Longitudinal flow of student test scores at the campus level

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Introduction

From 2003 to 2011, every student in the Texas public school system from 3rd to 11th grade took the Texas Assessment of Knowledge and Skills (TAKS). We analyze the student scores of this test using a nonlinear, nonparametric model inspired by fluid mechanics for the study of semideterministic data. This model has been used to highlight characteristics in the TAKS data set that might not be observed using other analytic techniques. This is due to the adaptability of our method. We can look at any aggregate subset of the data based on poverty level, campus, gender, ethnicity, teacher preparation method, and many others.

We define the velocity (\( \mathbf{v} \)) of a group of student scores in year \( t \) as

\[
\mathbf{v}(x, y; t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} \left( \mathbf{z}(x, y; t + \Delta t) - \mathbf{z}(x, y; t) \right)
\]

The definition of average allows for the calculation of velocity fields. For the previously shown velocity fields and these streamlines, the difference in flow is attributed to high stakes testing and a statewide intervention called the Student Success Initiative (SSI), which was enacted in such a way that, out of these cohorts, only the class of 2012 was impacted.

Arrow Plots

The definition of \( \mathbf{v} \) allows for the calculation of arrow plots, also called velocity vector fields, where arrows in every score bin for a year point to those students’ average score in the next year, shown here for two cohorts of students.

Accordingly, each arrow corresponds to a transition from one grade to the test.

For these plots, the area of the arrows indicates the number of students in that score bin, and horizontal lines indicate thresholds for passing and commended scores. There are distinct differences in these flow plots. In particular, compare the size of the arrows for cohorts in the 5-6 transition.

Streamlines

Continuing with a fluid mechanics theme, streamline plots are the integral curves of the arrow plots, depending on some initial conditions. This allows for a qualitative representation of the flow using a Lagrangian description.

These plots follow two cohorts of students selected based on their school in 9th grade. Arrow plots and streamlines also show the elementary and middle school data for those students. The streamlines may highlight more about the voluntary lottery selection process for attending the project based school and the school itself.

Campus Level Comparisons

A comparison between the two high schools in a central Texas city was made. School A adopted a project based curriculum, while School B uses a traditional pedagogy. A further level of disaggregation lets us compare the flow of scores for these schools. These plots illustrate the outcome of SSI, an intervention that forced the scores of this test using a nonlinear, nonparametric model inspired by fluid mechanics for the study of semideterministic data. This model has been used to highlight characteristics in the TAKS data set that might not be observed using other analytic techniques. This is due to the adaptability of our method. We can look at any aggregate subset of the data based on poverty level, campus, gender, ethnicity, teacher preparation method, and many others.

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Trajectories

An Eulerian description of the student scores arises from explicitly following the groups of students given some initial score bin and following that group’s average score over time. Here we follow cohorts of students who, in 4th grade, scored between 100% and 90%, 90% and 80%, and so on. Line thicknesses show the number of students in that trajectory. Again, the scores have different flow properties. SSI forced the scores for the class of 2012 to a higher trajectory than the corresponding 2011 trajectories.

Other Interventions

These plots illustrate the outcome of SSL; an intervention that was in effect for the entire state which we had no knowledge of prior to making these plots. If these effects are so visible at the state level, can we see similar effects, such as a particular pedagogical method, using a campus or teacher level plot?

Future Directions

We are moving towards a causal description to identify similar interventions at the school, teacher, and classroom level. One example of a causal model at the campus level is shown below. We are also examining teacher preparation and years of experience as causal effects for student scores.

Literature cited


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