Board 209: Adaptive Expertise: A Potential Tool for Supporting S-STEM Student Retention and Graduation

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Adaptive Expertise: A potential tool for supporting S-STEM student retention and graduation

A recent self-study at Stevens Institute of Technology revealed that our 2nd and 3rd year retention rates for low-income STEM students are lower than those for our non-low income STEM student body. To address this finding, the goal of our S-STEM program is to implement evidence-based best practices to increase retention and graduation rates of low-income academically talented STEM students to levels that match our overall STEM population. To accomplish this goal, we are seeking to:

1. implement best-practices with regards to cohort development and faculty, peer, and alumni mentoring programs to support the ADAPT Scholars,
2. develop targeted enrichment and mentoring activities focused on developing and nurturing the concept of Adaptive Expertise within our Scholars,
3. integrate new programming specific for low-income students with existing campus supports and activities, and
4. increase departmental and institutional awareness of, and support for, the challenges faced by academically talented, low-income students.

We are seeking to determine whether contextualizing our cohort activities around the concept of Adaptive Expertise will both provide a unifying programming theme to maintain cohort engagement, and support students in the application of classroom knowledge in professional practice which will enhance their resiliency and sense of belonging which will positively impact retention.

Here we will summarize a series of targeted research studies seeking to characterize the levels of adaptiveness measured in low-income and non-low-income STEM undergraduate students using a validated survey instrument, including how adaptiveness may change as STEM students progress through their undergraduate programs.

What is Adaptive Expertise?

Within the learning sciences, the concept of Adaptive Expertise (AE) is used to describe the ability to apply or expand knowledge and skills to new contexts [1], [2]. This definition differs from that of routine expertise, which is used to define someone who has deep knowledge of their subject area, but who may not be able to apply this knowledge or their skills across a range of problems from other fields. Adaptive Expertise is an important concept to consider in the context of undergraduate engineering education given the increasing demand for engineers of the future to be adaptable professionals who can work across disciplines and apply their knowledge across a broad range of problems [3-5]. While there is an understanding of the need for students to be adaptive, to date there has been relatively little research published concerning educational practices that promote adaptiveness among students [6], [7].

Two broad definitions of Adaptive Expertise can be found in the learning sciences literature. One definition considers Adaptive Expertise to be composed of two dimensions; innovation and efficiency. An adaptive expert is then someone who is both efficient and innovative in the manner in which they can apply their knowledge [6], [7]. A second definition grounds AE in four different dimensions; goals and beliefs (GB); multiple perspectives (MP); metacognition (META); and, epistemology (EPIST) [8]. These

specific dimensions were chosen by the authors of this study (based on a literature review) as they represent dispositions that enhance one's ability to effectively use and apply their knowledge. Both definitions have been used in prior work and a consensus on the correct representation of AE has yet to be established. It is generally accepted, however, that the dimensions of adaptiveness, based on either definition, are rarely taught explicitly in undergraduate engineering programs [9-12].

In 2021, members of the ADAPT project team conducted a contemporary review of the literature concerning AE in order to assess the current state of the art. This work is described in [13] and indicates that while, as discussed, several definitions of Adaptive Expertise exist in the literature, few validated tools for the measurement of AE have been developed. A paucity of data concerning levels of AE displayed by various populations was also observed. Fortunately, a survey instrument [14], originally developed in 2001, was found to still be in use as a tool for measuring AE, and various studies had indicated its reliability [9], [15]. Based on this review of the literature, the definition of Adaptive Expertise and the survey for its measurement put forward by Fisher and Peterson [16] was chosen for this work.

The AE measure includes 42 items on a scale of 1 (*Strongly Disagree*) to 6 (*Strongly Agree*). In terms of the AE dimensions previously identified by Fisher and Peterson [16] there are four distinct subscales; (1) multiple perspectives (MP), (2) metacognition (META), (3) goals and beliefs (GB), and (4) epistemology (EPIST). Multiple perspectives (MP) assesses participants' ability to use different approaches to analyze and solve a problem. Sample items for multiple perspectives include "when I consider a problem, I like to see how many different ways I can look at it" and "I am open to changing my mind when confronted with an alternative viewpoint." Metacognition (META) assesses participants' understanding and performance as well as recognize areas where existing knowledge may be incomplete. Sample items for metacognition include "as I learn, I question my understanding of the new information" and "I monitor my performance on a task." Goals and beliefs (GB) assesses participants' perception of challenge as a way to grow (e.g., growth mindset). Sample items for goals and beliefs (GB) include "challenge stimulates me" and "even if frustrated when working on a difficult problem, I can push on." Epistemology (EPIST) assesses participants' belief of knowledge as an ongoing process and that learning continues to evolve. Sample items for epistemology (EPIST) include "scientists are always revising their view of the world around them" and "scientific knowledge is developed by a community of researchers."

As the ADAPT program has cohort activities grounded in the conceptual framework of Adaptive Expertise, and given the noted gap in the literature concerning levels of AE displayed by various populations, early efforts in the ADAPT program have sought to establish baseline levels of AE displayed by students. These measurements will then serve as values against which future gains can be assessed, as well as indicators of cognitive dimensions in which there is room for growth among our scholars.

Summary of Measurements of Adaptive Expertise

Given the lack of data concerning levels of Adaptive Expertise in the literature, initial efforts concerned the development of baseline data against which measurements of Adaptive Expertise could be compared. The aforementioned survey of Fisher and Peterson was deployed at Stevens Institute of Technology to measure AE levels displayed by a large cohort of first-year students. A total of n=711 first-year, typically first semester students responded to the survey of which the majority (n=647) were STEM majors.

In this initial baseline study of first-year students, AE levels were compared across gender, race, ethnicity, and income, with the following major findings:

- Women (compared to men) reported significantly higher levels of AE for three of the four AE subscales (MP, META, EPIST), whereas men reported significantly higher goals and beliefs (GB).
- White students scored statistically higher than Asian students in multiple perspectives (MP) and goals and beliefs (GB), while no statistically significant differences were observed when White and Black/African American students were compared.
- White, non-Hispanic students achieved statistically higher scores in EPIST than Hispanic students.
- Non-low-income students were observed to score higher in Epistemology (EPIST) than low-income students.

This work is described in more detail in [17].

Following this initial study of first-year students at Stevens, another study was conducted with a targeted survey aimed at measuring the adaptiveness of low-income students in STEM programs at various stages of their undergraduate degree program (not just first-year students) [18]. There are 19 eligible STEM undergraduate programs at Stevens. Low-income students were defined by Stevens' Office of Financial Aid as students whose (FISAP/FAFSA) total family income was less than $65,000. NSF S-STEM Scholarship Eligibility includes the following, the student is: 1) enrolled in an S-STEM eligible program with a cumulative GPA over 3.0; 2) has a FISAP total family income of less than $65,000; and 3) has unmet financial need.

Major findings from this second study include the following:

- No statistically significant differences in any of the AE subscales between this cohort of first-year low-income students (n=49) and the general first-year non-low-income student population from the initial baseline study (n=571) were observed. These results are consistent with those of the previous study, except for the EPIST subscale, where low-income students scored significantly lower than non-low-income students.
- Low-income women (n=88) scored significantly higher in the META subscale, as compared to low-income men (n=118), with no significant differences observed in any of the other subscales. In the previous study, women (n=249) scored significantly higher than men (n=454) in the META, MP and EPIST subscales, while men scored significantly higher than women in the EPIST subscale.
- Fourth- and fifth-year students scored significantly higher in all AE subscales except EPIST, indicating a general growth in adaptiveness as students progress through their degree program.

The first two results of this study [18] are somewhat consistent with those of the previous study [17]. The discrepancies stated above may be attributed to the smaller sample size in the second study and will be investigated further in subsequent work. It should also be noted that an interview protocol was developed

and interviews conducted with low-income students as part of [18]. Preliminary analysis of these interviews revealed that different majors at Stevens provide different metacognitive opportunities for students within that particular program. Particular reference was made to programming and design activities that inherently required self-reflection at various points in the activity. Further work to quantify themes and patterns in the interview response data will be conducted and allow us to better understand AE and its perception among students, as well as to examine activities and interventions that promote growth in the dimensions of AE.

Discussion of Results and Relevance to the ADAPT Program

In the initial baseline study [17] with a large first-year cohort, non-low-income students were observed to score higher in Epistemology (EPIST) than low-income students. This indicates a potential need to specifically focus on discussing the nature of knowledge as we develop the AE activities for our program.

From the targeted study with low-income STEM students [18], the overall growth in adaptiveness observed over the course of their program of study (cross-sectional data) is encouraging. It is unclear however whether the trend is skewed by survivor bias, where only students with higher AE levels are being retained while those with lower AE levels are leaving the program. Further work is needed to determine whether students with lower adaptiveness are at higher risk of leaving the program. Clearly however, there is the opportunity for growth along the dimensions of AE identified for this program.

This study [18] also identified differences in activities and classes taught within the various majors at Stevens that allow for growth in the dimensions of AE. This early data suggests that students in different majors may be given different opportunities to grow in these dimensions and, as such, differences in AE may be observed when students are broken down by major of study as well as along other characteristic dimensions. As the ADAPT scholars will be drawn from various majors, these programmatic differences that the scholars experience could provide useful tools for our work, and serve as the basis of discussions with, and between, students concerning AE.

Summary and Future Work

The ADAPT program theorizes that an S-STEM cohort experience, grounded in the concept of Adaptive Expertise will be effective at increasing the retention and graduation rates of our academically talented low-income students. The research elements of the ADAPT program are driven by the following research question: *Can leveraging Adaptive Expertise through our targeted cohort and mentoring activities increase the retention and graduation rates for low-income students*?

In order to address this research question, both preliminary and early work in the ADAPT program has sought to establish baseline data concerning the levels of Adaptive Expertise (AE) that are displayed by various student populations using a previously validated survey instrument. Early work has established that statistically significant differences exist in the levels of AE displayed by various student groups, as summarized here. Future work is however required to better establish the AE levels characterizing various groups of interest. In order to better understand how AE develops and changes over time, we will continue to track the AE of individual students through their undergraduate studies, as well as the AE levels displayed by our ADAPT scholars (those receiving the S-STEM Scholarship). Tracking students

over time will address one of the key limitations of our existing data, in that it does not assess possible longitudinal changes among the same sample of students.

In February 2023, 16 ADAPT Scholars were accepted into the ADAPT program and notified of their scholarships which will provide $3,000 for each semester of their remaining undergraduate studies. Early work with these scholars to introduce them to the ADAPT program has begun but activities designed to promote growth in the dimensions of AE have yet to be implemented as this project is still in its infancy. As these activities are developed and as the ADAPT scholars progress through their program of study, the ADAPT population will be required to periodically take the AE survey to track changes in their adaptiveness. This data will be then correlated with institutional data such as course grades and GPA to examine the effectiveness of ADAPT programming. Retention and completion rates will also be measured at the end of their college careers. Attitudinal and experiential feedback on the program will be collected through surveys, interviews, and focus groups.

A larger study to compare the progression of AE levels between low-income and non-low-income STEM students will also be conducted. This data will inform whether AE levels are developed at the same rate in both groups, and yield some evidence as to the effectiveness of the specialized ADAPT programming in promoting the growth of AE.

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References

[1] Hatano, G., (1990). The Nature of Everyday Science: A Brief Introduction. British Journal of Developmental Psychology, Vol. 8, pp. 245-250.

[2] Wineburg, S., (1998). Reading Abraham Lincoln: An Expert/Expert Study in the Interpretation of Historical Texts. Cognitive Science, Vol. 22(3): pp. 319-346.

[3] American Society for Engineering Education (2013). Transforming Undergraduate Education in Engineering Phase I: Synthesizing and Integrating Industry Perspectives, Arlington, VA.

[4] National Academy of Engineering (2004). The Engineer of 2020: Visions of Engineering in the New Century. National Academy Press: Washington, DC.

[5] ABET (2021). Criteria for Accrediting Engineering Programs, 2020 – 2021. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/. Accessed: Oct 21, 2022. [Online].

[6] Bransford, J., Stevens, R., Schwartz, D., Meltzoff, A., Pea, R., Roschelle, J., Vye, N., Kuhl, P., Bell, P., Barron, B., Reeves, B., & Sabelli, N. (2006). Learning Theories and Education: Toward a Decade of Synergy, in P. A. Alexander & P. H. Winne (Eds.), Handbook of Educational Psychology, pp. 209–244. Lawrence Erlbaum Associates Publishers.

[7] Pierrakos, O., Anderson, R.D., & Welch, C.A. (2016), Measuring Adaptive Expertise in Engineering Education, 123rd ASEE Annual Conference & Exposition, New Orleans, LA

[8] Peterson, P., & Fisher, F. (2001, June), A Tool To Measure Adaptive Expertise In Biomedical Engineering Students Paper presented at 2001 Annual Conference, Albuquerque, New Mexico. 10.18260/1-2--9908

[9] Ozturk, E., Yalvac, B., Johnson, M., Peng, X., Liu, K. (2015). Adaptive Expertise and its Manifestation in CAD Modeling: A Comparison of Practitioners and Students. 2015 ASEE Annual Conference & Exposition, June 14-17, Seattle, WA.

[10] Martin, T., Rayne, K., Kemp, N.J., Hart, J., & Diller, K.R. (2005). Teaching for Adaptive Expertise in Biomedical Engineering Ethics. Science and Engineering Ethics, Vol. 11(2), pp. 257-276.

[11] McKenna, A. F., Colgate, J. E., Olson, G. B., & Carr, S. H. (2006). Exploring Adaptive Expertise as a Target for Engineering Design Education. In ASME 2006 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (pp. 963-968), ASME Digital Collection.

[12] Martin, T., Baker Peacock, S., Ko, P., & Rudolph, J. J. (2015). Changes in Teachers' Adaptive Expertise in an Engineering Professional Development Course. Journal of Pre-College Engineering Education Research, 5(2), Article 4.

[13] Fisher, F. T., & De Rosa, A. J. (2021, April), A review of Adaptive Expertise and its integration within undergraduate engineering curricula Paper presented at Middle Atlantic ASEE Section Spring 2021 Conference, Virtual . https://peer.asee.org/36282

[14] Peterson, P., & Fisher, F. (2001, June), A Tool To Measure Adaptive Expertise In Biomedical Engineering Students Paper presented at 2001 Annual Conference, Albuquerque, New Mexico. 10.18260/1-2--9908

[15] Johnson, M., Ozturk, E., Johnson, J., Yalvac, B., & Peng, X. (2012). Assessing an Adaptive Expertise Instrument in Computer-aided Design (CAD) Courses at Two Campuses Paper. 2012 ASEE Annual Conference & Exposition, June 10-13, San Antonio, TX.

[16] Peterson, P., & Fisher, F. (2001, June), A Tool To Measure Adaptive Expertise In Biomedical Engineering Students Paper presented at 2001 Annual Conference, Albuquerque, New Mexico. 10.18260/1-2--9908

[17] De Rosa, A. J., Fisher, F. T., & Lytle, A. (2022, April). Measuring adaptive expertise amongst first-year STEM students. In 2022 Spring ASEE Middle Atlantic Section Conference.

[18] De Rosa, A. J., Fontaine, M. Fisher, F. T., & Lytle, A. (2022, November). Measurements of adaptive expertise among low-income STEM students. In 2022 Fall ASEE Middle Atlantic Section Conference.