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The Advanced Placement (AP) program provides an opportunity for students to learn rigorous, college-level content while they are in high school. In addition, it provides financial benefit as students can earn college credit with a qualifying score on the end of course exam (Kolluri, 2018). The College Board, who designs the AP courses and exams, aims to increase both access and equity in the AP program. Consequently, in the past two decades, the number of students who take an AP course has doubled, to nearly three million (Saavedra et al., 2021). Despite recent efforts to expand both equity and access to AP courses, however, significant gaps remain in both areas. Historically, high-income schools offered more AP courses than their low-income schools. Due to dramatic financial support from federal, state, and local governments, 90% of students now attend a school offering at least one AP course (Long et al., 2019). However, gatekeeping practices such as prerequisite mathematics and science courses like chemistry, algebra II, and precalculus, create barriers to AP science courses which, in turn, yield student populations that are less diverse than introductory courses (Kolluri, 2018). Further, quality AP programs require effective teachers along with support from school and district (Long et al., 2019). In particular, given the close relationship between teachers' instructional practices and student learning outcomes (Hattie, 2012; Liou, 2021), understanding how AP courses are delivered in classrooms is imperative to better support AP teachers to implement effective teaching approaches that will promote science learning for all students from diverse backgrounds. In this regard, this review study aims to identify and characterize instructional strategies implemented in AP science courses biology, chemistry, environmental science (APES), and physics, that are featured in research articles about AP courses published for the past ten years using a systematic approach to literature review. In addition, this review aims to identify instructional strategies that are empirically supported to contribute to student learning outcomes in AP science courses. This review was guided by the following questions:

1. What are the characteristics of instructional practices utilized in Advanced Placement science courses described in research papers about AP science courses?
2. Which instructional strategies are supported by empirical evidence that positively impacts student learning in science courses?

Findings from this review will help discern not only the current status of instructional strategies, but also identify effective instructional strategies to promote student learning in AP science courses.

Methods

This systematic literature review utilized the PRISMA guideline to ensure transparency in the literature selection (Page et al, 2021).

Screening & Selection of Literature: To locate relevant literature published between 2012 and 2022, EBSCOhost's ERIC database as well as the ProQuest Education database were used with the following search terms: "Advanced placement" OR "AP" AND "science" OR "biology" OR "chemistry" OR "physics" OR "environmental" AND "teaching" OR "instruction" OR "pedagogy". Google Scholar was also used to check that all relevant articles had been found, and yielded two additional studies.The initial screening yielded 152 articles and of those, 72 duplicate articles were removed. Eighty studies were then screened for inclusion with the criteria summarized in Table 1. Snowball sampling was performed by mining the references from the

screened articles, but did not add any more inclusions. A total of 21 articles were retained for this review. The identified studies were further screened with the inclusion criteria shown in Table 1.

Table 1: *Inclusion and Exclusion Criteria*

Criterion	Inclusion (Exclusion)
Source	Peer-reviewed journals (Conference papers/proceedings, book chapters, non-peer-reviewed journals)
Language	English (Non-English)
Publication Type	Peer-reviewed article in a scholarly journal
Research focus	Instructional strategies in AP science courses
Participants	high school AP science courses (biology, physics, chemistry, and/or environmental science), and feature instructional practices which occur within the classroom.

Analysis of Selected Literature: Thematic analysis (Thomas & Harden, 2008) was used to identify patterns in instructional strategies in AP science courses in relation to the two research questions. First, initial codes were developed by reading each retained article and developing descriptive themes from frequent or common concepts. Initial codes included methodology, instructional strategy, materials, context, topic, AP course, and students. Second, the initial codes were grouped by similar elements. Lastly, these groups were arranged into categories through which emerging themes were identified. The resulting categories and codes are shown in Table 2.

Table 2: *Breakdown of Selected Papers (N=21)*

Category		# of Papers	Course		# of Papers
Diverse Learners	Marginalized Groups	1	Content Area	AP Biology	1
	Students with Disabilities	1		AP Chemistry	2
				AP Physics	1
				AP Environmental	1
Inquiry	Computer-Based	3	Content Area	AP Biology	2
	Hands-On	6		AP Chemistry	6
				AP Physics	1
				AP Environmental	0
Other Considerations	Writing	2	Content Area	AP Biology	1
	Outreach	2		AP Chemistry	6
	Flipped & PBL	2		AP Physics	1
				AP Environmental	3
	Modeling	3			

Note: The sum of papers for some characteristics is more than 21 due to papers coded with more than one category.

Findings

Characteristics of Selected Literature: Of the 21 retained articles, 15 of them pertained to AP Chemistry instruction. Of the remaining six articles, two related to AP Biology and APES each, one to AP Physics, and the remaining article applied to either AP Chemistry or APES. The abundance of AP Chemistry articles likely is related to the AP Chemistry curriculum frameworks update during the 2013-2014 school year (College Board, 2022).Fifteen of the articles were qualitative, four were quasi-experimental, one was experimental, and one was an ethnography.

Instructional Strategies in AP Science Courses: The first research question asks about the characteristics of instructional practices utilized in AP science courses. To address this question,

the following themes were extracted from the retained articles, organized into three key categories: (1) diverse learners, (2) inquiry, and (3) other considerations.

Diverse Learners: Two of the articles addressed the special populations of students, students historically marginalized in science fields, and students with disabilities. Howard et al. (2013) recommended five strategies to help ensure students with disabilities are as successful in AP science courses as their non-disabled peers. AP Chemistry focusing on social justice science issues (SJSI) impacted students and their views about the impact of science on society as well as their role as scientists in society (Morales-Doyle, 2017).

Inquiry: Nine of the retained articles described a wide range of guided inquiry and hands-on activities that take place in the classroom. Some of the activities engaged students in online simulations or platforms, while others were more traditional hands-on experiments.

Computer-Based Lessons: Using a bioinformatics database, students examined the different protein structures found on viruses (Anderson & Wilch, 2021). Pyatt (2014) conducted a quasi-experimental study to examine the effectiveness of a specialized software package compared to explicit instruction on understanding of reaction types in AP Chemistry. Lastly, Matsumoto (2014) found that a computer algebra system helps teach chemistry concepts to students who have weak mathematics backgrounds.

Hands-On Activities: In the only article about hands-on activities in AP Biology, Johnson and Lark (2018) described a learning cycle for natural selection utilizing a guided-inquiry experiment followed by an online simulation. McManus, J. (2017) used an apparatus that hangs from the ceiling, from which AP Physics students took measurements and made calculations about Gauss's Law. The four articles related to AP Chemistry (Carraher et al., 2016; Sattsangi, 2014; Benigna, 2014; and Lanni, 2014) generally described unique approaches using specialized apparatus, such as a portable spectrophotometer, or household materials, such as vinegar and baking soda.

Other Considerations*:* Articles in this category described or evaluated instructional strategies that spanned an entire course or a portion of the course beyond just one activity or instructional unit. Additionally, some of these articles present extensions of the curriculum that go beyond the classroom.

Writing in the Content: Two of the retained articles focused on writing as a means of engagement and assessment. Crumley and DeJarnette (2022) incorporated both argumentative and creative writing into a unit about momentum in AP Physics. Similarly, Putti (2011) utilized the Science Writing Heuristic (SWH) as an alternative approach to a traditional lab report in AP Chemistry.

Outreach and Interactions with STEM Professionals: Two articles described programs that bring STEM professionals into the classroom. Schiffer et al. (2020) described the sequence of a three-day Microplastics Outreach Program, which engaged students in learning about both the chemistry of plastics, as well as the environmental impact of plastics. Ware et al. (2019) examined approach to outreach by bringing STEM professionals into the classroom to model a research approach with students.

Flipped Classroom and Project-Based Learning: Project-Based Learning (PBL) and the Flipped Classroom are two instructional strategies that have demonstrated some success in the classroom. In a quasi-experimental study comparing the PBL approach to a traditional approach in a unit about world hunger in APES, the PBL classroom showed marginal gains (Sahabi et al, 2018). The flipped classroom model by Schultz, D. et al. (2014) relied on students watching video or taking notes at home, freeing up time to engage in more discussions and activities during class.

Modeling & Representations: The final three articles in this search addressed the use of representations and models to teach AP Chemistry, addressing a key focus of the revised curriculum frameworks. The Data First approach described by Nichol et al. (2014) engaged students with data prior to teaching the concepts. Particulate models (Pentecost et al., 2016) and the Chemistry Modeling Curriculum (CMC) (Posthuma-Adams, 2014) are similar pedagogical approaches which focus on conceptual understanding, reasoning, and critical thinking skills using various forms of representations.

Effective Instructional Strategies for Student Learning in AP Science Courses: The second research question examined the most prevalent instructional practices supported by empirical evidence that has positive impacts on student learning. Only five of the selected articles were experimental or quasi-experimental and evaluated the effectiveness of the instructional strategy. The Data First approach (Nichol, 2014), modeling diagrammatically or using software (Pentecost, 2016; Pyatt, 2014), the flipped classroom (Schultz, 2014) and PBL (Sahabi, 2018) all showed positive learning gains on teacher-made assessments, although the gains were statistically insignificant for Sahabi et al. (2018). Furthermore, the impact of instructional strategy on student learning is mostly measured by self-reported data from either students or teachers (e.g. Putti, 2011; Crumley & DeJarnette, 2022). Consequently, very little is known regarding how effective the reviewed strategies are at improving student learning. Only one of the included articles (Morales-Doyle, 2018) employs instructional practices that address equity, access, and culturally relevant teaching practices, which focus on the learning of Latinx and African-American students' experiences.

Discussion & Implications

This systematic literature review provides an overview of current instructional practices in AP science classes. There has been a clear shift toward science practices away from acquisition of factual knowledge in the redesign of each of the AP science course curriculum frameworks (College Board, 2022). In accordance, AP science courses come to utilize a variety of instructional practices, including simulations, writing, modeling, and data-focused investigations, focusing more on science communication and reasoning skills in AP courses (Long et al., 2019). This trend is well aligned with the finding of this review in that instructional strategies in AP science courses presented in the selected articles center on diverse learners, inquiry, and some innovative teaching approaches including PBL and SWH.

With the rapid expansion of the AP program over the past several years, AP courses are increasingly diverse. However, African-American and Latinx students remain least represented in AP science and math courses (Kolluri, 2018). A key challenge of access and effectiveness for students from historically marginalized backgrounds is for teachers to utilize culturally relevant pedagogy (Kolluri, 2018). The ethnography by Morales-Doyle (2017) is an excellent example of research that describes student outcomes, while also addressing the unique needs of teaching a diverse AP student population.

Inquiry-based teaching is the most prevalent strategy found in this review, and is generally viewed as the hallmark for teaching science (Hayes et al., 2016). However, Liou (2021) found that many studies about inquiry-based teaching revealed conflicting results of its impact on learning outcomes, largely stemming from ambiguity about the definition of inquiry, and teachers' ability to facilitate such activities. While the AP frameworks encourage inquiry-based activities, many teachers do not feel prepared to teach using this approach (Long, 2019), and they often need to be explicitly taught to teachers to ensure positive student outcomes (Margot & Kettler, 2019). In order to gain necessary support from administrators with planning

time, resources, and professional development (Margot & Kettler, 2019) there is a need for empirical research to identify effective instructional strategies that have positive impacts on student learning.

The College Board (2022) developed PBL based learning units for APES. Early research suggests that PBL has potential not only to improve results on the AP exam, but also to increase long-term retention of material (Saavedra et al. 2021). Although Sahabi et al. (2018) reported that the learning gains were not statistically significant, the student work product of a poster in the PBL group demonstrated a more nuanced and detailed understanding of the content, suggesting deeper learning with this approach. In this regard, further empirical examination of the learning impacts of PBL in APES, and potentially other AP science courses, creates a promising area for potential research.

This review offers an idea of instructional practices utilized in AP science courses. However, there is little insight into which practices have positive impacts on student learning. In order to improve teaching and learning in AP sciences, teachers should know what instructional strategies are most effective. The best way to determine which strategies work is from empirical research studies involving the collection of objective qualitative and quantitative data. In this way, relevant research on instructional strategies can drive high quality, innovative instruction in schools, leading to positive student outcomes. In this way, researchers and educators will contribute to the current body of knowledge the instructional strategies that have positive (and negative) impacts on student learning, achievement, and attitudes toward science.

Conclusions

The lack of empirical studies on the impact of instructional strategies on student outcomes across a variety of student and school contexts, highlights gaps in the literature, and calls for more research effort in this area. Taken together, this research synthesis contributes to the interest of NABT members in that it provides insights and directions for future research on instructional strategies in AP science courses in order to inform science instruction, teacher training, and professional development.

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