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ABSTRACT
Recent advances in Machine Learning and Data Mining enable new branches of educational research to thrive, particularly e-learning and data capturing through e-learning systems. [17] Academic performance research benefits strongly from this trend through better predictive models. In this paper, I investigate **hierarchical models** - a flexible family of advanced parametric models - that could achieve not only high out-of-sample prediction power but also meaningful confidence intervals for statistical inference. Reviews and empirical comparisons versus traditional machine learning methods on an educational dataset are also provided in details.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; J.4.m. Computer Applications: SOCIAL AND BEHAVIORAL SCIENCES; G.3.m. Mathematics of computing: Probability and Statistics - Multivariate statistics; G.3.m. Mathematics of computing: Probability and Statistics - Statistical Computing; I.5.1.m. Computing methodologies: Pattern Recognition - Models

Author Keywords
Parametric Models; Education Research; E-learning; Student Performance; Predictive Modeling; Statistical Inference; Bayesian computation; STAN; Hierarchical Models; MCMC; Approximation; Maximum a posteriori estimation; Confidence Interval; Prediction Interval

EDUCATION RESEARCH REVIEW
The paper briefly compares the evolution of quantitative predictive methods in education research.

Parametric Statistical Models
Traditionally, research in education and educational policies have applied similar quantitative methods to those used in the social sciences [9], because the main goal of these educational inquiries is to established causal effects. Parametric, sparse models which allow ease of hypothesis testing therefore are both prevalent and important, while black-box, flexible predictive models are not popular. [23]

Good parametric models offer prediction capability with both point estimates and confidence intervals. However, unlike causality testing, prediction and prediction methods only take secondary roles in traditional education research, so these models are not built to optimize for out-of-sample prediction. [17].

Recent Machine learning methods
Advances in Machine Learning enable new branches of educational research to thrive, particularly e-learning. [17] E-learning allows new ways of generating data and new types of data enable researchers build better predictive models. Naturally, people apply more modern methods on these datasets, and **ensembles, neural nets** and **SVMs** are the most favorable methods. [19], [2]

The body of work that apply predictive ML methods on educational data tends to weight practicality more than interpretability, and they optimize for overall prediction power instead of answering traditional causality/inference questions. [17, 15]

RESEARCH GOAL AND METHODOLOGY
The current state of academic performance research thus motivates me to investigate if we could build ***flexible predictive models that could achieve not only high out-of-sample prediction power but also meaningful confidence intervals for statistical inference.***. **Hierarchical models** is a family of advanced parametric models that could satisfy this demand.

Hierarchical modeling and prediction
Hierarchical modeling and prediction offer a balanced pay-off between predictive accuracy and interpretability [8, 20, 11] Hierarchical models are particularly suitable for educational research datasets, because education data are generally collected from a hierarchy. For example, you can have performance scores for students in a state, at different districts, different schools within the same district, different class level within the same school etc. Of course, if the data are generated in a true controlled fashion with balanced groups representation across all covariates, then we can just do a pooled t-test, but these are survey or longitudinal data with known biases and imbalances. [14]

There are few studies focusing on hierarchical models in academic performance [24, 21], and there is no current study that focuses on building a highly predictive hierarchical model first before interpreting confidence intervals and statistical significance.

Bayesian Technique in Hierarchical modeling

Fitting hierarchical model is one of the major usage of Bayesian techniques. Previously, due to computational complexity of the sampling algorithms in these Bayesian techniques, building hierarchical models are hard. However, recent advances in hardware and software have opened up these techniques to a wider range of social science problems. [4]

Comparison of modeling techniques

This research builds hierarchical models on a student performance dataset and compares those hierarchical models' predictive power against state-of-the-art esembles/tree-based models built on the same data.

In particular, Amrieh et. al. [2] apply ensemble methods on features of students collecting through an electronic system to predict academic performance and show that ensemble models achieve strong out-of-sample prediction. However, the predicted values themselves do not come with useful information that aids decision making, such as confidence intervals and significant of contributing factors. [7, 15] For example, the dataset in [2] is unbalanced: Technology has 95 students vs. Maths has 21 students, so performance prediction for a new Maths student should be a lot less certain than that of a new Technology student. Meanwhile, none of the ensemble models can reflect such confidence adjustments based on their predictive values.

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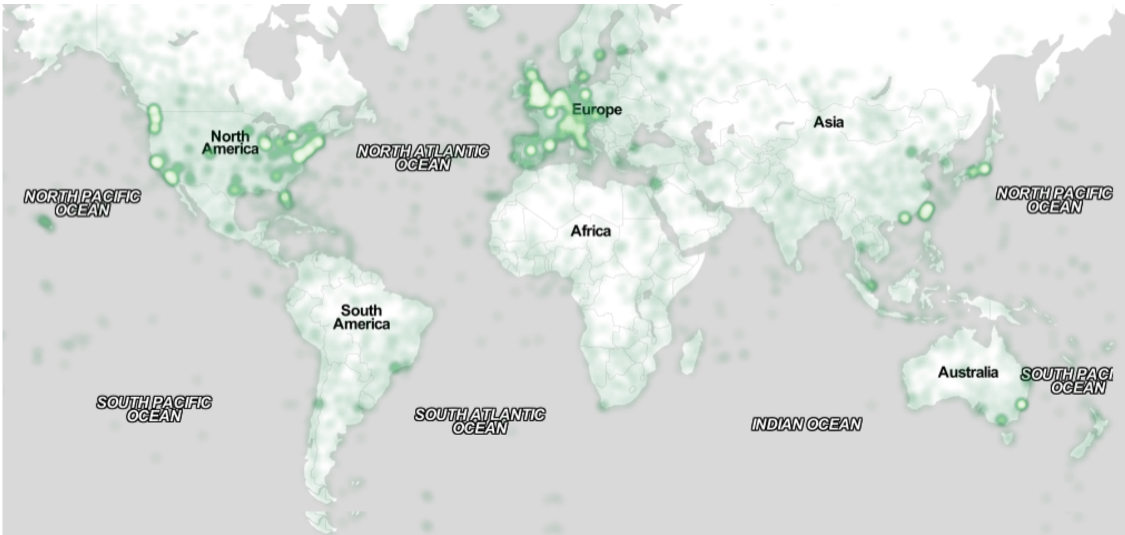

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ACKNOWLEDGMENTS

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