Early Intervention Surveillance Strategies (EISS) in Dental Student Clinical Performance: A Mathematical Approach

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Abstract: Graduating dental practitioners requires the mastery of a number of skills and a significant body of basic information. Dental education is a complex combination of didactic and physical skill learning processes. It is necessary to develop appropriate tools to measure student clinical performance to allow the provision of interventional strategies at the right time targeted at the right individuals. In this study, an approach to early intervention surveillance strategies was developed that is cost-effective, transparent, and robust based on mathematical predictions of student clinical achievements. Using a cohort of students’ clinical activity profile, a polynomial pair was developed that represents the predictive function of low and high achieving students. This polynomial pair can then be applied to students to predict their final achievement based on their current status. The polynomial methodology is adaptable to local variation such as access to clinical facilities. The early intervention surveillance strategy developed in this study provides a simple, cost-effective, predictive risk assessment system that relies on data sets already collected in most dental schools and can be completed without the need for significant human intervention. The mathematical approach allows the focusing of educational support towards students that require the assistance, thus augmenting the better use of resources.

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fication of treatment provided to patients and thus allows the detailed recording of clinical activity. The Australian Department of Veterans Affairs (DVA) publishes a fee schedule that uses the ADA item numbers as its codification system. This fee schedule is used widely as the basis of pricing dental care. In this study, the DVA schedule was not used as a monetary fee schedule but was applied as a measure of the complexity of different items of care. A complete dataset of clinical activity (ADA item number by month) was collected for a single cohort of students (n=35) as they moved through the last two years of their dental education (2002-03). These data were used to develop the mathematical EISS.

At the end of the cohort’s clinical education, six senior experienced clinical academics were asked to stratify the cohort based on their knowledge and experience of the students’ performance. These independently collected stratifications were collated (by frequency analysis), and the stratification produced a list of the four highest and the four lowest achieving students. The six clinical academics were selected from the Board of Examiners. They represented a wide spread of disciplines, and all had more than six hours per week previous exposure to the students. There were no criteria guidance to rank the students, but all the raters were clinical supervisors with knowledge of the students’ work.

To effectively complete dental training requires a student to complete a series of care plans on patients. All steps of the care plans are reviewed and agreed to by senior clinicians; this process also ensures the treatment is carried out in a clinically acceptable manner. Care that requires completion by someone other than the student is not recorded (in the data set) against the student, but against the clinician who completed the procedure. This methodology does not allow the measurement of the “quality” of the outcome, but it sets a basic level of competency (for the item to be recorded against the student). The EISS developed in this study is a surveillance tool that facilitates the early prediction of students at risk and requiring educational support. It is not designed to be an assessment tool.

It is universally acknowledged that some dental procedures are more complex to undertake than others. More complex care (e.g., crown and bridge work) is not undertaken by students until there is mastery of simple procedures. However, students who advance rapidly in their skill base may achieve this earlier. To ensure that any predictor accounts for rapid mastery, each procedure needs to be weighted for relative difficulty (i.e., undertaking a simple intraoral radiograph needs to be weighed differently as compared to a full gold crown). Although it might be tempting to develop a weighting system de-novo, it can be simply acknowledged that price (in a non-demand-driven student environment) reflects relative difficulty. As such, in this study the DVA schedule fee of each item was used as a weighting factor. However, this does not preclude others from developing separate weighting scales to match their unique environment.

**Polynomial Development**

Using the dataset of activity against time, the cumulative DVA value of care for each student was calculated at each month of the two final years of education. In each month the low achieving subset and the high achieving subset were calculated separately. (The two subsets were obtained from the expert appraisal frequency analysis.) A polynomial curve of best fit was then developed for each cohort subset: high and low (Figure 1). These two polynomial functions predict, based on the month of experience (over the two years), the value of care at any given time. It should be noted that polynomial functions were chosen as they most closely fitted the distribution of the cumulative value of care. These functions (one for the low and one for the high achiever subsets) are five deep polynomial functions with an $R^2$ approaching 0.99. Other functions (e.g., power and exponential) were tested but were found to be poor fits with $R$ values significantly less than the polynomial functions.

The functions for these two close fit curves are:

$$y = 0.0006x^5 + 0.0044x^4 - 0.4928x^3 + 4.7555x^2 + 30.099x - 41.411 \text{ (high)}$$

$$y = 0.0021x^5 - 0.0825x^4 + 0.9434x^3 - 1.3379x^2 - 5.3018x + 59.323 \text{ (low)}$$

where $x$ is the month and $y$ is the predictive cumulative schedule value of care for that month. Obviously, as more data become available (as more cohorts move through the course), it is possible to refine the functions to be even closer predictors of performance.

**Relative Risk Ratio**

The derived polynomial functions can then be applied to the value of care at a given time for any student to predict his or her future value of care. Most
importantly, it allows a simple mathematical approach to predict the value of care a student will produce at the end of their two years of clinical training. This end-point value of care can then be used to determine a relative risk ratio (RRR) for a student. The RRR gives a risk estimate of the student’s predicted ability to meet the care outcomes that would be expected to provide adequate clinical experience. It is calculated using the difference between the test student’s value of care and the average between the high and low risk polynomials. The RRR eliminates dollars from the reported data, thus eliminating the “perceived risk” of students being driven by value of care.

**Application of the Polynomials**

A randomly chosen student’s data for the third year is presented compared to the high and low polynomials (Figure 2). Applying the formulas to the test student’s data delivers three endpoints for the fourth year: a high and low prediction (Figure 3). The RRR for the test student is superimposed on Figure 4. Noting that the RRR is below zero, and although some improvement can be seen midway through fourth year, it is predicted that the RRR at the end of the fourth year would be significantly negative and highlights a need for intervention to prevent a future “risk position” with this student’s ability to achieve.

A second example (using hypothetical data) is presented where the RRR becomes positive (Figure 5). This hypothetical situation predicts that a student is relatively safe in the predicted outcome.

**Increasing the Robustness of EISS**

Clearly, the opportunity for clinical activity by students is determined by their access to clinical facilities. This access is dependent on a host of factors including the design of the curriculum. This means that each education facility would have to develop its own unique polynomial pair. It also means that changes in curriculum (and other factors) that result in a change in student access to facilities will influence the shape of the polynomial. Thus, an additional development on the polynomial calculation would be to calculate

![Figure 1. The fitting of five deep polynomial predictive functions to the high (UGD) and low (UGC) groups](image-url)
Figure 2. The depiction of data for a test student and its comparison with the low and high functions.

Figure 3. Predicting the test student end of fourth-year position.
Figure 4. Overlay of the RRR with the predictive functions

Figure 5. A hypothetical example of a test student where the RRR is greater than 0
the value of care relative to hours of access each week. This would be undertaken prior to curve fitting and would produce a polynomial independent of facility access, thus improving the robustness of the predictive nature in a time when rapid curriculum changes are taking place. However, for simplicity of presentation, this additional calculation has not been presented in this article.

**Conclusion**

In the current climate of diminished resources for dental education and an ongoing desire by the profession to produce competent, effective practitioners, the EISS developed in this study provides a simple, cost-effective predictive risk assessment system. This system relies on datasets already collected in most dental schools and can be completed without the need for significant human intervention. The mathematical approach allows the focusing of educational support resources towards students that require more assistance, thus directing resources to where they are needed.

**REFERENCES**


