WIP: An Evidence Gap Map Analysis of Personalized Adaptive Learning in Undergraduate Mathematics

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***Abstract*—This work in progress research paper presents preliminary results of a meta-analysis using an evidence gap map that examines personalized adaptive learning (PAL) in undergraduate mathematics. Personalized adaptive learning (PAL) implements intelligent learning systems, integrates learner preferences, and analyzes individual learning data to create a unique learner path personalized to the needs of students. PAL may benefit students in mathematics courses such as college algebra which serves as a gatekeeper course, especially for those majoring in science, technology, engineering, and mathematics (STEM) fields. Our comprehensive meta-analysis of group design studies examines the average effect of PAL on undergraduate mathematics outcomes broadly and specifically on algebra. Thirteen databases were searched. At the first stage, titles and abstracts were screened. Articles violating one or more inclusion criteria were excluded. The second stage of screening was full-text review. Retained studies will have data extracted that will allow the effect size results to be meta-analyzed (which is beyond the scope of the evidence gap maps). Results to date: The search identified 12,734 studies and of those, 44 met inclusion criteria, four of which were merged into two studies resulting in 42 included studies. Of the 42 studies, 19 were published in the previous ten years and constitute the analytic sample for the EGM. Of these 19 studies, two (11%) incorporated a randomized design. The EGM of the number of studies by publication outlet and publication year indicates that of the six journal publications, about two-thirds were published in 2020 or more recent. In comparison, of the 13 non-journal publications, 69% of the non-journal publications were published between 2015-2019. The EGMs suggest the need for researchers to continue to seek rigorous designs for evaluating PAL to provide the strongest evidence. There is a growing and positive trend for PAL research to be published in journals which should assist in making results more discoverable. This project seeks to advance undergraduate STEM education research by meta-analyzing studies related to implementation of innovative technological advancements in instruction and how PAL intervention relates to students' success in mathematics-going beyond results from just one institution, one setting, one sample. As a Work-in-Progress, next steps include extracting and meta-analyzing data from the included studies.**

***Index Terms*—adaptive computer learning, mathematics, undergraduate**

I. Introduction

This research category work-in-progress paper describes an evidence gap map analysis of personalized adaptive learning in undergraduate mathematics. Personalized adaptive learning (PAL) implements intelligent learning systems, integrates learner preferences, and analyzes individual learning data to create a unique learner path [1]. PAL has been found to effectively increase mastery of content and predict final course grades (e.g., [2]). PAL may be particularly beneficial to students in mathematics courses such as college algebra and calculus as they serve as gatekeeper courses, especially for those majoring in science, technology, engineering, or mathematics (STEM) fields [3], [4].

Successful STEM pathway completion has been a persistent challenge in higher education [4]. Beginning with low completion in developmental math [5] (50% at 2-year; 58% at 4-year institutions) [6] and low success (A, B, C grade) in college algebra (less than 50%) [7] , students struggle with the prerequisite math required to enter and successfully complete

STEM degrees. In addition, poor college performance and high withdrawal/failure in STEM courses are associated with an increased probability of dropping out of college for STEM entrants [8] .

Furthermore, although underrepresented minorities are as likely to enter STEM degrees as non-underrepresented peers [9], they are less likely to attain a STEM degree [10] . Experts call for reassessing curricula and pathways and a focus on evidenced-based instructional techniques to address the struggle of undergraduates STEM completion [11].

Few syntheses/systematic reviews/meta-analyses have examined the effect of PAL. Existing meta-analyses on PAL [1], [12] have used restrictive search criteria (i.e., databases searched, publication type, publication period), failed to examine research quality, and failed to present meta-analytic results. One study that was broader in search (but still restrictive) [12] was restricted to pre-kindergarten to high school.

II. Purpose

Mathematics can be a major obstacle to entering and completing a STEM degree [13], [14]. Additionally, mathematics courses traditionally have high D-F-W (grades D or F or Withdraw) rates [15]. This may result in barriers to college degree attainment for many students, regardless of degree, and may particularly impact underrepresented students [16], [17]. The Mathematical Association of America's Committee on Curriculum Renewal Across the First Two Years (CRAFTY) derived a set of recommendations to redesign college algebra [18]. Since then, colleges have invested considerable effort toward addressing the key challenges in teaching college algebra [19]. In this regard, the use of PAL offers students the opportunity to develop mathematical skills in a personalized way, while enabling instructors to identify, and take appropriate remedial actions, for students' struggle areas [14], [20], [21] and aligns with CRAFTY's guidelines.

This work-in-progress research paper presents preliminary results of a meta-analysis using an evidence gap map that examines mathematics outcomes for personalized adaptive learning (PAL) in undergraduate mathematics. We are completing a comprehensive meta-analysis of group design studies to examine the average effect of personalized adaptive learning on undergraduate mathematics outcomes broadly (study 1) and specifically on algebra (study 2). This work-in-progress will provide information on PAL undergraduate mathematics studies published in journals using evidence gap maps (EGMs).

III. Methods

A. DEVELOPMENT OF THE SEARCH STRATEGY

PRISMA 2020 was followed to describe the search strategy [22] - [24]. Initial keywords were identified by the project team and advisory board with additional keywords based on terms used in previous PAL reviews [1] indexed terms for databases, and terms from PAL publisher websites.

B. LITERATURE SEARCH

Thirteen databases, those most likely to index PAL studies, were identified in collaboration with an academic librarian and searched. They included: Academic Search Premier ACM Digital Library, APA PsycInfo, Compendex, Education Source, ERIC, IEEE Xplore, Inspec, ProQuest Dissertations & Theses Global, ProQuest SciTech Premium Collection, ProQuest Social Science Premium Collection, Science Direct, and Web of Science.

C. INCLUSION CRITERIA

Articles were included if they were: 1) a study; 2) reported in English; 3) conducted in the U.S., U.S. territories, freely associated states, or Washington DC; 4) in undergraduate courses; 5) in an educational setting; 6) in a mathematics course; 7) a group design randomized controlled trial or quasi-experimental design; 8) includes PAL; 9) incorporated a cognitive or affective mathematics student measure.

D. CITATION SCREENING

At the first stage, titles and abstracts were screened. Articles excluded clearly violated one or more inclusion criteria. The second stage of screening was full-text review. Only articles that met all inclusion criteria were retained. Retained studies will have data extracted that will allow the effect size results to be meta-analyzed (which is beyond the scope of the evidence gap maps).

E. DATA ANALYTIC STRATEGY: EVIDENCE GAP MAPS

Evidence gap maps (EGMs) are an alternative method for presenting research synthesis results that allows results to be more intuitively understood via visual or tabulation representation in grid format [25]. As compared to meta-analyses, EGMs present the evidence that exists, "not what the evidence says" [26]. EGMs that are represented in graphical form have markers within cells which denote aspects of the synthesis such as number of studies. Empty cells indicate the absence of the characteristic, i.e., the gap [25].

IV. Results

The search identified 12,734 studies. Of those, 2,162 duplicates were removed, resulting in 10,572 studies at the abstract and title screening phase, all of which have been double screened. Of the 10,572 studies, 10,271 were excluded, and 301 were moved to full text eligibility screening. Of the 301 studies, 44 studies met inclusion criteria, four of which were merged into two studies resulting in 42 included studies. Of the 42 studies included to date, 19 were published in the previous ten years (2014 or more recent) and constitute the analytic sample for which the EGM is created.

A. EVIDENCE GAP MAP ANALYSIS

About 37% of studies (n = 7) have been conducted since 2020, and about 58% conducted between 2015-2019. The evidence gap map in Figure 1 presents the number of studies by research design and publication year. Of the 19 studies

within the past ten years, only two (11%) have incorporated a randomized design. In the past five years (i.e., 2020 or more recent), there have been no randomized design studies. Of the

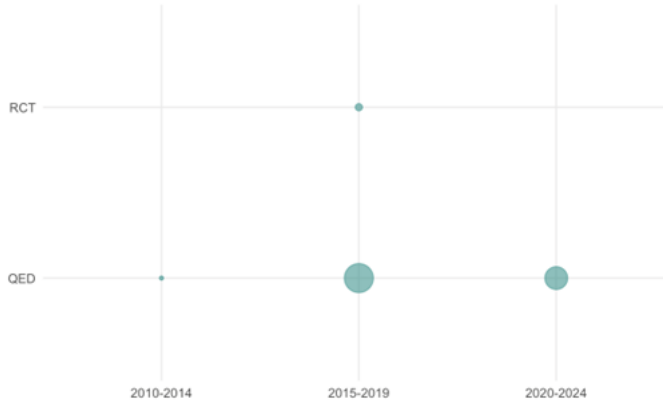

Fig. 1. Evidence gap map of research design by publication year.

19 studies published in the previous ten years, about one-third (n = 6) were published in journals, and the remaining were non-journal outlets (e.g., dissertations or conference proceedings). The evidence gap map in Figure 2 presents the number of studies by publication outlet and publication year. Of the six journal publications, about two-thirds (n =4, 67%) were published in 2020 or more recent. In comparison, of the 13 non-journal publications, 69% of the non-journal publications (n = 9) were published between 2015-2019.

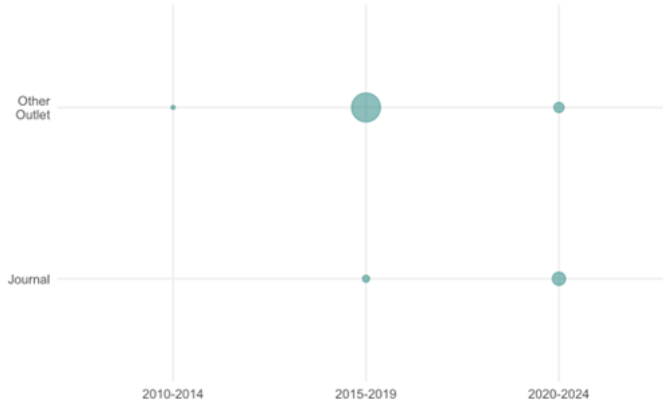

Fig. 2. Evidence gap map of publication outlet by publication year.

Conclusion

The EGMs of PAL in undergraduate mathematics published within the previous ten years suggests the need for researchers to continue to seek rigorous designs for evaluating PAL to provide the strongest evidence. There appears to be a growing and positive trend for PAL research to be published in journals which should assist in making results more discoverable. Because scholarly journals are the most credible outlet for research findings, publication of PAL in journals is central to disseminating results that can be used by the academic community.

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