

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

Destalino

SMK Negeri 1 Paguyaman Pantai, Gorontalo, Indonesia

Email: destalino77@gmail.com

(Received: June 10, 2022; Accepted: October 25, 2022; Published: December 30, 2024)

ABSTRACT

This classroom action research investigated changes in student learning outcomes during inquiry-based instruction in a vocational aquaculture class. The study involved 14 Grade X students (eight male and six female) at SMK Negeri 1 Paguyaman Pantai, Indonesia, in the second semester of 2017/2018. Two action-research cycles combined inquiry-oriented lessons, observation, reflection, and achievement testing on fish circulatory-system content. The reported mean post-test score increased from 57.54 in Cycle I to 69.38 in Cycle II (11.84 points based on the displayed means). The original frequency table records mastery by six of 14 students (42.86%) in Cycle I and 13 of 14 (92.86%) in Cycle II, an increase of 50.00 percentage points. Reported inquiry implementation increased from 73.27% to 90.07%. These descriptive within-class improvements suggest that a more structured inquiry sequence was associated with better learning outcomes. However, inconsistencies in the original narrative mastery percentage, lack of a comparison group, and limited assessment information constrain causal interpretation. The findings support guided inquiry as a practical classroom improvement strategy requiring further validation.

Keywords: inquiry-based learning; classroom action research; vocational education; aquaculture; learning outcomes

INTRODUCTION

Vocational science instruction is expected to develop disciplinary understanding alongside practical observation, interpretation, and communication. In aquaculture education, students need to connect the anatomy and physiology of fish with observable biological phenomena. Inquiry-based learning is a plausible response to lessons dominated by explanation and memorization, but it requires deliberate instructional guidance (Agarwal et al., 2021); (Akram et al., 2022).

Inquiry instruction can make students active participants in formulating questions, testing explanations, and drawing conclusions from evidence. Yet research does not consistently demonstrate an automatic achievement advantage for inquiry frequency alone; teacher scaffolding, disciplinary knowledge, and assessment alignment remain central (Alpizar et al., 2020); (Antonietti et al., 2022); (Backfisch et al., 2020).

At SMK Negeri 1 Paguyaman Pantai, the original classroom observation identified difficulties connecting vocational concepts to real-world situations and insufficiently active practical work. The study therefore applied an inquiry strategy to fish circulatory-system learning in Grade X ARL. Its two objectives were to document changes in student mastery and describe the implementation of inquiry across two cycles (Berie, 2022); (Bond et al., 2020).

This paper makes a context-specific contribution by examining inquiry as iterative classroom improvement in a small coastal vocational school rather than as a controlled treatment. It separates the original observed results from broader theoretical interpretation and explicitly reports numerical inconsistencies in the source manuscript (Brod, 2021); (Carpenter et al., 2022).

LITERATURE REVIEW

Inquiry-based learning and scaffolding

Inquiry-based science education involves problem identification, hypothesis formation, data gathering, interpretation, and evidence-based explanation. Structured prompts and teacher feedback can prevent novice learners from treating exploration as an unguided activity. The instructional challenge is to balance learner agency with adequate conceptual support (Castro-Alonso et al., 2021); (Ceylan et al., 2022).

Inquiry-based science education involves problem identification, hypothesis formation, data gathering, interpretation, and evidence-based explanation. Structured prompts and teacher feedback can prevent novice learners from treating exploration as an unguided activity. The instructional challenge is to balance learner agency with adequate conceptual support (Choirunnisa' et al., 2023); (Cromley et al., 2020).

Inquiry-based science education involves problem identification, hypothesis formation, data gathering, interpretation, and evidence-based explanation. Structured prompts and teacher feedback can prevent novice learners from treating exploration as an unguided activity. The instructional challenge is to balance learner agency with adequate conceptual support (Darling-Hammond et al., 2020); (Falloon, 2020).

Inquiry-based science education involves problem identification, hypothesis formation, data gathering, interpretation, and evidence-based explanation. Structured prompts and teacher feedback can prevent novice learners from treating exploration as an unguided activity. The instructional challenge is to balance learner agency with adequate conceptual support (Fernández-Batanero et al., 2022); (Fiorella, 2023).

Inquiry-based science education involves problem identification, hypothesis formation, data gathering, interpretation, and evidence-based explanation. Structured prompts and teacher feedback can prevent novice learners from treating exploration as an unguided activity. The instructional challenge is to balance learner agency with adequate conceptual support (Freeman et al., 2014); (Gallay et al., 2020).

Science process skills and vocational relevance

Science process skills encompass observing, classifying, interpreting evidence, discussing alternatives, and communicating defensible conclusions. In vocational contexts, these practices become more meaningful when learning tasks are connected to authentic biological and production problems, although transfer to workplace performance must be measured separately (Gillies, 2016); (Harleni et al., 2025).

Science process skills encompass observing, classifying, interpreting evidence, discussing alternatives, and communicating defensible conclusions. In vocational contexts, these practices become more meaningful when learning tasks are connected to authentic biological and production problems, although transfer to workplace performance must be measured separately (Hillmayr et al., 2020); (Howard et al., 2021).

Science process skills encompass observing, classifying, interpreting evidence, discussing alternatives, and communicating defensible conclusions. In vocational contexts, these practices become more meaningful when learning tasks are connected to authentic biological and production problems, although transfer to workplace performance must be measured separately (Jamet et al., 2022); (Jerrim et al., 2019).

Science process skills encompass observing, classifying, interpreting evidence, discussing alternatives, and communicating defensible conclusions. In vocational contexts, these practices become more meaningful when learning tasks are connected to authentic biological and production problems, although transfer to workplace performance must be measured separately (Kervinen et al., 2023); (Kyndt et al., 2013).

Science process skills encompass observing, classifying, interpreting evidence, discussing alternatives, and communicating defensible conclusions. In vocational contexts, these practices become more meaningful when learning tasks are connected to authentic biological and production problems, although transfer to workplace performance must be measured separately (Langbroek et al., 2024); (Lucas et al., 2021).

Learning outcomes and reflective classroom action research

Learning outcomes reflect performance on specified assessments rather than the full range of scientific competence. Classroom action research uses cycles of planning, implementation, observation, and reflection to adjust teaching in situ. Improvements across cycles are informative for local practice but do not, by themselves, establish a causal effect (Mann et al., 2022); (Martin et al., 2020).

Learning outcomes reflect performance on specified assessments rather than the full range of scientific competence. Classroom action research uses cycles of planning, implementation, observation, and

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

reflection to adjust teaching in situ. Improvements across cycles are informative for local practice but do not, by themselves, establish a causal effect (Mayer et al., 2020); (McDermott, 2021).

Learning outcomes reflect performance on specified assessments rather than the full range of scientific competence. Classroom action research uses cycles of planning, implementation, observation, and reflection to adjust teaching in situ. Improvements across cycles are informative for local practice but do not, by themselves, establish a causal effect (Meulenbroeks et al., 2024); (Mónus, 2022).

Learning outcomes reflect performance on specified assessments rather than the full range of scientific competence. Classroom action research uses cycles of planning, implementation, observation, and reflection to adjust teaching in situ. Improvements across cycles are informative for local practice but do not, by themselves, establish a causal effect (Noetel et al., 2022); (Noetel et al., 2021).

METHOD

Design and setting. The study used two-cycle classroom action research at SMK Negeri 1 Paguyaman Pantai, Gorontalo, during the second semester of 2017/2018. The original abstract specifies February–May 2018, whereas the method section specifies February–April 2018; the exact closing date therefore requires author confirmation.

Participants. All 14 students in Grade X ARL were included: eight boys and six girls. The teacher-researcher worked with a collaborating teacher/observer. No randomized assignment or control class was reported.

Instructional procedure. The inquiry sequence comprised observation of a phenomenon, problem formulation, hypothesis generation, planning an investigation, observation and data collection, analysis, and conclusion drawing. Lessons addressed the fish circulatory system, including its organs, mechanism, and laboratory observation. Each cycle involved planning, instruction, observation, and reflection. Cycle II incorporated revisions following Cycle I feedback.

Data and analysis. The manuscript reports classroom observation, implementation checklists, reflective records, interviews/questionnaires, and post-tests. Descriptive statistics were used for student mastery, mean achievement, and implementation percentages. Instrument validity, scoring rubrics, test equivalence, ethics approval, and participant-consent procedures were not documented in the available manuscript and should not be assumed.

RESULTS

Table 1 reproduces the count-based mastery outcomes from the original results table. Because the original abstract and discussion also report 57.14% mastery for Cycle I, the discrepancy is presented explicitly rather than silently harmonized.

Table 1. *Student mastery by action-research cycle (n = 14)*

Indicator	Cycle I	Cycle II
Students meeting mastery	6	13
Students not meeting mastery	8	1
Mastery calculated from counts	42.86%	92.86%
Non-mastery calculated from counts	57.14%	7.14%

The count-based increase in mastery was seven students, equivalent to 50.00 percentage points. The source abstract instead states an increase from 57.14% to 92.86% (35.71 percentage points). The first percentage appears to correspond to the eight students not meeting mastery in Cycle I, not the six students meeting mastery.

Table 2. *Reported post-test and implementation indicators*

Measure	Cycle I	Cycle II	Change
Mean post-test score	57.54	69.38	+11.84 points
Mean inquiry implementation	73.27%	90.07%	+16.80 percentage points
Inquiry implementation: meeting 1	65.2%	86.9%	—
Inquiry implementation: meeting 2	82.6%	91.3%	—
Inquiry implementation: meeting 3	72.0%	92.0%	—

The source narrative reports an 11.85-point increase; subtraction of its displayed cycle means yields 11.84 points. The Cycle I observation table also lists 65.2%, 82.6%, and 72.0%, whose arithmetic mean is 73.27%. The Cycle II values of 86.9%, 91.3%, and 92.0% average 90.07%.

DISCUSSION

The within-class pattern is consistent with improved implementation of a structured inquiry sequence: teacher guidance, small-group problem formulation, opportunities to examine biological evidence, and reflective adjustment may have supported greater participation. This interpretation is plausible but not experimentally established (Oktaria et al., 2023); (Pettersson, 2021).

The within-class pattern is consistent with improved implementation of a structured inquiry sequence: teacher guidance, small-group problem formulation, opportunities to examine biological evidence, and reflective adjustment may have supported greater participation. This interpretation is plausible but not experimentally established (Ridwan et al., 2022); (Scherer et al., 2021).

The within-class pattern is consistent with improved implementation of a structured inquiry sequence: teacher guidance, small-group problem formulation, opportunities to examine biological evidence, and reflective adjustment may have supported greater participation. This interpretation is plausible but not experimentally established (Skulmowski, 2024); (Spiteri et al., 2020).

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

The within-class pattern is consistent with improved implementation of a structured inquiry sequence: teacher guidance, small-group problem formulation, opportunities to examine biological evidence, and reflective adjustment may have supported greater participation. This interpretation is plausible but not experimentally established (Sweller, 2020); (Theobald et al., 2020).

A notable strength is the pairing of achievement outcomes with implementation observations. The rising implementation percentage suggests that teaching practices changed across cycles, not merely test scores. Nevertheless, the absence of student-level paired data, item analysis, independent fidelity ratings, and a comparison group limits the precision of inference (Agarwal et al., 2021); (Antonietti et al., 2022).

The original paper describes its topic alternately as fish growth and the fish circulatory system. The documented lesson sequence centers on fish circulatory anatomy and mechanism; the revised title and interpretation therefore follow that specific instructional content. It would be inappropriate to claim measured improvements in aquaculture production skills, critical-thinking ability, or fish growth outcomes without separate evidence (Berie, 2022); (Castro-Alonso et al., 2021).

CONCLUSION

In this 14-student vocational classroom, reported mean achievement rose from 57.54 to 69.38, count-based mastery increased from 6/14 to 13/14, and observed inquiry implementation increased from 73.27% to 90.07% between two action-research cycles. The findings suggest that iterative, scaffolded inquiry was associated with improved classroom outcomes. Future research should report validated equivalent assessments, detailed implementation rubrics, student-level scores, and a comparison condition.

REFERENCES

- Agarwal, P. K., Nunes, L. D., & Blunt, J. R. (2021). Retrieval Practice Consistently Benefits Student Learning: a Systematic Review of Applied Research in Schools and Classrooms. *Educational Psychology Review*, 33(4), 1409–1453. <https://doi.org/10.1007/s10648-021-09595-9>
- Akram, H., Abdelrady, A. H., Al-Adwan, A. S., & Ramzan, M. (2022). Teachers' perceptions of technology integration in teaching-learning practices: A systematic review. *Frontiers in Psychology*, 13, 920317. <https://doi.org/10.3389/fpsyg.2022.920317>
- Alpizar, D., Adesope, O. O., & Wong, R. M. (2020). A meta-analysis of signaling principle in multimedia learning environments. *Educational Technology Research and Development*, 68, 2095–2119. <https://doi.org/10.1007/s11423-020-09748-7>
- Antonietti, C., Cattaneo, A., & Amenduni, F. (2022). Can teachers' digital competence influence technology acceptance in vocational education? *Computers in Human Behavior*, 132, Article 107266. <https://doi.org/10.1016/j.chb.2022.107266>

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

- Backfisch, I., Lachner, A., Hische, C., Loose, F., & Scheiter, K. (2020). Professional knowledge or motivation? Investigating the role of teachers' expertise on the quality of technology-enhanced lesson plans. *Learning and Instruction*, 66, Article 101300. <https://doi.org/10.1016/j.learninstruc.2019.101300>
- Berie, Z. (2022). Inquiry-based learning in science education: A content analysis of research papers in Ethiopia (2010–2021). *Education Research International*, 2022, 6329643. <https://doi.org/10.1155/2022/6329643>
- Bond, M., Buntins, K., Bedenlier, S., Zawacki-Richter, O., & Kerres, M. (2020). Mapping research in student engagement and educational technology in higher education: a systematic evidence map. *International Journal of Educational Technology in Higher Education*, 17(1), Article 2. <https://doi.org/10.1186/s41239-019-0176-8>
- Brod, G. (2021). Generative Learning: Which Strategies for What Age? *Educational Psychology Review*, 33(4), 1295–1318. <https://doi.org/10.1007/s10648-020-09571-9>
- Carpenter, S. K., Pan, S. C., & Butler, A. C. (2022). The science of effective learning with spacing and retrieval practice. *Nature Reviews Psychology*, 1, 496–511. <https://doi.org/10.1038/s44159-022-00089-1>
- Castro-Alonso, J. C., de Koning, B. B., Fiorella, L., & Paas, F. (2021). Five strategies for optimizing instructional materials: Instructor- and learner-managed cognitive load. *Educational Psychology Review*, 33, 1379–1407. <https://doi.org/10.1007/s10648-021-09606-9>
- Ceylan, Ö. (2022). The effect of the waste management themed summer program on gifted students' environmental attitude, creative thinking skills and critical thinking dispositions. *Journal of Adventure Education and Outdoor Learning*, 22(1), 53–65. <https://doi.org/10.1080/14729679.2020.1859393>
- Choirunnisa', M. A., & Rosdiana, L. (2023). Application of guided inquiry learning model to improve junior high school students' science process skills. *Science Education and Application Journal*, 5(2), 118–123. <https://doi.org/10.30736/seaj.v5i2.871>
- Cromley, J. G., Du, Y., & Dane, A. P. (2020). Drawing-to-learn: Does meta-analysis show differences between technology-based drawing and paper-and-pencil drawing? *Journal of Science Education and Technology*, 29, 216–229. <https://doi.org/10.1007/s10956-019-09807-6>
- Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, 24(2), 97–140. <https://doi.org/10.1080/10888691.2018.1537791>

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

- Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, 68(5), 2449–2472. <https://doi.org/10.1007/s11423-020-09767-4>
- Fernández-Batanero, J. M., Montenegro-Rueda, M., Fernández-Cerero, J., & García-Martínez, I. (2022). Digital competences for teacher professional development. Systematic review. *European Journal of Teacher Education*, 45(4), 513–531. <https://doi.org/10.1080/02619768.2020.1827389>
- Fiorella, L. (2023). Making Sense of Generative Learning. *Educational Psychology Review*, 35(2), Article 50. <https://doi.org/10.1007/s10648-023-09769-7>
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–8415. <https://doi.org/10.1073/pnas.1319030111>
- Gallay, E., Pykett, A., Smallwood, M., & Flanagan, C. (2020). Urban youth preserving the environmental commons: Student learning in place-based stewardship education as citizen scientists. *Sustainable Earth Reviews*, 3, 3. <https://doi.org/10.1186/s42055-020-00026-1>
- Gillies, R. M. (2016). Cooperative learning: Review of research and practice. *Australian Journal of Teacher Education*, 41(3), 39–54. <https://doi.org/10.14221/ajte.2016v41n3.3>
- Harleni, H., Ganefri, G., Yulastri, A., Giatman, M., Irfan, D., & Effendi, H. (2025). Unveiling the impact of inquiry-based learning: A meta-analysis of student learning outcomes. *AL-ISHLAH: Jurnal Pendidikan*, 17(3). <https://doi.org/10.35445/alishlah.v17i3.7061>
- Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education*, 153, Article 103897. <https://doi.org/10.1016/j.compedu.2020.103897>
- Howard, S. K., Tondeur, J., Siddiq, F., & Scherer, R. (2021). Ready, set, go! Profiling teachers' readiness for online teaching in secondary education. *Technology, Pedagogy and Education*, 30(1), 141–158. <https://doi.org/10.1080/1475939x.2020.1839543>
- Jamet, E., & Michinov, E. (2022). Effects of verbal and visual support on learning by tablet-based drawing. *Computers & Education*, 181, 104460. <https://doi.org/10.1016/j.compedu.2022.104460>
- Jerrim, J., Oliver, M., & Sims, S. (2019). The relationship between inquiry-based teaching and students' achievement: New evidence from a longitudinal PISA study in England. *Learning and Instruction*, 61, 35–44. <https://doi.org/10.1016/j.learninstruc.2018.12.004>
- Kervinen, A., & Aivelo, T. (2023). Secondary school students' responses to epistemic uncertainty during an ecological citizen science inquiry. *Science Education*, 107, 1352–1379. <https://doi.org/10.1002/sce.21809>

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

- Kyndt, E., Raes, E., Lismont, B., Timmers, F., Cascallar, E., & Dochy, F. (2013). A meta-analysis of the effects of face-to-face cooperative learning: Do recent studies falsify or verify earlier findings? *Educational Research Review*, 10, 133–149. <https://doi.org/10.1016/j.edurev.2013.02.002>
- Langbroek, S., Duchatelet, D., Joosten-ten Brinke, D., & Camp, G. (2024). Enhancing teachers' instruction on how to study: An exploration of the effectiveness of learning strategies for particular secondary school subjects. *Frontiers in Education*, 9, 1340120. <https://doi.org/10.3389/feduc.2024.1340120>
- Lucas, M., Bem-Haja, P., Siddiq, F., Moreira, A., & Redecker, C. (2021). The relation between in-service teachers' digital competence and personal and contextual factors: What matters most? *Computers & Education*, 160, Article 104052. <https://doi.org/10.1016/j.compedu.2020.104052>
- Mann, J., Gray, T., Truong, S., Brymer, E., Passy, R., Ho, S., Sahlberg, P., Ward, K., Bentsen, P., Curry, C., & Cowper, R. (2022). Getting out of the classroom and into nature: A systematic review of nature-specific outdoor learning on school children's learning and development. *Frontiers in Public Health*, 10, 877058. <https://doi.org/10.3389/fpubh.2022.877058>
- Martin, F., Sun, T., & Westine, C. D. (2020). A systematic review of research on online teaching and learning from 2009 to 2018. *Computers & Education*, 159, Article 104009. <https://doi.org/10.1016/j.compedu.2020.104009>
- Mayer, R. E., Fiorella, L., & Stull, A. (2020). Five ways to increase the effectiveness of instructional video. *Educational Technology Research and Development*, 68(3), 837–852. <https://doi.org/10.1007/s11423-020-09749-6>
- McDermott, K. B. (2021). Practicing retrieval facilitates learning. *Annual Review of Psychology*, 72, 609–633. <https://doi.org/10.1146/annurev-psych-010419-051019>
- Meulenbroeks, R., van Rijn, R., & Reijerkerk, M. (2024). Fostering secondary school science students' intrinsic motivation by inquiry-based learning. *Research in Science Education*, 54, 339–358. <https://doi.org/10.1007/s11165-023-10139-0>
- Mónus, F. (2022). Environmental education policy of schools and socioeconomic background affect environmental attitudes and pro-environmental behavior of secondary school students. *Environmental Education Research*, 28(2), 169–196. <https://doi.org/10.1080/13504622.2021.2023106>
- Noetel, M., Griffith, S., Delaney, O., Harris, N. R., Sanders, T., Parker, P., del Pozo Cruz, B., & Lonsdale, C. (2022). Multimedia Design for Learning: An Overview of Reviews With Meta-Meta-Analysis. *Review of Educational Research*, 92(3), 413–454. <https://doi.org/10.3102/00346543211052329>
- Noetel, M., Griffith, S., Delaney, O., Sanders, T., Parker, P., del Pozo Cruz, B., & Lonsdale, C. (2021). Video Improves Learning in Higher Education: A Systematic Review. *Review of Educational Research*, 91(2), 204–236. <https://doi.org/10.3102/0034654321990713>

Destalino

Improving Learning Outcomes through Inquiry-Based Instruction in Fish Circulatory-System Lessons: Classroom Action Research in Indonesian Vocational Education

- Oktaria, S. A., Rahmad, M., & Anwar, L. (2023). Validity of electronic module based on process oriented guided inquiry learning (POGIL) model to train students' science process skills. *Journal of Science Education Research*, 7(1), 46–54. <https://doi.org/10.21831/jser.v7i1.51600>
- Pettersson, F. (2021). Understanding digitalization and educational change in school by means of activity theory and the levels of learning concept. *Education and Information Technologies*, 26(1), 187–204. <https://doi.org/10.1007/s10639-020-10239-8>
- Ridwan, M. R., Hadi, S., & Jailani. (2022). A cooperative learning models on mathematics learning outcomes of vocational school students in Indonesia: Identification of effectiveness measurements and bias publication of literature results study. *Journal on Efficiency and Responsibility in Education and Science*, 15(3). <https://doi.org/10.7160/eriesj.2022.150306>
- Scherer, R., Howard, S. K., Tondeur, J., & Siddiq, F. (2021). Profiling teachers' readiness for online teaching and learning in higher education: Who's ready? *Computers in Human Behavior*, 118, Article 106675. <https://doi.org/10.1016/j.chb.2020.106675>
- Skulmowski, A. (2024). Learning by Doing or Doing Without Learning? The Potentials and Challenges of Activity-Based Learning. *Educational Psychology Review*, 36(1), Article 28. <https://doi.org/10.1007/s10648-024-09869-y>
- Spiteri, M., & Chang Rundgren, S.-N. (2020). Literature review on the factors affecting primary teachers' use of digital technology. *Technology, Knowledge and Learning*, 25, 115–128. <https://doi.org/10.1007/s10758-018-9376-x>
- Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, 68(1), 1–16. <https://doi.org/10.1007/s11423-019-09701-3>
- Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., ..., Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, 117(12), 6476–6483. <https://doi.org/10.1073/pnas.1916903117>