The Advanced Authentic Research (AAR) program, an opportunity for high school students to engage in original research, is offered in Palo Alto Unified School District (PAUSD). This district serves 12,485 students in the heart of California’s Silicon Valley (1). The program was initiated and implemented during 2015 in the district’s two high schools (Henry M. Gunn High School with 1,939 students and Palo Alto High School with 1,994 students). These two high schools are where students from 10th-12th grades are invited to participate in the effort to connect student learning to real-world problem solving. This program strives to fulfill a mission of nurturing student interest and igniting student passion through real world, hands-on research while enabling students to explore career pathways. The program innovatively adapts Career and Technical Education foundation standards (2) in conjunction with Next Generation Science and Engineering Practice Standards (3), and PAUSD’s vision statement that: “We support all PAUSD students as they prepare themselves to thrive as global citizens in a rapidly changing world. We develop our students’ knowledge, critical thinking, and problem solving skills, and nurture their curiosity, creativity, and resilience, empowering every child to reach his or her fullest intellectual, social, and creative potential” (4). Alignment with these foundational standards paves the way for students to explore topics in a wide variety of disciplines including STEM, Humanities, Business, and Social Science fields. With this, AAR students bring passion, curiosity, and perseverance to the program.

The program was initiated during the academic year of 2014-15. It started with eleven students recommended by school teachers from Henry M. Gunn and Palo Alto High Schools collaborating with a Singapore research-based high school. These students worked on projects that focused on Biology and Chemistry. For example, students’ projects ranged from working on
identifying metabolites that exhibited anti-microbial properties to using density functional theory to study graphene as a CO (carbon monoxide) and NO (nitrogen monoxide) gas sensor. This initial project-based, collaborative learning experience was the incubator for the AAR program’s pilot year. With approval and support from PAUSD’s Board of Education during the academic year of 2014-15, the pilot program then officially started in the fall of 2015. The pilot year operated with a district coordinator and liaison at each school who dedicated one course period to development of the program. During this inaugural year, the program expanded to engage seventy-three students (33 Henry M. Gunn H. S., 40 Palo Alto H. S.) with the retention rate of 93%. In the academic year of 2016-17, the program expanded to accommodate approximately two hundred students, which also reflects forty percent of students (excluding graduating seniors) who are returning to continue their project in the following academic year. This expansion was fueled by student desire to participate in a program where student learning and real-world problem solving are synthesized in a personalized learning environment. With the support from the Special Education staff at both high schools, fourteen special education students are part of the program’s second cohort in an effort to make this learning accessible to a diverse student population.

All AAR students begin their projects with the support of a process-oriented curriculum developed by the AAR team. There is a strong need for the curriculum to be delivered through a structured course; many students will be tackling a real-world problem while engaged in authentic research praxis for the first time. More specifically, the curriculum is designed as a cumulative and mastery-based learning sequence. Each week, students are guided through the research process starting from Background Information to the Discussion in their final paper. Through the weekly meetings, the curriculum directly and indirectly engages students in a recursive research process (Fig. 1).
Figure 1. Flow Chart of Cumulative AAR Research Curriculum. The diagram demonstrates different components of research processes covered in various units throughout one academic year to cumulatively generate a final research paper.
While students engage with curriculum and instruction during weekly meetings, they are also connected with the outside mentors who use their professional and academic expertise to guide students through their projects. Combining their differentiated learning through mentor as well as their course meeting time, students typically spend 3-4 hours per week, which is equivalent to approximately 60 hours per semester. In conjunction with the weekly meetings, the program hosts two major events: Opening Social and Celebratory Showcase (Appendix A). The Opening Social serves as an opportunity for students (and parents), mentors, and PAUSD educators to network and connect as the program begins the year. This session includes networking activities, discussion of student and mentor responsibilities and expectations, as well as addressing any of their questions. The Celebratory Showcase closes the year with a final presentation of student work. This is an opportunity for students to showcase their projects and present their research to peers, parents, mentors, educators, and community members in a symposium-style event.

The AAR mentors are volunteers who choose to mentor one to two students, depending on the project(s). They serve as content experts to support and facilitate students’ work. The mentors who are bench scientists can supervise student work in labs, offices or other appropriate environments. It is acceptable to delegate supervision to a TA, Grad Student, etc., for direct interaction with the student. Suggested guidelines for student interaction are one hour per week over phone, Skype & email, one hour/ month in person check-in if applicable, and periodic email interaction, as needed. One of the expected outcomes of an online platform built using Google Sites (Fig. 2) for the mentors and the students to interact for the academic year 2016-17 also aims to provide equitable access to mentor and student interaction regardless of transportation.
availability for both parties. The general expected time commitment for the mentors is about 40-50 hours over the 7-8 months of the program, depending on the number of students.

![Advanced Authentic Research](image)

**Figure 2. Project Portal.** A mock up page of where students and mentor can interact and share their profile, correspond, write journal entries to record project related reflections, and course materials.

Providing the Advanced Authentic Research opportunity to high school students is modeled after two programs: the Student Inquiry Research program at Illinois Math and Science Academy, which is a high school program that serves as “a model learning environment that provides a framework for students to conduct original investigations on compelling questions of interest, collaborate with other students and on-campus or off-campus professionals” (5) and the Center for Authentic Practice in Education (CASPiE), which is an undergraduate research program serving as “a model to engage first and second year undergraduates in research within traditional lab courses as part of their mainstream curriculum (6).” The AAR program is similar to these two programs in terms of engaging the students in process-oriented authentic research.
However, it is different from them in the following ways: it is offered in a unified public school system; it is not subject specific; and it is available to all students (10th-12th grade) at varying academic levels and backgrounds who have passion or interest in specific areas giving them an opportunity to explore them. For example, a senior mentored by a retired English teacher systematically researched different genres of creative writing in order to generate a novel in a project titled “A creative writer looks at STEM’s Impact on What It Means to be Human,” as opposed to traditional scientific research such as the project developed by another AAR senior mentored by a biochemist completing a project titled, “Analyzing Furanone Variants for Quorum Sensing Inhibition (7).” It is also different from other programs in terms of providing structured weekly curriculum delivered by instructors typically at a 30:1 student-teacher ratio. The weekly curriculum includes curricular tools and skills that better supports students to conduct their research project including topics such as how to design a research question, how to design qualitative versus quantitative methodologies, how to write a research proposal and more (Appendix B). The program is also unique in terms of helping students explore careers while earning Career Technical Education credit through a University of California approved course. Students are paired with mentors who are experts in the field of the student's choosing. It is possible, and encouraged, for students to collaborate with one another on a given project. Mentors support and facilitate the students’ work in the mentor's lab, office, or other appropriate environment.

The curriculum discussed above is supported by the work of Burgin et al (8). The findings in their study suggest that due to the many variables involved in educational research programs (such as support the mentor provides, how much the collaboration occurs in the research environment, how much the student is allowed to contribute to the direction and design
of the research), it is important for teachers and researchers to guide the students to consider their roles carefully and engage in professional development opportunities to refine their skills at guiding and mentoring the students, which involves more than simply directing or advising (8). However, there are challenges in designing and implementing a personalized, project-based learning experience that addresses the twenty-first century skills including critical thinking, communication, collaboration, and creativity (9). While the educational movement supporting relevant twenty-first century Skills has been explored for over a decade, educators still pose important questions about how to move twenty-first century education forward. The National Education Association (NEA) has been an advocate of the twenty-first century education movement from its inception and wants to empower educators to move it forward in their own practice (9). “Despite these challenges educators face, many research findings support benefits of the high school students being engaged in research process that address the twenty-first century skills.” National Research Council (NRC) states every student conducts research on daily basis as “they confront problems with unknown solutions, observation for which underlying causes are unknown, and propositions to evaluate.” This process can be as simple as investigating why or how their car or MP3 players stop working, and as a student proposes an explanation or solution and tests it. As these students progress on to adulthood, these earlier simple research experiences that only required “a few rudimentary science skills and logical thinking, but illustrated science practices that are directly embedded in the lives of all students” could prepare them to tackle much more complicated, complex, and integrated research questions related to their careers (10). There also has been a report that suggests students engaged in research processes during high school become more aware of career options (11). Although this specific finding pertains to
scientific research, the process of scientific elements can be embedded in other areas of research, including social science and humanities.

Regardless of student research topics, integral aspects of the research process include personalized, project-based experiences that integrate knowledge and later promote communication in order to share the research finding. “Project-Based Learning (PBL) is an innovative approach to learning that teaches a multitude of strategies critical for success in the twenty-first century. Students drive their own learning through inquiry, as well as work collaboratively to research and create projects that reflect their knowledge (12).” Therefore, it brings an importance of considering 1) personalization, 2) integration of knowledge, and 3) communication when designing curriculum for a high school research program. In the study conducted by Wink et al. (13), students, who originally felt alienated from science, more specifically in chemistry, was able to overcome this alienation and increase their interest in the subject by engaging in a chemistry project in the context of topics that mattered deeply to them. The curriculum is built on the following three elements of a) personalized learning, b) integration of knowledge and process, and c) communication of research project.

**a. Personalized Learning:** As part of the application process, students share information about their area(s) of interest, their passions and their reasons for applying to the AAR program. The AAR team evaluates each application and matches the student with a mentor who is an expert in the student's chosen area. Some iteration may be necessary based on the availability of mentors in given areas.

**b. Integration of Knowledge and Process:** Most projects begin with a literature review, during which students learn what has already been covered in their chosen area and work towards formulating their research question. The next phase is to perform appropriate experiments,
collect data, and analyze this data. Students work closely with their mentor during this phase to ensure the scope is appropriate, the experiments are legitimate, and the data is valid.

c. Communication of Research Project: Developing students' communication skill is an integral part of the AAR curriculum. Students may use different forms of communication to share progress on their project. Students will have regular check-in meetings with the AAR coordinating team during their project. They will be communicating with their mentors and their peers about their work. Students are required to write a research proposal, a final paper, and to participate in the poster presentation, which is an end-of-year celebration of the program.

The Advanced Authentic Research program continues to build upon personalized learning, integration of knowledge and process, and communication of research project, and external organizations and educators are recognizing that the work of AAR could be shared and adapted. Khan Academy produced a video (14) featuring AAR as an innovation program in order to share with other educational leaders who are seeking to promote innovation at their own institutions. The AAR program may be perceived as being in a unique position and one of the first high school programs that expands the research process across disciplines at a district-wide level while learning outcomes are aligned with the CTE foundational standards (2) and NGSS practice (3) in accordance with the district vision (4). Universities are now starting to re-evaluate their admissions criteria to incorporate personalized, project-based learning. Harvard’s Graduate School of Education reported recently that many universities are finding that some of their incoming students are not genuinely exploring their passions before they get to college. These universities are also recognizing the value in students being connected to their community (15). Others are recognizing that the common admissions criteria, such as test scores, are not promoting the diverse background in their applicant pool, as well as not providing enough
information about students’ interests and ability to succeed (16). Therefore, schools and new standards are adapting in a way that students can engage in more practical and process-oriented learning experiences that prepare them to solve the problems that don’t exist yet. The AAR program strives to be aligned with the transforming educational climate. While the program is immersed in this new aspect of education, it also aims to showcase students pursuing their passions and exploring their interests.

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Literature Cited


