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Interactive Stratified Attribute Tracking Diagram for Learning Analytics

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***Abstract*—Interactive Stratified Attribute Tracking Diagram (iSAT) is a data visualization and tool to assist interactive visual analytics of multi-attribute learning dataset. The present work reports the evolution of this diagram through a design based research methodology following its three design iterations. There are two output at the current stage i) iSAT and its web-based interaction. ii) A Learning Analytics method suitable for both researchers and practitioners to trace student attribute value. We received satisfactory user testing score for Pre-test and post-test marks visualization through a two-phase iSAT.**

Keywords- iSAT; SAT Diagram; State Transition Diagram; Design Based Research methodology.

I. INTRODUCTION

With emergence of Massive Open Online Courses (MOOCs) and technology intensive education resources, lot of attention is given to Learning Analytics (LA) to understand and optimize learning process and its environment [1]. To facilitate such comprehensive and exploratory data analysis we propose Interactive Stratified Attribute Tracking Diagram (iSAT). Given a dataset with each record having multiple attributes and stratification criteria for each attribute, iSAT is an interactive representation of the composition and migration pattern in that data set. It considers one attribute per phase and indicates the stratified composition of the sample for each phase and then tracks them across phases of different attributes. In this short article we highlight the evolution of the diagram following a Design Based Research (DBR) method over 3 design iterations.

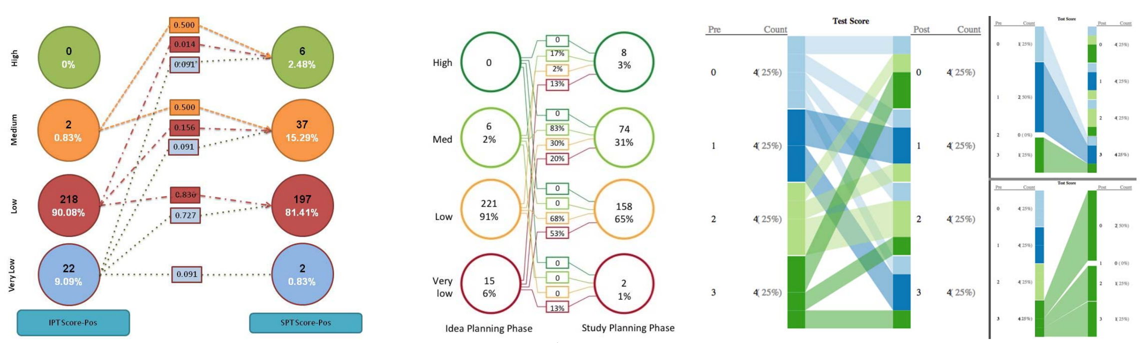
II. MOTIVATION AND RELATED WORK

The initial motivation was to diagrammatically represent a model of the observed behavior of students in a multiphase active learning session in a large class [2]. We wanted to trace the variations in the population in different engagement levels across phases. The objective was to visualize two major statistics. i) The proportion of sample in each level (stratum) of engagement ii) The migration pattern, in terms of the portion of each category (stratum) that went to different strata in the next phase. A contingency table between each phase would essentially capture this data, but it is difficult to explicate any pattern from the tabular form.

Hence we looked into diagrammatic representations like Sieve diagrams, Mossaic displays and Fourfold display as possible candidates [3]. But in these diagrams the metaphor of changing phases is implicit. Their representation had frequencies of distribution for the different variable as a unified element. Also following the grammar of graphics [4], we were mostly limited to static visualization while multivariate contingency table is often difficult to comprehend and would be useful to have an interactive visualization. Literature has ample evidence that diagrams are useful in the process of problem solving. They minimize computation of implicit elements and also help in six major ways to amplify cognition [5]. An interactive system would also enable manipulation that would assist distributed cognition for the user.

III. DESIGN BASED RESEARCH (DBR) ITERATIONS

In the present context of LA, with the help of visualizations, we essentially want to explicate any pattern that exists implicitly in the learning data collected over time. DBR is a research method "which can address multiple interacting variables and allow for iterations of the intervention until it becomes effective"[6]. Over the 3 iterations (research cycles) of implementing, evaluating and modifying the design, we conceptualized, developed an algorithm to look into meso-view of the data and finally introduced iSAT. The highlights of the DBR cycles are given in TABLE I.



a b c

Figure 1. The evolution: a. State Transition Diagram b. Stratified Attribute Tracking Diagram c. interactive Stratified Attribute Tracking

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TABLE I. DESIGN BASED RESEARCH MATRIX

Cycle	Objective	Problem(s)	Solution	Implementation	Output	Testing / Findings
Research Cycle (RC) 1 State Transition Diagram	Model the behaviors of the students during the phases of in-class active learning activity	Extracting patterns from large observation data. The richness of the data was lost if only aggregate statistics was only reported	Proposed an analysis methodology to categorize data and then represent it.	Methodology of the analysis reported in [2] Proposed the structure of the State Transition Diagram	State Transition Diagram + Quantified Engagement model [2]	4 researchers analyzed the developed model Evaluated generalizability
RC 2 Stratified Attribute Tracking (SAT) Diagram	Make a diagrammatic representation to describe and explicate patterns for data collected over multiple stages	The aggregate statistics took a very high level view of the dataset and tracking data at individual level was very tedious.	A meso-view generated from the available data to capture the dynamics of the population in terms of its composition in each phase and tracks how it changes	Development of algorithm to pre-process data and represent it	Stratified Attribute Tracking Diagram	5 researchers used it to report their results Highlighted need to include interactivity
RC 3 iSAT	Revising the design to add interactivity Add automation to assist the user	The visual clutter in static design.	Applying visual design principles to enhance usability	HTML5 and Java Script based implementation using D3 library	iSAT	Usefulness and Usability tests are satisfactory for two attribute dataset

We wanted to find a visual metaphor to indicate stratified sample in buckets according to attribute value in a phase and then trace their migration to the next phase. We looked at the body of work in grammar of graphics [4] to decide about aesthetics, geometric objects, statistical transformations, and positional adjustments of elements in the visualization. We developed a 3-step process to transform the data to visualization. During 1st iteration the State Transition Diagram follows: Setup and Pre-processing – Label and Count – Represent. In the 2nd iteration we developed Stratified Attribute Tracking diagram and introduced partial automation by using Pivot tables in Microsoft Excel to generate the contingency table. While visualizing contingency table, design principles of perception, detection, and comparison of categorical data suggests that frequencies can be represented as area [3]. Later in the 3rd iteration we adopted Data-Driven Documents (D3) to introduce interactivity in quantitative data visualization [7]. It is a representation-transparent approach for visualization on the web. We developed a platform to upload a data file with attributes and the system would generate an iSAT.

IV. SUMMARY – REFLECTIONS AND FUTURE WORK

It started with the State Transition Diagram to quantify student's engagement levels, and then the methodology of analysis and representation was extended to other educational research context. This version was known as Stratified Attribute Tracking Diagram. The present version iSAT is interactive but limited to tracing and explicating patterns in two phases. We are working on extending to multi-phase interactive projection. The usefulness and usability (mean is 3.66 on a 5 point Likert scale) of the web based rendering shows the automation is appreciated by the users and the ongoing survey wants to elicit specific advantages that the interactivity gave to explicate patterns. Our previously conducted study [8] provides the usefulness in 8 Learning Analytics case-studies.

This design effort has given us insights to the various parameters that one can collect and possible look at during analyzing any educational context. While handling similar attributes in both phases (e.g. Pre-Post Test marks) apart from doing a test for statistical significance of differences, researchers can actually seek patterns of migration. It would give insights with respect to which portion of the sample was benefited even if there existed no statistical difference. Practitioners can also to track the performance of their students across a period. The involvement with the data while generating the diagram often gave rise to more research questions that could be asked for deeper analysis.

The next round of usability testing of the iSAT platform would try to log the type of data and the context that the user visualized with the help of iSAT. This would help us to understand the usefulness, applicability and adoptability in Learning Analytics.

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