PRELIMINARY META-ANALYTIC FINDINGS EXAMINING PERSONALIZED ADAPTIVE LEARNING IN UNDERGRADUATE MATHEMATICS

D. Hahs-Vaughn, K. Teixeira, P. Moskal, T. Muhs, O. Farotimi, C. Carassas, C. Bishop

University of Central Florida (UNITED STATES)

Abstract

This study presents preliminary results of a meta-analysis that examines personalized adaptive learning (PAL) in undergraduate mathematics using evidence gap maps. PAL has been increasingly adopted in the U.S. and may be particularly beneficial to students in mathematic courses such as college algebra and calculus as they serve as gatekeeper courses, especially for those majoring in STEM fields. However, the impact of PAL's use in undergraduate mathematics has yet to be fully explored with meta-analytic methods. This project seeks to advance undergraduate STEM education research by meta-analyzing studies related to the implementation of innovative technological advancements in instruction and, specifically, how PAL intervention impacts students' success in mathematics—going beyond results from just one institution, one setting, one sample.

Keywords: Meta-analysis, personalized adaptive learning, undergraduate, mathematics.

1 INTRODUCTION

Personalized adaptive learning (PAL) emerges from the combination of personalized and adaptive learning. While personalized learning refers to the method of instruction tailored to the individual needs of each learner [1], Adaptive learning utilizes technologies that monitor a student's progress and leverages data to enhance instruction [2]. Personalized learning systems consider learners' trajectories and provide learners with suitable paths and materials [3].

Personalized learning has many different terms [4]. The U.S. National Education Technology Plan 2017 defines personalized adaptive learning (PAL) as "instruction in which the pace of learning and the instructional approach are optimized for the needs of each learner. Learning objectives, instructional approaches, and instructional content (and its sequencing) may all vary based on learner needs. In addition, learning activities are meaningful and relevant to learners, driven by their interests, and often self-initiated" [5].

According to Xie et al. [6], PAL curates a unique learner path by implementing intelligent learning systems that incorporate learner preferences and analyze their learning data. Furthermore, PAL is an effective technology-driven teaching approach that dynamically adjusts instructional strategies based on real-time monitoring of learners' differences and changes. This real-time monitoring considers individual characteristics, performance, and personal development [1].

PAL is used in conjunction with various course modalities (e.g., online, blended, face-to-face) and instructional models (e.g., supplemental instruction, asynchronous learning, synchronous learning, emporium model). This study will include the broad use of PAL to capture, identify and detail any models which succeed in improving student success in STEM. PAL has been found to effectively enhance content mastery and accurately predict final course grades [e.g., 7] and may be beneficial for students enrolled in STEM (science, technology, engineering, or mathematics) majors offering gatekeeper mathematics courses like college algebra and calculus [8, 9].

Undergraduate mathematics courses can be roadblocks to college degree attainment. Personalized adaptive learning (PAL) offers the opportunity to develop mathematical skills in a personalized way, while enabling instructors to identify students' struggle areas and take prompt remedial actions. Through PAL, unique learner paths are created through the implementation of intelligent learning systems, integration of learner preferences, and analyses of individual learning data [6]. Advocates argue that PAL provides tools which allow students to succeed [10], and researchers who have studied PAL have found it to be effective in increasing mastery of content and predicting final course grades [7]. As such, PAL may be particularly beneficial to postsecondary students enrolled in courses such as college

ISBN: 978-84-09-62938-1

algebra and calculus, as they serve as gatekeeper courses, especially for those majoring in science, technology, engineering, or mathematics (STEM) fields [8, 9].

When comparing the use of PAL in statistics courses at four-year and two-year institutions, course grades and passing rates, as well as statistical competency, were significantly greater for students at four-year institutions only, but there was no difference based on student subgroups, such as whether they were first-generation college students or Pell grant recipients [11]. Within content areas, PAL is increasingly adopted as an instructional tool for math, and specifically developmental math, to assist in addressing the substantial proportion of college students who are underprepared for college-level math, resulting in the low success rate for students placed into developmental courses [12-14]. In a randomized trial, researchers found that PAL students were more likely to earn one or more developmental math credits and complete a higher proportion of the math sequence, relative to their controlled counterparts [15]. In follow-up semesters, PAL students were more likely to persist to the second semester, enroll in a math class, and earn at least one math credit. However, there were similar success rates of PAL and control students who completed the first one-half of the developmental math sequence, who were deemed college-ready (i.e., completed the entire developmental math sequence), and who passed their first college-level course in math [15].

Within the United States, personalized adaptive learning (PAL) has been increasingly adopted in the last ten years, but arguably more attention has been paid to it as an instructional strategy since the passing of the Every Student Succeeds Act (ESSA), in which schools are encouraged to increase student access to rigorous PAL. Highlighted within ESSA is the need for educational agencies (both state and local) to develop innovative learning environments personalized to the needs of the students that utilize modern technology, adopt flexible instructional practices, and are aligned to Universal Design for Learning (UDL) principles [16]. This study aims to provide insight into PAL as an instructional strategy in undergraduate mathematics courses, including gatekeeper courses, that may inform the choice of tools that can be used to assist STEM pathway completion in higher education.

2 METHODOLOGY

2.1 Literature Search

The search strategy adhered to PRISMA 2020 guidelines for conducting a systematic review [17, 18]. Key words for searching the literature were identified based on previously used terms in PAL syntheses as well as terms identified by the research team and terms identified on websites of PAL publishers. Thirteen databases were searched and included: Academic Search Premier ACM Digital Library, APA PsycInfo, Commended, 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.

2.2 Criteria for Included Studies

Inclusion criteria were: 1) described a study; 2) reported in the English language; 3) conducted in the U.S., U.S. territories, freely associated states, or Washington DC; 4) conducted within an undergraduate courses; 5) conducted within an educational setting; 6) conducted within a mathematics course; 7) designed as a group design randomized controlled trial or quasi-experimental study; 8) included PAL as an intervention; 9) incorporated a student-level outcome related to mathematics (cognitive or affective).

2.3 Evidence Gap Map

Evidence gap maps (EGMs) are used to systematically present all relevant evidence specific to a focal area, sector, or sub-sector. EGMs synthesize evidence relating to a specific research question and organize it into primary dimensions or a framework (represented by rows and columns) and secondary dimensions or filters that allow for focused exploration, such as examining specific populations or study designs etc. As an evidence synthesis tool, EGMs utilize a deductive approach, using a pre-specified framework to categorize data and identify gaps in existing literature [19].

Evidence and gap maps (EGMs) produce visual output [20] and are systematic evidence synthesis tools that identify gaps where new evidence is needed, compile collections of studies for review, and enhance the discoverability and utilization of studies by stakeholders or decision-makers.

3 RESULTS

The results include a summary of the identified studies and examination of studies using evidence gap maps.

3.1 Included Studies

There were 12,734 studies identified from the search, which included 2,162 duplicates. After removing duplicates, 10,572 studies were screened at the abstract and title stage. Based on abstract and title screening, 10,271 studies were excluded and 301 moved to the full text eligibility screening stage. Forty-four of the 301 studies were identified at the full text phase as meeting all inclusion criteria. Of the 44 studies, four studies were identified to be merged (i.e., one dissertation later published in a journal; one study with later follow-up). This resulted in 42 unique studies.

3.2 Evidence Gap Map Analysis

Over two-thirds of studies (n = 30, 71%) have been conducted within the last 15 years (i.e., 2010 or more recent). All but one study was conducted within the last 25 years (2000 or more recent). The evidence gap map in Fig. 1 presents the number of studies by research design and publication year. Of the 4 randomized control trials (RCT), all were conducted between 2010-2019.

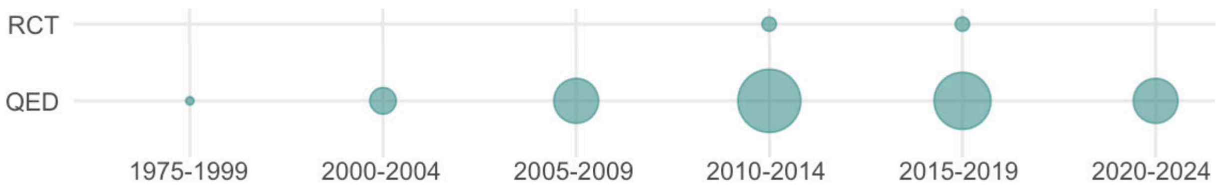

Figure 1. Evidence Based Gap Map of Design by Publication Year.

Less than one-third of studies (n = 12, 29%) have been published in journals. The evidence gap map in Fig. 2 presents the number of studies by publication outlet and publication year. Only within the past five years has there been more published PAL undergraduate mathematics studies within journal outlets than other types of outlets (e.g., dissertations, conference proceedings).

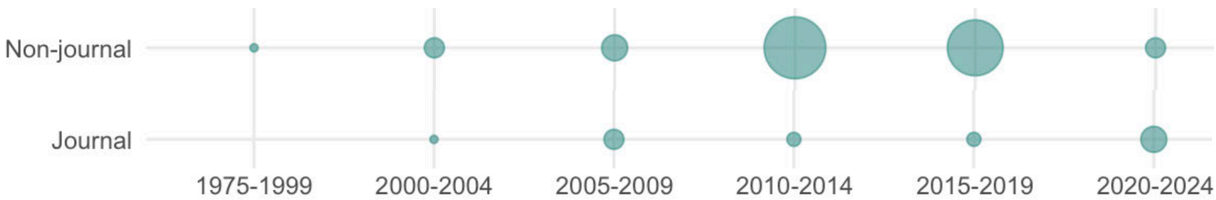

Figure 2. Evidence Based Gap Map of Publication Outlet by Publication Year.

4 CONCLUSIONS

As implementation of personalized adaptive learning continues to grow in undergraduate mathematics courses, additional research is needed to evaluate the effectiveness of this strategy as it relates to mathematics outcomes. Future research that applies randomized controlled designs are needed given the greater ability for causal inference. Although there have not been any randomized studies since 2020, we are hopeful there are randomized studies in the pipeline and encouraged for this given that all the randomized studies have been conducted in the last 15 years. Authors should also consider submission to journal outlets which may increase dissemination of results related to examination of PAL in undergraduate mathematics. The uptick in journal publications of PAL since 2020 is especially encouraging and should benefit the dissemination of PAL effects in undergraduate mathematics.

ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation (NSF) under grant number 2236074. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

[1] H. Peng, S. Ma, and J. M. Spector, "Personalized adaptive learning: An emerging pedagogical approach enabled by a smart learning environment," *Smart Learning Environments,* vol. 6, no. 1, pp. 1-14, 2019, doi: 10.1186/s40561-019-0089-y.

[2] S. Adams Becker *et al.*, *NMC horizon report: 2017 higher education edition*. Hamburg, 2017.

[3] M. A. Salahli, M. Ozdemir, and C. Yasar, "Concept based approach for adaptive personalized course learning system," *International Education Studies,* vol. 6, no. 5, p. 92, 2013, doi: 10.5539/ies.v6n5p92.

[4] A. Shemshack and J. M. Spector, "A systematic literature review of personalized learning terms," *Smart Learning Environments,* vol. 7, no. 1, pp. 1-20, 2020, doi: 10.1186/s40561-020-00140-9.

[5] U.S. Department of Education Office of Educational Technology, "Reimagining the role of technology in education: 2017 national education technology plan update," 2017. Accessed: 9/18/2020. [Online]. Available: https://tech.ed.gov/files/2017/01/NETP17.pdf

[6] H. Xie, H.-C. Chu, G.-J. Hwang, and C.-C. Wang, "Trends and development in technology-enhanced adaptive/personalized learning: A systematic review of journal publications from 2007 to 2019," *Computers & Education,* Article vol. 140, 10/01/October 2019 2019, doi: 10.1016/j.compedu.2019.103599.

[7] E. L. Simon-Campbell and J. Phelan, "Effectiveness of an adaptive quizzing system as an institutional-wide strategy to improve student learning and retention," *Nurse Educator,* vol. 41, no. 5, pp. 246-251, 09//Sep/Oct2016 2016, doi: 10.1097/NNE.0000000000000258.

[8] J. F. Rech and J. Harrington, "Algebra as a gatekeeper: A descriptive study at an urban university," *Journal of African American Men,* Article vol. 4, no. 4, pp. 63-71, 2000, doi: 10.1007/s12111-000-1022-7.

[9] B. Toven-Lindsey, M. Levis-Fitzgerald, P. H. Barber, and T. Hasson, "Increasing persistence in undergraduate science majors: A model for institutional support of underrepresented students," *CBE - Life Sciences Education,* vol. 14, no. 2, pp. 1-12, 06/01/ 2015, doi: 10.1187/cbe.14-05-0082.

[10] L. E. Jones and M. C. Casey. "Personalized learning: Policy and practice recommendations for meeting the needs of students with disabilities." National Center for Learning Disabilities. https://www.ncld.org/wp-content/uploads/2016/04/Personalized-Learning.WebReady.pdf (accessed December 8, 2020).

[11] J. Joo and R. R. Spies, "Aligning many campuses and instructors around a common adaptive learning courseware in introductory statistics: Lessons from a multi-year pilot in Maryland." [Online]. Available: https://sr.ithaka.org/publications/adaptive-learning-courseware-introductory-statistics/

[12] S. W. Wheeler and N. Bray, "Effective evaluation of developmental education: A mathematics example," *Journal of Developmental Education,* vol. 41, no. 1, pp. 10-17, 01/01/ 2017. [Online]. Available: https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1192548&site=eds-live&scope=site&custid=current&groupid=main&authtype=shib.

[13] T. Bailey *et al.*, "Strategies for postsecondary students in developmental education: A practice guide for college and university administrators, advisors, and faculty. NCEE 2017-4011," ed: What Works Clearinghouse, 2016.

[14] X. Chen, "Remedial coursetaking at U.S. public 2- and 4-year institutions: Scope, experiences, and outcomes," National Center for Education Statistics, Washington, DC, NCES 2016-405, 2016.

[15] M. J. Weiss and C. Headlam, "A randomized controlled trial of a modularized, computer-assisted self-paced approach to developmental math," MDRC, 2018.

[16] 20 U.S.C., 2015.

[17] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *British Medical Journal,* vol. 372, 2021, doi: 10.1136/bmj.n160

[18] M. J. Page *et al.*, "PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews," 2021.

[19] F. Campbell *et al.*, "Mapping reviews, scoping reviews, and evidence and gap maps (EGMs): The same but different— the “big picture” review family," *Systematic Reviews,* vol. 12, no. 1, pp. 45-45, 2023, doi: 10.1186/s13643-023-02178-5.

[20] H. White *et al.*, "Guidance for producing a Campbell evidence and gap map," *Campbell Systematic eview,* vol. 16, no. 4, pp. e1125-n/a, 2020, doi: 10.1002/cl2.1125.