempted to maintain the number of possible paths from an assessment between four and six, by experience to reduce and manage complexity, and so problems had to be very carefully designed, that is limited in content, to ensure that the next instruction path is relevant and addresses not only the student's error, but also their conceptual misunderstanding.

Finally, all problems included the option for the student to navigate to a more basic tutorial to insure students are not forced to wander through problems where they are essentially lost. An example of one of the screens for our storyboard is shown in Figure 3.2. In this example, there are three possible tutorial paths. If the top radio button were selected, the student would select the correct resistance. The provided answers attempt to determine the specific error made by the student. For example, if the student incorrectly found the resistance of the parallel resistors the assessment path would be diverted to a review that would be completed by the student before moving on to the next topic, in this case, current division.

As shown in the logic diagram in Figure 3.3, each answer provided by the student is associated with a conceptual error and the student is directed to an instruction set to correct the misunderstanding. For example, after finding the equivalent resistant of $R_2$ in parallel with $R_3$ the student is asked to find $V_3$ using Voltage Division. If the student selects 4.1 volts, it is assumed that the student incorrectly applied the voltage division equation and actually found the voltage across $R_2$. Similarly, after correctly finding the voltage across $R_3$ the student is asked to find the current through $R_3$. If the student selects 2.04 Amps it is assumed that the student incorrectly divided by the parallel combination of $R_2$ and $R_3$, and an explanation of the error is provided before diverting to a short tutorial. The intent is to provide the experience of one-on-one feedback to the student.

Clearly, there are many additional important instructional concepts that could be addressed; however, the prototype model was developed to assess only the complexity of such an approach and to gather insight for design of larger tutorials. Thus, the objective of the prototype was for the authors to obtain hands on experience developing content, and to experiment with design criteria for providing quality interactivity while maintaining a reasonable level of complexity.

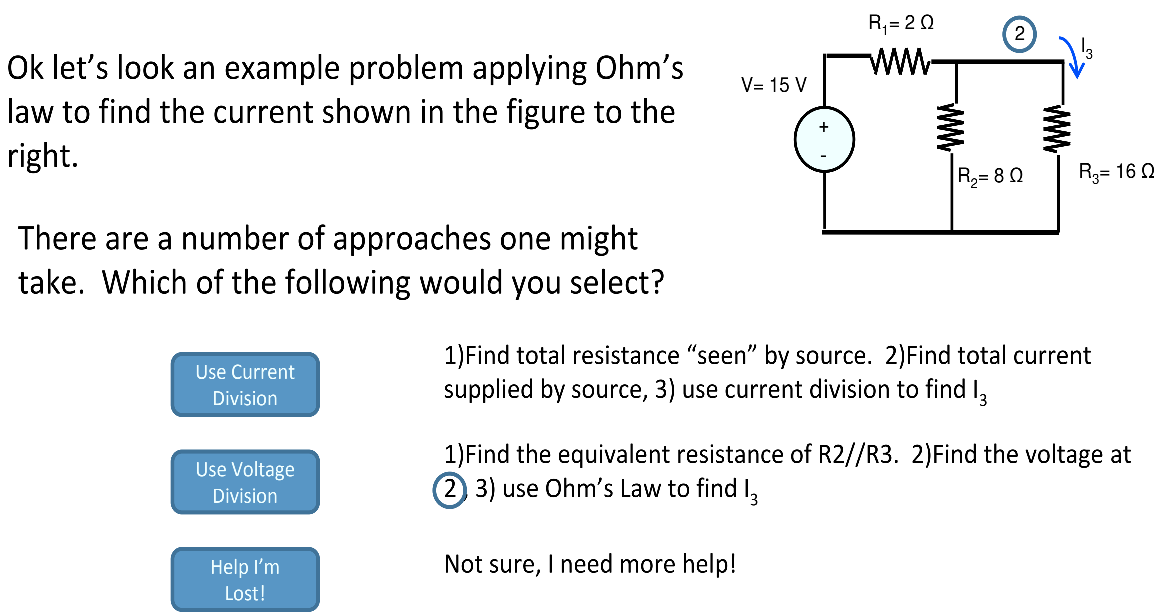



Figure 3.2 Example Storyboard screen.

**Results**

The scope of this effort did not include student testing or evaluation of the prototype automated instructional system. However, several observations can be made without such formal testing. This experience suggests that the largest challenge in scaling up these prototypes to include the breadth of subjects envisioned for the department electrical program IRTLS would be content development.

While the best available commercial software development and publication tools can provide adequate presentation and flow control, the interactivity and the desired perception of a one-on-one interaction is a function of the content. Further, it appears that each new module would require a similar amount of care in developing content and the effort needed to provide additional modules to expand the subjects covered would be extensive.

The authors have found that the metaphor of an iceberg fits the activity of the instructor in a tutorial session: most of the activity in assessment and response selection is unconscious, and the amount of activity is substantial. Moreover, it is this portion of the iceberg activity under the surface that must be reconstructed to achieve an effective IRTLS.

Although no student testing was performed, several faculty members did exercise the prototype using a mixture of correct and incorrect answers. The general view was that the experience with the early prototype was too limited to render a full assessment of the approach and its value as a substitute tutoring method. The prototype modules will need to be expanded to include more examples and problems, further supporting the observation that content development is the major challenge.

The results of this effort suggest that authoring tools specifically for this application may be needed to develop larger scale interactive learning system of this type. In addition, a hybrid approach could be investigated in the short term. This hybrid approach would rely on a blend of very interactive segments and short lecture or demonstration video segments. An experiment using such a hybrid approach is being considered to determine if video segments, custom designed to optimize the remedial environment, would be perceived as positive in the student's experience. Such an experiment might lead to better tradeoff analyses and optimum system design.

**Conclusions and Further Work**

A means was identified and research begun toward providing autonomous computer based remedial tutoring for advanced placement engineering technology students with identified skills or knowledge weaknesses. Initial development of a prototype tutoring session provided insight into design tradeoffs of embedded intelligence (complexity) and cost of development. Two measures of complexity were identified as tools for assessing and projecting the system development effort.

Intelligent tutoring systems, including remedial learning systems, have been researched and implemented in many training and teaching environments in government and industry. Four-year programs in engineering and engineering technology experience the problem wherein qualified advanced placement students demonstrate skills or knowledge weaknesses. Proven theories of system design and student learning in intelligent tutor systems, best practices of existing systems, and the experience of the authors in developing prototype learning modules, all

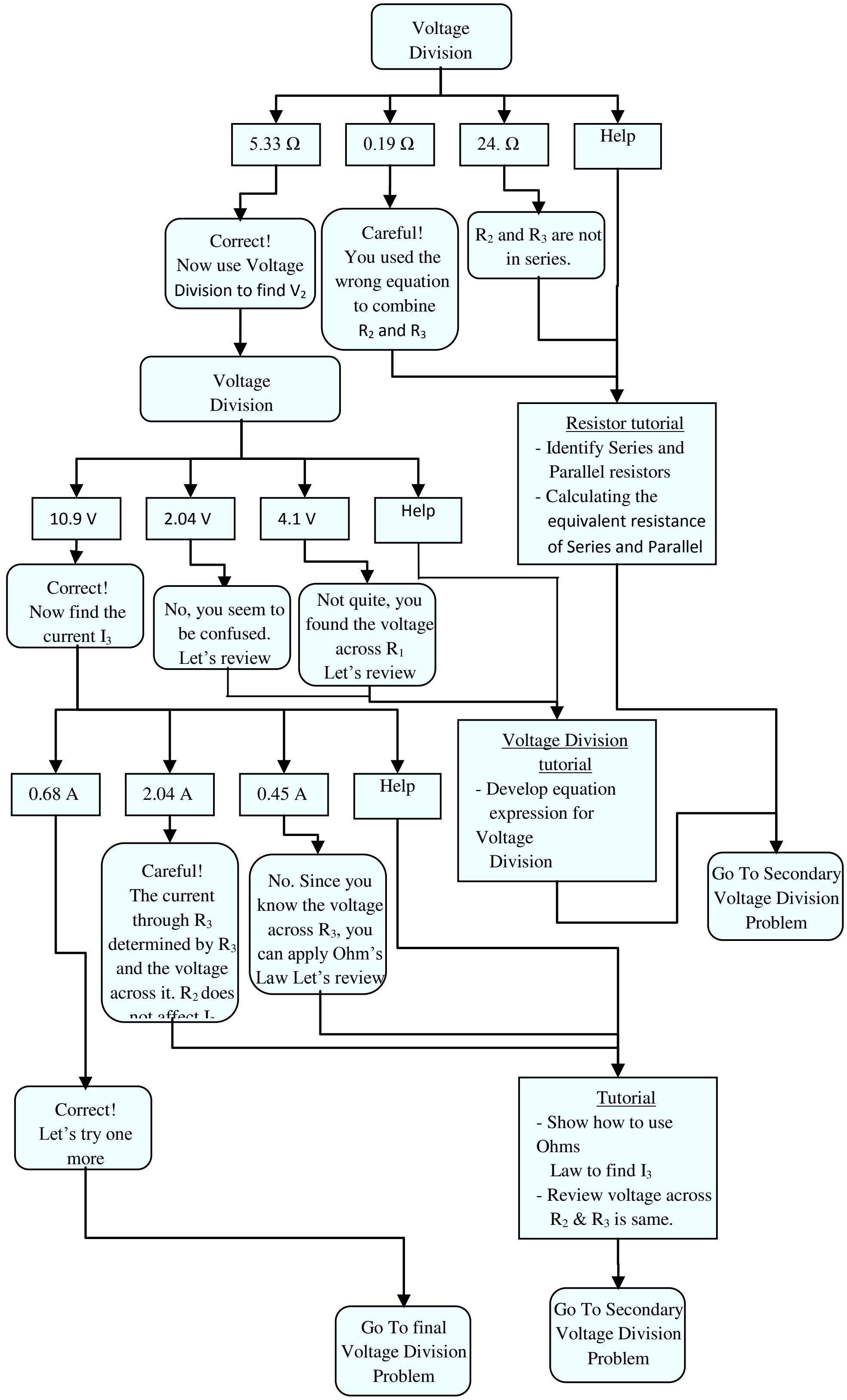



Figure 3.3 Logic and path flow diagram for example screen.

can be used to develop the scaffolding and authoring tools for a broadly applicable intelligent remedial tutorial learning system (IRTLS) for remedial tutoring of advanced placement engineering and engineering technology students.

When complete, the IRTLS will help to facilitate and assure the success of advanced placement students, i.e., students matriculating from 2-year school, continuing their education after military service, or otherwise seeking advanced placement status, in engineering and engineering technology programs nationwide. Feedback from student outcomes can be used to improve continuously advanced placement student preparation through collaborative links and cooperation with 2-year program affiliates with matriculation agreements with the 4-year school.

The authors are preparing proposals to national funding sources to continue development content in expanded topics modules, experiment with artificial intelligence methods for quality and effectiveness of the remedial learning experience, and to refine system quality and effectiveness metrics to project resource and cost estimates to full system design.

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