Effect of an Online, Inquiry- & Mentor-Based Laboratory on Science Attitudes of Students in a Concurrent Enrollment Biology Course: The PlantingScience Experience

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RESEARCH ON LEARNING

Effect of an Online, Inquiry- & Mentor-Based Laboratory on Science Attitudes of Students in a Concurrent Enrollment Biology Course: The PlantingScience Experience

ELIZABETH A. DESY, CATRINA T. ADAMS, TERESA MOURAD, SCOTT PETERSON

Abstract

The goal of this project was to determine the impact of supplementing a concurrent enrollment (CE; also called dual enrollment) nonmajors biology course with online mentoring from professional scientists via the PlantingScience (PS) program (http://plantingscience.org). Student attitudes and motivation toward science were measured using the Test of Science-Related Attitudes (TOSRA) questionnaire as well as open-ended questions. Students in both the experimental group (CE biology course supplemented with PS) and the control group (CE biology course with no PS supplement) were surveyed during two academic years (2015–2017). The impact of PlantingScience on students' attitudes toward science is discussed.

Key Words: *concurrent enrollment; PlantingScience; student attitudes and motivation.*

○ Introduction

For over a decade, studies have documented the benefits to students of inquiry-based, undergraduate research experiences in science (Lopatto, 2004; Hunter et al., 2007; Russell et al., 2007; Seymour et al., 2004). Informed by these studies, the nationally prominent report *Vision and Change in Undergradutate Biology Education* (AAAS, 2011) calls for changes in undergraduate biology curricula that better align the teaching of science with the practice of science. One key action strongly advocated by *Vision and Change* is to provide more inquiry-rich, investigative experiences for students in introductory biology courses.

In addition to providing students opportunities to learn biology by direct experience with the methods and processes of scientific inquiry (National Science Foundation, 1996), authentic research experiences may have broader effects. For example, Lopatto (2007) reported that undergraduates experience gains in independence and motivation to learn after an undergraduate research experience. More recently, Brownell et al. (2012) found that undergraduates in research-based biology labs that feature open-ended questions with no predetermined results had higher self-confidence in performing lab-related tasks and more positive attitudes toward authentic research compared with students in a cookbook laboratory course. Thus, research opportunities that allow students to experience the process of science appear to stimulate students' curiosity, improve their critical-thinking skills, and increase their confidence and motivation (Lopatto, 2004; AAAS, 2011).

A key component of a high-quality undergraduate research experience is the faculty mentor who plays a significant role in guiding students through all aspects of the scientific process (Russell et al., 2007). For example, Hunter et al. (2007) found that the student researcher–mentor interaction was critical in helping students think and work like a scientist in addition to increasing student interest in pursuing a STEM career. Thus, mentors can have a positive effect on student learning and career choice (National Research Council, 2003).

Authentic research experiences for students taking concurrent enrollment (CE) courses (i.e., credit-bearing college courses taught in high schools by college-approved high school teachers) may be more limited than for students taking the same courses on a college campus. CE courses are increasingly popular among high schools, particularly in rural school districts, as they provide students the opportunity to take college-level courses while still in the familiar surroundings of their high school (NACEP, 2017). Since high school is a time when 15–24% of students shift their interest into or away from potential STEM careers (Sadler et al., 2012), it is imperative to provide students with experiences that may draw them to STEM fields after high school. Opportunities to provide students enrolled in CE STEM courses with authentic research experiences may be especially important, yet challenging, for students in rural school districts where resources – including exposure to career scientists and college faculty – may be more limited.

One international resource that may alleviate this challenge is PlantingScience (PS), a free online resource for teachers and schools (https://plantingscience.org). PS offers a unique opportunity for teachers and administrators to provide inquiry experiences for their students by connecting volunteer scientists to small student teams

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for student-centered research projects. It provides nine different investigation themes on big ideas in plant biology to focus students' investigations. Student team members and their scientist mentor communicate asynchronously. Each team's project page provides areas for investigation information (e.g., research question, methods, conclusion), file sharing, and a blog-style conversation area. Teachers can monitor and contribute on all of their teams' project pages. An early-career scientist is assigned to each teacher in a liaison role to help set up and manage the teams' projects and to step in if a mentor is temporarily unavailable. Scientist mentors employ an array of scaffolding techniques. The interplay of the techniques they use models the integration of science content and practice and enculturates students to the science community (see Adams & Hemingway, 2014). Through the PS experience, students have an opportunity to work like real scientists with their scientist mentors, enhancing their team skills and their understanding of science.

No previous studies have examined the effects of an online, authentic research experience on attitudes of CE students in an introductory biology course. The purpose of this study was to determine the impact of an online, inquiry- and mentor-based research experience, offered via PS, on students' attitudes toward science.

○ Methods

Our study focused on students enrolled in CE sections of an introductory nonmajors biology course (BIOL 100) offered by Southwest Minnesota State University (SMSU). High school teachers taught the CE course under the direction and mentorship of an SMSU tenured professor of biology. All high school students enrolled in the CE BIOL 100 course were either juniors or seniors. CE students are not a random sample of all high school students. Rather, SMSU requires seniors to have a 3.0 GPA and to be ranked in the top 50% of their class; juniors must have a 3.0 GPA and be ranked in the top third.

All CE students in this study were from rural school districts (i.e., local population <25,000). Five rural Minnesota high schools participated in the PS mentoring program (the experimental group). Another four high schools, also rural, served as controls – that is, their students did not participate in the PS program but did complete the Test of Science-Related Attitudes (TOSRA) survey (described below).

Both the experimental and control students conducted a seed germination experiment as part of their laboratory experience. The PS project students worked on the "Wonder of Seeds" seed germination and growth investigation theme, with a focus on seed ecology. This theme required students to propose their own hypothesis regarding seed germination, to design and conduct an experiment to test their hypothesis, to collect and analyze data, and to draw conclusions based on their data. This process was done in consultation with their PS scientist mentor. Students worked in small groups of two to four, with each group being assigned a PS online mentor. The control group of students also did a seed germination lab in which they developed their own hypothesis. The lab did not have a predetermined outcome (i.e., it was not a cookbook lab). The control students, however, lacked the intensive consultations with a mentor as they worked through developing their hypothesis, designed their experiment, and collected and analyzed data.

Throughout the PS project, students in the experimental group posted information to the PS website and communicated asynchronously online with professional biologists who served as mentors offering feedback and encouragement. No information was posted to the PS website that would identify any of the students as participants in a research study.

We used a modified version of the TOSRA questionnaire (called TOSRA 2; see Ledbetter & Nix, 2002; available at http://www.chemchapterzero.com/pdfs/AppendixJ1.pdf) to measure seven distinct science-related attitudes called "scales." The seven scales were Social Implications of Science, Normality of Scientists, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science.

The TOSRA pretest was given prior to the beginning of the PS project for the experimental group and prior to the seed germination lab for the control group. The TOSRA posttest was given within a week of the end of the PS project for the experimental group and at the end of lab exercises for the control group (7–10 weeks). The PS project was conducted over a period of 6–8 weeks in fall 2015 and repeated with different students in spring 2017.

In addition to the TOSRA, we administered an open-ended questionnaire in spring 2017 only to students who participated in the PS program. The intent of the questionnaire was to gather qualitative summative data from students that would augment the quantitative survey data that we collected. The six open-ended questions can be found in Table 1.

Four orientation-like webinars were developed by Desy, Adams, and Mourad for high school teachers participating in PlantingScience. The webinars included a discussion of (1) the logistics of the PS program; (2) what students should be able to do, know, and value at the end of the experience; and (3) an article related to practicing scientific inquiry by Ebert-May et al. (2004). The final webinar was used to debrief, reflect on what worked and what did not, the impact of PlantingScience on students, and ways to improve the program.

○ Results

TOSRA scores were computed for each of the seven attitude scales for both the pretest and posttest, and for students in both the control group and experimental group. Each TOSRA scale contains 5 items with Likert-style responses (1 = strongly disagree, 5 = strongly agree, negatively worded items reverse-coded). Thus, scores on each scale can range from 5 to 25, with higher scores more supportive of the concept measured by the scale. A score of 15 represents the neutral point on each scale. A total TOSRA score was also computed for each student by summing the seven scale scores, yielding a measure that ranges between 35 and 175, with a score of 105 representing an overall neutral attitude about science. Data were included in the analysis only for students who completed both the pretest and posttest (45 control group students and 129 experimental group students). Mean scores for these students on the seven TOSRA scales are shown in Figure 1. Pretest scale scores for both the control and experimental groups were two to four points above neutral for all scales except Leisure Interest in Science.

A 2 × 2 mixed-design ANOVA was conducted for each of the seven TOSRA scales as well as the total TOSRA score. The between-subjects factor was Group (experimental vs. control) and

Table 1. Summary of student responses (N = 69 students) to open-ended questions regarding participation in the PlantingScience (PS) program.

Questions	Student Responses
Describe your experience with PlantingScience.	54% of students reported a positive experience, 34% neutral, 12% negative. Sample student comments: • "It was not very helpful. My mentor was not much help so posting things was kind of a waste of time." • "My experience was good. I learned a lot about how to work with a group and how to conduct my own experiment and to do research."
What did you learn about doing science that you didn't know before your PS project?	Sample student comments: • "I learned that even if your experiment doesn't support your hypothesis, you still learn valuable information." • "Science is a lot of work – it isn't as easy as one may think."
Do you think more like a scientist in your daily life after the PS research project?	27% of students indicated they did, 63% did not, 10% not sure. Sample student comments: • "I feel like I do because I analyze things more and think about things that could affect the outcome." • "Sort of, I don't think it changed my daily life, but (it) will help in future science courses."
Did participating in the PS project make you more or less interested in pursuing science as a career?	54% of students said PS did not change their interest in science, 34% indicated increased interest, 11% indicated decreased interest. Sample student comments: • "It made me a little more interested because it would be an interesting job to learn more about the world. I also realized that experiments can be a fun experience." • "I do want to pursue a career in science, but not in biology. This project really solidified that for me."
Did working with the PS mentor change your ideas about scientists?	Sample student comments: • "It is comforting to see that scientists grow attached to their studies and do not simply view everything as data." • "I think that they are busy people because they didn't respond as much as I expected them to."
Are you interested in taking another science course that involves an experiment?	Sample student comments: • "Yes, because I think doing science experiments to figure things out is fun and better than just being told about things all the time." • "Depends on the type of experiments."

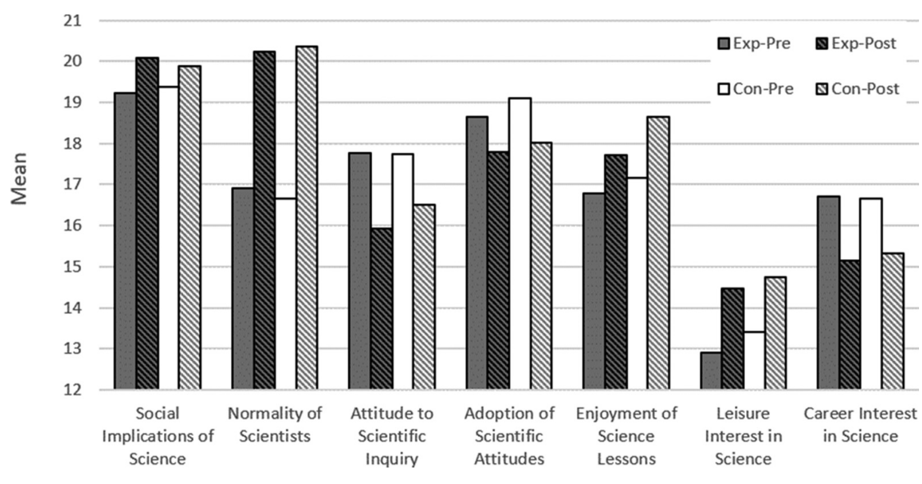

Figure 1. Mean scores on TOSRA scales for control and experimental groups measured at pretest and posttest.

the within-subjects factor was Time (pretest vs. posttest). A significance level of 0.05 was assumed for all tests. None of the Group main effects was found to be significant, and thus the experimental and control groups are combined in the results reported below except where noted otherwise. A significant main effect of Time was found for all scales, in some cases representing an increase in scores from pretest to posttest and in other cases a decrease (see below). However, there were no significant interactions between Group and Time, suggesting that both groups exhibited similar changes in science attitudes by simply being enrolled in BIOL 100.

A significant *increase* from pretest to posttest was found for four of the TOSRA scales: Social Implications of Science ($F_{1,172} = 18.11$, $P < 0.0001$), Normality of Scientists ($F_{1,172} = 277.02$, $P < 0.0001$), Enjoyment of Science Lessons ($F_{1,172} = 24.77$, $P < 0.0001$), and Leisure Interest in Science ($F_{1,172} = 45.14$, $P < 0.0001$). There was also a significant *increase* in total TOSRA score from pretest to posttest (pre M = 119.22, post M = 121.93; $F_{1,172} = 11.06$, $P = 0.001$). A significant *decrease* from pretest to posttest was found for the other three TOSRA scales: Attitude to Scientific Inquiry ($F_{1,172} = 45.09$, $P < 0.0001$), Adoption of Scientific Attitudes ($F_{1,172} = 21.08$, $P < 0.0001$), and Career Interest in Science ($F_{1,172} = 42.51$, $P < 0.0001$).

Further analysis was performed to examine the amount of attitude change for students with differing attitudes toward science at the beginning of the class. Students (experimental and control combined) were divided into the following three groups based on their pretest total TOSRA score: Low TOSRA (62–110, n = 55), Medium TOSRA (111–124, n = 56), and High TOSRA (125–163, n = 63). Mean pretest and posttest scores for each of these three groups are shown in Figure 2. A 3 × 2 mixed-design ANOVA was conducted with TOSRA Group (Low, Medium, and High) as between-subjects factor and Time (pretest vs. posttest) as within-subjects factor. Results indicated significant main effects for both TOSRA Group ($F_{2,171} = 204.22$, $P < 0.0001$) and Time ($F_{1,171} = 11.23$, $P < 0.001$). The interaction between TOSRA Group and Time, however, did not reach significance.

Follow-up pairwise comparisons revealed significant pretest to posttest gains in total TOSRA score only for the Low and Medium TOSRA groups (again, experimental and control combined). The lack of improvement for the High TOSRA students could possibly be explained as a ceiling effect, as these students already had quite positive attitudes toward science at the beginning of the semester.

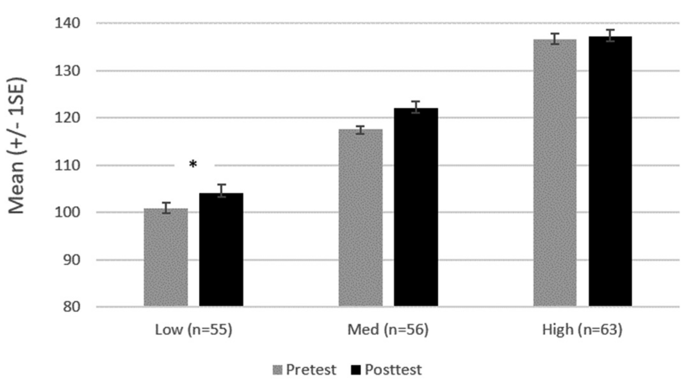

Figure 2. Mean total TOSRA scores at pretest and posttest for students in the Low, Medium, and High groups.

To supplement the TOSRA data, students in the experimental group only were asked to respond, in writing, to six open-ended questions (Table 1). Although student responses varied, their experience with their PS mentor and the difficult nature of science in conducting experiments were specifically noted. Also worth noting is that of the students who scored their experience with PS as neutral or negative, 50% specifically mentioned experiencing difficulties with their mentor.

Student responses to some of the open-ended questions appeared to be contrary to TOSRA results. For example, 88% of students gave a positive or "same" response to the open-ended question about their interest in science as a career (Table 1) while pre-to-post TOSRA results indicated a significant decrease in science career interest.

High school teachers who participated in the PS project were asked to provide written self-reflections regarding the impact of the PS experience on their students. Teachers' comments were positive regarding the nature and type of impact that PS participation had on their students:

- "Students took more ownership and pride in their respective research projects because of the mentors."
- "With the science mentors, my students had better research ideas than ever before."
- "Mentors were helpful to teachers as they gave students more help than just the high school teacher."
- "PS is a great way to bring scientists into the classroom when exposure to outside, career scientists is limited."
- "More than the inquiry part of PS, the biggest impact on students was mentoring by scientists."
- "Many of my students gained insight into what research and science really is."
- "The communication piece was a major benefit that PS provided."
- "PS experience helped students with answering questions on the ACT."
- "Students learned team-building and communication skills."

Table 2. High school teacher comments regarding the impact on students of participating in the PlantingScience program.

• Students took more ownership and pride in their respective research projects because of the mentors.
• With the science mentors, my students had better research ideas than ever before.
• Mentors were helpful to teachers as they gave students more help than just the high school teacher.
• PS is a great way to bring scientists into the classroom when exposure to outside, career scientists is limited.
• More than the inquiry part of PS, the biggest impact on students was mentoring by scientists.
• Many of my students gained insight into what research and science really is.
• The communication piece was a major benefit that PS provided.
• PS experience helped students with answering questions on the ACT.
• Students learned team-building and communication skills.

○ Discussion

None of the seven TOSRA attitude scales used in this study was significantly different between control and PS-experience students from pretest to posttest. Students who participated in BIOL 100 (both with the PS mentoring experience and without) exhibited similar changes in science attitudes. Overall, attitude changes as measured by total TOSRA scores were significantly positive in both experimental and control groups.

Since we found no difference between PS experimental and control students, we combined student responses and found a significant increase from pretest to posttest for Social Implications of Science, Normality of Scientists, Enjoyment of Science, and Leisure Interest in Science scales. This finding is consistent with previous studies (Osborne et al., 2003) that found quality of teaching to be a significant determinant of student attitudes toward science. CE teachers (both PS-experimental and control) in this study may have motivated their students through their own motivation and enthusiasm for teaching a college-level course.

TOSRA results in control and experimental groups combined showed a significant decrease in three scales: Attitude to Scientific Inquiry, Adoption of Scientific Attitudes, and Career Interest in Science from pretest to posttest. Interpreting this result is difficult. Osborne et al. (2003) suggest that qualitative methodologies such as open-ended questions may give more insight into student attitudes than quantitative measures alone. When asked to respond to open-ended questions to provide context for the TOSRA response, students in the 2017 experimental group expressed frustration at times with their experiments and mentors and/or uncertainty associated with not getting the "right answer" (R. Stensvad, personal communication). Students also expressed the sentiment that "science is hard," and while they wanted to still pursue a career in science, they did not want to do experiments. These data may indicate that high school teachers need to be more intentional in helping students understand the role of experimentation in science career options.

TOSRA scores alone may not accurately reflect the impact of the PS learning experience on student attitudes and motivation. For example, 54% of students in 2017 reported a positive PS experience on open-ended questions (Table 1), whereas TOSRA results showed a significant *decrease* from pretest to posttest on the Attitude to Scientific Inquiry scale for the experimental group. Interestingly, students who reported a neutral or negative PS experience in the open-ended questions specifically mentioned problems with their mentor and were predominantly enrolled in a class where mentor matches were made after students had already developed their research question and were beginning experiments. Thus, timing of mentor interactions as well as teacher and PS mentor attitudes at the beginning and during the research experience may be a key, yet overlooked, factor in influencing student attitudes. In their study of factors that affect student attitudes toward biology, Rogers and Ford (1997) concluded that teachers (and ostensibly PS mentors in this study) need to be aware of students' attitudes toward the subject matter and the effect teachers have on students' attitudes. Indeed, in this study, students who expressed a neutral/negative attitude toward scientists in open-ended questions seemed to also perceive a lack of interest or adequate communication on the part of their PS mentor, possibly because of the aforementioned truncated interaction.

High school teachers indicated that the orientation webinars provided to them in the first year of the study were helpful. However, since the same teachers participated in the second year of the study, the webinars were not offered again. In retrospect, it may have been desirable to provide a forum for teachers to discuss their own experiences with one another, all of which were generally positive, as well as their students' experiences throughout the PS project. Judging from the teachers' comments quoted above, they may have observed a greater impact on their students than the students themselves realized.

It is important to acknowledge the limitations of this study, particularly with regard to the control group of students. As Lopatto (2004) laments, finding a control group for in situ studies of undergraduates that is like the treatment group in all respects except the treatment is challenging. Small sample sizes are a common feature of rural school districts such as the ones involved in this study. It is unfeasible to randomly assign students in a small class to a control group that is deprived of the treatment (in this case, the PS experience). In spite of the limitations of having a quasi-control group, our overall positive results for the experimental group may incentivize high school teachers to adapt this model as part of their curriculum, regardless of whether or not it is part of a CE program. Patterns of student attitudes may thus emerge from a larger number of high schools adopting mentor- and research-based biology laboratories such as those provided by PlantingScience.

Finally, our data indicate that to maximize the impact of the PS experience on students' attitudes, two conditions must be met. First, PS teachers must allow sufficient time for mentor interaction, and mentors must be actively engaged and communicate frequently with students throughout the experiment. To do otherwise appears to negatively affect student motivation and attitudes. Secondly, teachers may need to be more intentional in frequently and explicitly explaining the relevance of the PS experience to students, because establishing relevance may be an effective way to motivate student learning (Kember et al., 2008). Teachers should not only emphasize the gains in disciplinary content knowledge as a result of the PS experience, but also gains in skills such as communication, problem solving, data analysis, and the ability to apply knowledge and skills in real-world settings and science careers.

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References

Adams, C.T. & Hemingway, C.A. (2014). What does online mentorship of secondary science students look like? *BioScience*, *64*, 1042–1051.

AAAS (American Association for the Advancement of Science) (2011). *Vision and Change in Undergraduate Biology Education: A Call to Action*. Retrieved from http://visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf.

Brownell, S.E., Kloser, J.M., Fukami, T. & Shavelson, R. (2012). Undergraduate biology lab courses: comparing the impact of traditionally base “cookbook” and authentic research-based courses on student lab experiences. *Journal of College Science Teaching*, *41*(4), 36–45.

Ebert-May, D., Williams, K.S., Weber, E.P., Hodder, J. & Luckie, D. (2004). Practicing scientific inquiry: what are the rules? *Frontiers in Ecology and the Environment*, *2*, 492–493.

Hunter, A.-B., Laursen, S.L. & Seymour, E. (2007). Becoming a scientist: the role of undergraduate research in students’ cognitive, personal, and professional development. *Science Education*, *91*, 36–74.

Kember, D., Ho, A. & Hong, C. (2008). The importance of establishing relevance in motivating student learning. *Active Learning in Higher Education*, *9*, 249–263.

Ledbetter, C.E. & Nix, R.K. (2002). [Adapted from Fraser, B.J. (1981)] Test of Science-Related Skills. Hawthorn, Australia: Australian Council for Educational Research.

Lopatto, D. (2004). Survey of undergraduate research experiences (SURE): first findings. *Cell Biology Education*, *3*, 270–277.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education*, *6*, 297–306.

NACEP (National Alliance of Concurrent Enrollment Partnerships) (2017). What is concurrent enrollment? Retrieved from http://nacep.org.

National Research Council (2003). *BIO 2010: Transforming Undergraduate Education for Future Research Biologists*. Washington, DC: National Academies Press.

National Science Foundation (1996). *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*. Washington, DC: National Science Foundation.

Osborne, J., Simon, S. & Collins, S. (2003). Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, *25*, 1049–1079.

Rogers, W.D. & Ford, R. (1997). Factors that affect student attitude toward biology. *Bioscene*, *23*(2), 3–5.

Russell, S.H., Hancock, M.P. & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science*, *316*, 548–549.

Sadler, P.M., Sonnert, G., Hazari, Z. & Tai, R. (2012). Stability and volatility of STEM career interest in high school: a gender study. *Science Education*, *96*, 411–427.

Seymour, E., Hunter, A.-B., Laursen, S.L. & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates: first findings from a three-year study. *Science Education*, *88*, 493–594.

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