

# A Dynamic Learning Model for Accelerated Pre-Matriculation Mathematics Programs: A Work-in-Progress

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**Abstract** – Accelerated pre-matriculation mathematics remediation programs are a popular strategy for improving the placement levels of underprepared students. Although limited assessments of such programs have been reported in the literature, most work is focused either on immediate placement level improvement or longitudinal indicators of student success. While valuable, both techniques offer no insight regarding the learning progression of students while participating in the program, which is of tremendous value in optimizing program policy, such as determining the ideal number of contact hours. The research described herein proposes a first-order dynamic learning model for describing students' content acquisition process within accelerated remediation programs. Details regarding model formulation are presented within this work-in-progress paper. A brief evaluation of model efficacy is also conducted using data gathered from daily ALEKS learning assessments employed within a one-week remediation program for intending engineering students.

*Index Terms* – Preparation, Time to Degree, Computer Based Learning

## I. INTRODUCTION

For over five decades, accelerated pre-matriculation mathematics programs, often referred to as either “bridge programs” or “boot camps”, have provided an opportunity for enrollees to improve college readiness in a truncated timeframe [1]. Programming within this class has reported substantial positive outcomes, including increased participation in STEM fields amongst underrepresented populations [2] - [4]. While diverse in their specific form, most programs offer incoming students the opportunity to retake their mathematics placement exam after completing an accelerated period of intensive preparation. This option is particularly valuable for STEM fields, where entering the mathematics portion of the curriculum below calculus is a key predictor of attrition [5], [6].

In spite of the multitude of offerings of such interventions nationwide, limited attention has been devoted in the

literature towards their formal assessment [7]. Some results are available, including those provided by Barnett et al., who employed a randomized controlled experiment for students entering eight different two and four year institutions across the state of Texas [8]. Through longitudinal observations over a two-year period, the study concluded that the program had limited impact, with students in the experimental group slightly more likely to pass a collegiate math course within the following year. While assessment using longitudinal outcomes is of value, the clarity of the resulting inference may be distorted based upon confounding factors arising in the period between the intervention and assessment.

Additional literature in this area has largely focused on observational studies which analyze the efficacy of bridge programs through comparison of pre and post mathematics placement exam scores. For example, results from both the University of Alabama [8] and Wisconsin [9] have demonstrated substantial increases in the associated placement scores of participants. The latter program leveraged the ALEKS (Assessment and LEarning in Knowledge Spaces) intelligent tutoring software (ITS) during its implementation, and found that comprehension gains were directly related to the time which students spent in the software.

The research described herein expands the literature by proposing the assessment of student progression during their participation in accelerated mathematics remediation programming. This assessment is used to develop a dynamic learning model for describing content acquisition during program participation. Such an analysis framework offers value by enhancing analytical insight regarding program policy. For example, understanding such learning dynamics as a function of student characteristics may allow for an optimization of program contact hours or target population characteristics. A limited assessment of the model is provided using data acquired from daily ALEKS learning assessments employed during a one-week mathematics bridge program for intending engineering majors.

## II. METHODS

A baseline model for describing student learning in the target intervention class was formulated based solely upon the

inherent principles governing the development of the underlying programs themselves. Namely, such offerings are fundamentally rooted in the assumption that certain topics for which students have not yet demonstrated comprehension on a placement exam may be reviewed and mastered more quickly than others, thus allowing them to bypass formal coursework by improving their scores in a truncated timeframe. This naturally implies a loose binary characterization scheme for those topics for which mastery has not yet been demonstrated as a function of the associated time required to build measurable comprehension.

Topics within the first group, hereby referred to as a student's review space, are characterized by an expected acquisition rate which is assumed to exceed that typically demonstrated by the same student in a course environment. While many classes of piecewise functions are suitable for modeling this phenomenon, employing a decreasing function in the review space to describe acquisition rate is reasonable based upon the understanding that certain topics within the group may be mastered more quickly than others. This may be influenced by numerous student and content specific factors, including time elapsed from previous exposure, specific content type, etc. In the proposed model, these dynamics lead to a diminishing return on time devoted towards content acquisition during the review phase, ultimately saturating once the expected rate of acquisition is equivalent to a student's expected steady-state acquisition rate which would be observed in a traditional classroom mode. The proposed stochastic process describing this first-order learning model is parametrized in (1).

$$\underline{r}(t) = \begin{cases} \underline{\beta} - \underline{\alpha}t; & t < \underline{t}^* \\ \underline{\gamma}; & t \geq \underline{t}^* \end{cases} \quad (1)$$

Where  $\underline{\alpha}$ ,  $\underline{\beta}$ ,  $\underline{\gamma}$ , and  $\underline{t}^*$  are are student-specific random variables. Two potential realizations of the random process are depicted in Fig. 1. Both the initial comprehension rate, denoted by  $\beta_1$  as well as the duration of the review period, denoted by  $t_1$ , of the hypothetical first student are larger than the comparable parameters for those of the second student.

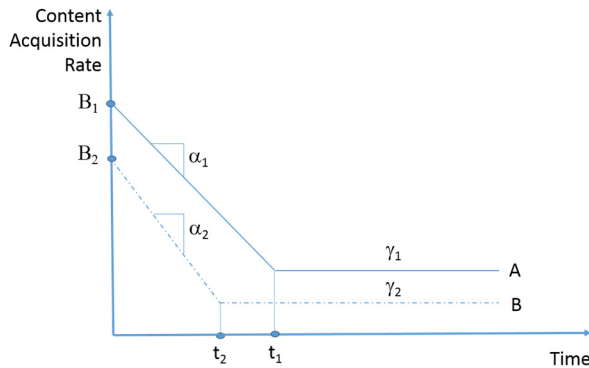


FIGURE 1: PROPOSED FIRST-ORDER LEARNING DYNAMICS

Such variability across students may be attributed to several mechanisms, including the fact that the intrinsic ability of the first may not be accurately reflected in the preliminary placement assessment.

### III. ANALYSIS

A limited assessment of the proposed model was conducted using data gathered from ALEKS learning assessments employed during the one-week Academic Advantage Program (AAP) conducted in 2014 at Wright State University (WSU), a public university located in Dayton, OH, USA. During the program, which has been offered by the College of Engineering and Computer Science for over a decade, students are initially segmented according to their incoming mathematics placement level (which may be determined using either performance on the ALEKS-based placement exam or ACT/SAT score), exposed to intensive classroom instruction over a four-day period, and then permitted to retake their placement exam on the final day of the program. This offering marked the first use of ALEKS software within the AAP program, motivated predominately by its successful inclusion within a preparatory math course offered by the College [10].

In addition to the initial ALEKS assessment conducted for determining baseline comprehension, four additional comprehensive assessments were conducted at the end of each instructional day. The assessment results for each of the students were then fitted according to a least squares quadratic model, corresponding to the assumed linear rate of progression within the review period, with a specified initial value corresponding to the initial assessment results presented in Fig. 2. An inherent assumption in this procedure as it relates the proposed model is that no student reached the saturation point terminating the review period within the four-day intervention. Results of the fitting process are demonstrated in Fig. 3.

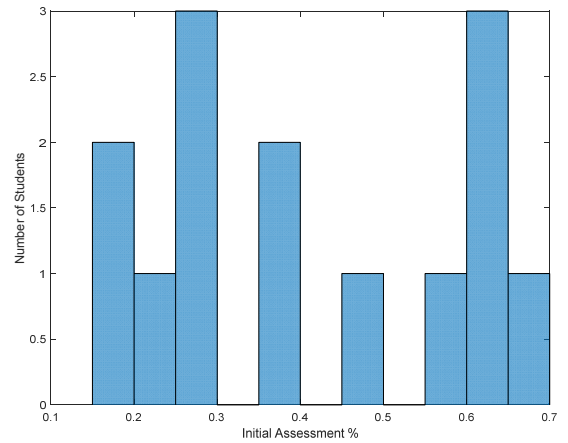


FIGURE 2: DISTRIBUTION OF INITIAL ASSESSMENT SCORES

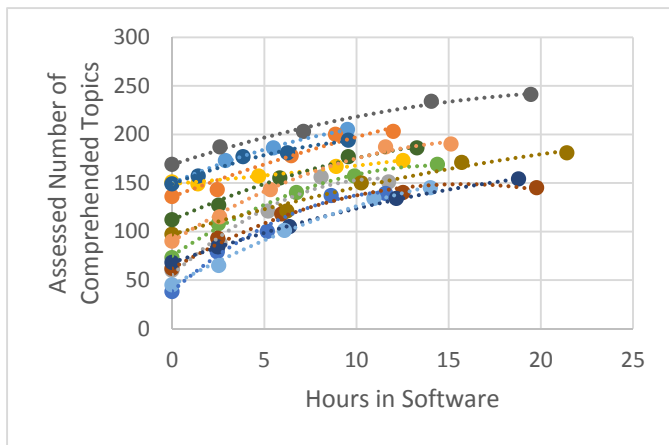


FIGURE 3: COMPREHENSION PROGRESSION OVER INTERVENTION DURATION

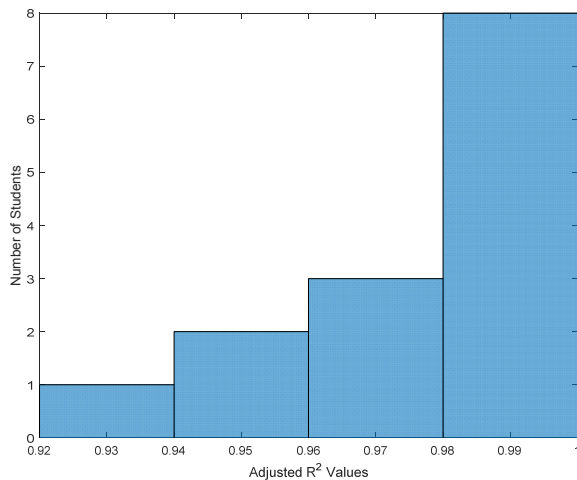


FIGURE 4: ADJUSTED  $R^2$  VALUES OF PROPOSED FIT

For evaluating goodness of fit, adjusted coefficient of determination ( $R^2$ ) values were calculated for each of the 14 students. The distribution of these values is presented in Fig. 4. The strong agreement across all students supports the proposed linear dynamics of the learning model over the review phase.

#### IV. CONCLUSIONS

Assessment of the learning progression of students during accelerated mathematics remediation programs offers significant insight regarding the underlying efficacy of such programming. Fundamental in the organization of these interventions is the assumption of the existence of a subset of content which enrollees are capable of mastering rapidly in a truncated timeframe. This paper suggests a formal mathematical framework for describing such learning dynamics in the form of a parametrized stochastic process.

Data collected for a small convenience sample of enrollees during the 2014 AAP program at WSU suggests that the proposed dynamics are feasible, as quantified by a strong adjusted coefficient of determination across the participating group. Continuation of this current work-in-progress will involve expanding both the sophistication of the underlying learning model, as well as enhancing the richness of the validation data set.

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