Peer Discussions Improve Student Learning

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Building a large and versatile toolkit of teaching strategies that engage and efficiently teach students is crucial for effective teachers. Many university instructors are trying to move away from using staid didactic lectures to more mentally lively activities. One engaging, active instructional strategy that is gaining use across many university classrooms is called peer instruction (Mazur, 1997). In fact, more than 25% of university physics professors report using peer instruction (Henderson & Dancy, 2009). During peer instruction, teachers present a challenging problem to students, students answer the question on their own, then students discuss their answers with a partner in the class, and finally students answer the question on their own again.

In our research, we examined whether and why peer instruction benefits learning in undergraduate and graduate psychology classes. Students' answers following discussion are typically more accurate than their answers before discussion. However, one concern with using peer instruction is that the more knowledgeable partner just tells the less knowledgeable student what the correct answer is. This kind of direct transmission of knowledge from the more knowledgeable student to the less knowledgeable student may involve shallow learning and not produce long-lasting learning benefits. Alternatively, peer instruction may prompt students to actively engage with each other to test ideas and yield a new understanding that neither student possessed prior to their interaction. We tested whether peer instruction encourages knowledge transmission or knowledge generation by assessing students' answers and their confidence in their answers before and after discussion. More specifically, we analyzed whether students just choose the answer of the more confident partner during discussion or whether the discussion between the partners generates novel information.

What We Did

We tested when and why peer instruction benefits learning across 6 different courses. These courses ranged from large undergraduate introductory courses in psychology to small master's level graduate courses in educational psychology at two public universities. In each of the six courses, we posed a multiple-choice question related to course content and students had to answer it on their own first. We required students to write down the answer to the question on their own (or submit it through a clicker device). We also required students to report their confidence in their answer on a scale of 1 (not at all confident) to 10 (very confident). After that, students discussed the question and answer with a neighbor in the class. After a brief (less than five minutes) discussion, students answered the question again on their own and reported their confidence in their second answer. We measured confidence to test whether who is more confident played an important role in students' final answers. (When implementing peer discussion in *your* classes, you do not need to have students report their confidence.) After students answered the second time, the instructor provided the correct answer and its justification.

Minor procedural details differed between courses. For example, in the large enrollment courses, students reported their answers and confidences through clicker systems, while in smaller courses students wrote their answers and confidences on paper. Most of the questions posed, regardless of their correctness, contributed to students' participation grades, but some of the questions were graded for accuracy.

Questions were designed to test the application and transfer of conceptual knowledge. An example of a question was:

> *Your online exam software randomizes your Exam 2 questions and answers. However, when you take the test, 4 questions in a row are "A". You think that the next answer CANNOT be "A". What is this an example of?*
>
> a. *Illusion of control*
> b. *Gambler's fallacy [the correct answer]*
> c. *Hot Hand fallacy*
> d. *Regression to the mean*

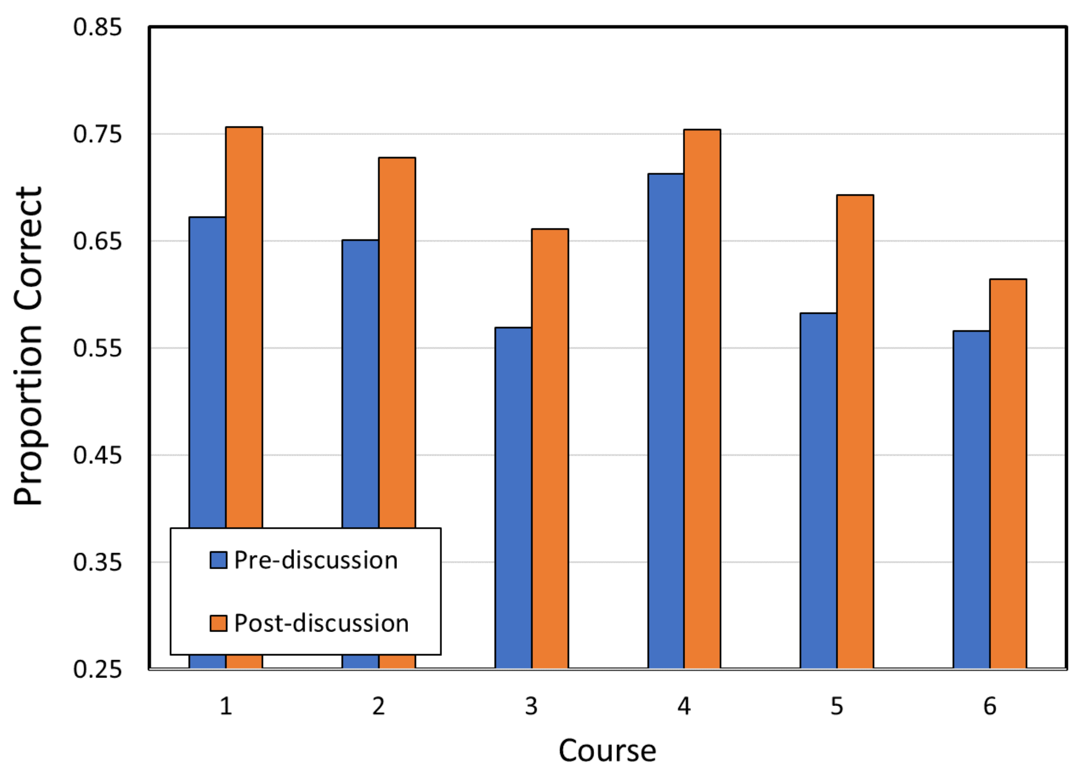
Overall, we collected over 1,600 full answers to 86 different questions from more than 200 students.

What We Found

The average accuracy in answering the questions improved from pre-discussion to post-discussion in each of the 6 classes, as shown in Figure 1.

Figure 1

Average Proportion Correct in Each of the Six Courses in Our Study Before and After Peer Discussion.

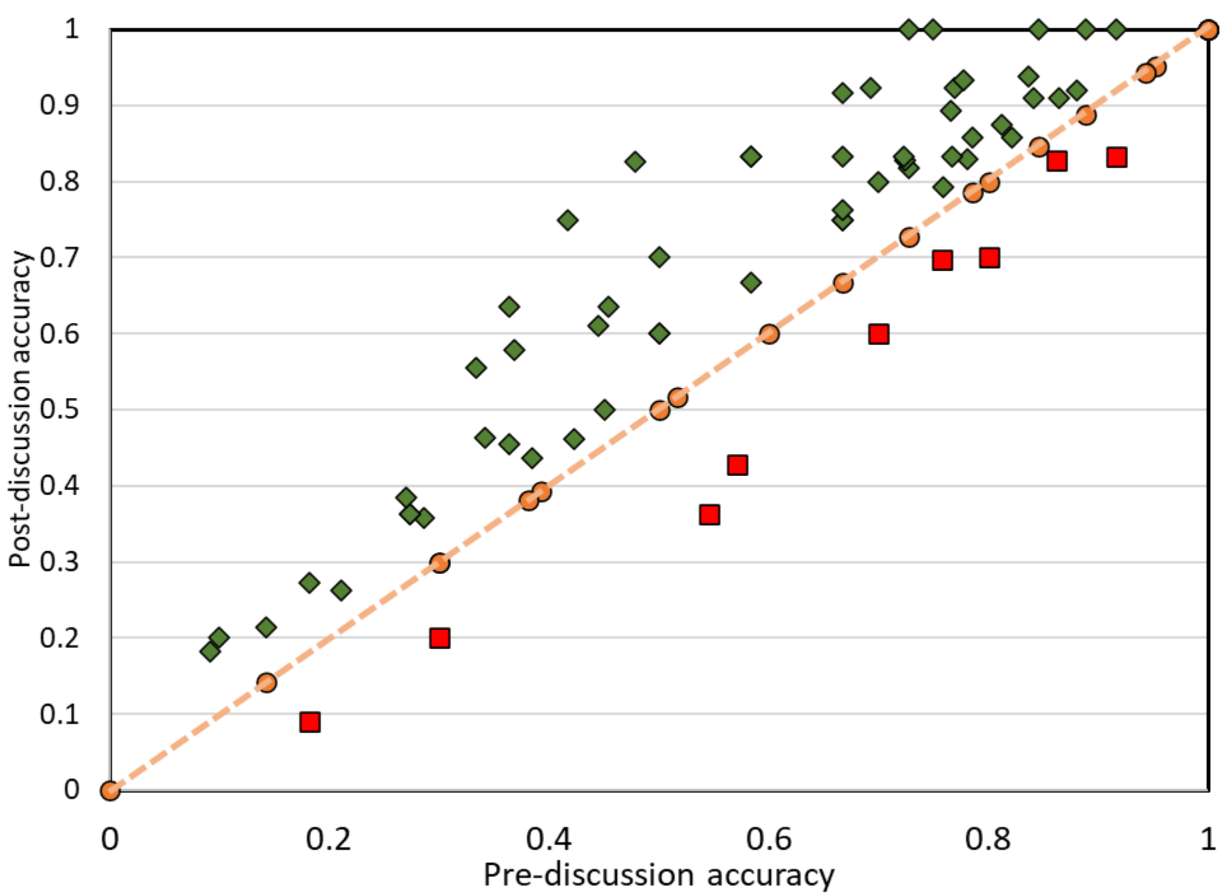


Almost all of the students benefited from peer instruction. In fact, when averaged across all the questions in our study, only 12% of students showed a decrease in their accuracy from pre- to post-discussion. This is important because it shows a wide variety of students, including both high-performing and low-performing students, benefited from engaging in discussions with their peers. Similarly, students' accuracy improved on the vast majority of the questions; only 9 questions (out of 86) showed worse accuracy following discussion than before discussion. These data are shown in Figure 2. The data show that accuracy improved just as much on very difficult questions as on easier questions.

The horizontal axis of Figure 2 represents the average proportion of correct responses to a question before discussion, while the vertical axis shows the average proportion correct after discussion. Each point on the graph represents a single question; the green diamonds show questions on which performance improved from pre- to post-discussion, the orange circles show questions where performance did not change (along the diagonal), and the red squares show questions where performance decreased after discussion. The large majority of questions show improvements from pre- to post-discussion (green diamonds). Further, questions ranging from difficult (left side of the graph) to easy (right side of the graph) benefited from peer discussions.

Figure 2

A plot of performance on individual questions.



Improvements in accuracy are driven by students appropriately shifting answers away from incorrect answers and towards correct ones. Across all answers, 28% of incorrect answers were switched to correct following discussion, while only 5% of correct answers were switched to incorrect, even though there were multiple ways for an answer to be incorrect and only one way for it be correct. Switching answers usually happened when peers initially disagreed; when peers agreed, they changed their answers less than 3% of the time. However, students were reluctant to switch their answers even when they disagreed with their peer. Students kept their answer 66% of the time when they disagreed with their partner. These results show that students trust in their own answers more strongly than their partner's answer.

One of our central questions was whether accuracy improves because students just switch their answers to the more confident partner in the pair. The data showed that students were doing much more than choosing the answer of the more confident peer. For example, when partners disagreed, peers only chose the answer of the more confident partner 58% of the time (which is far below 100%). Further, if students always chose the more confident answer, their final accuracy would have been 69% on average; instead it was 72% (a small, but significant advantage to not always choosing the answer of the more confident partner). Further analyses showed that students were drawn towards the correct answer, even after we accounted for initial confidences. Discussion productively helped students find the correct answer. In other words, peer discussion allowed students to test the coherence of their answers and generate new knowledge. Students did not simply transmit answers from the more confident partner to the less confident partner. One impressive result in this regard was that when students originally agreed on the same incorrect answer, they were more than four times more likely to switch to the correct answer than they were to switch to an incorrect answer when they originally agreed on the correct answer. Interactive discussion apparently helped students to forge better understandings even when neither student showed proper understanding at first.

We also examined how peer discussions impacted students' confidence in their answers. Students became more confident in their answers, particularly when their answers were correct (although their confidence also increased in incorrect answers), through discussions with partners. Further, discussion prompted students to more precisely judge the accuracy of their answer. Students were more confident in correct answers (and less confident in incorrect answers) following discussion than before discussion.

Why Peer Instruction Works

There are several reasons why this format of peer discussions may benefit student learning. First, students are required to answer the question first on their own. Answering practice questions prompts students to bring to mind relevant prior knowledge and use it to solve the novel problems. Considerable research shows the benefits of asking practice questions for the long-term retention of information. Specifically, trying to access information from memory helps us remember that information more than just re-reading it or listening to it (Yang and Luo, this volume). Further, answering practice questions can help students recognize what they know and do not know, organize existing knowledge, and learn from subsequent instruction. Finally, by answering the question first on their own, they enter into discussion with thoughts about the answers and an alternative for which they can advocate.

Second, beyond just the retrieval of information, peer instruction may be additionally helpful because it prompts peer interactions. Peer interactions, especially when there are disagreements within a pair, are likely to prompt argumentation and discussions of reasoning (Trouche, Sander, & Mercier, 2014). During argumentation, students must explain their answers to their partner. The process of explaining an answer may prompt students to notice gaps in their understanding, detect and correct errors in their explanations, and help construct new knowledge (e.g. Schwartz, 1995). In fact, self-explanations, in which a student verbalizes justification and reasons to themselves, can support student learning by themselves (Chi, De Leeuw, Chiu, & Lavancher, 1994).

Third, discussing with a peer may be more beneficial than receiving an explanation from the teacher, who may not understand the perspective of the novice student. Peers may better understand the knowledge of their classmates and be able to provide clearer reasoning in simple, familiar terms than experts can (Brown & Palincsar, 1989; Noddings, 1985; Tullis, 2018; Vygotsky, 1981). In addition, students may be particularly motivated to have their peers like and respect them. People are heavily influenced by the opinions of others, and social psychologists have distinguished between expectations that come from one's peers (descriptive norms) versus higher authorities (injunctive norms) (Schultz et al., 2007). Descriptive norms that come from one's peers are especially influential to learning (Cialdini, 2007). For example, people are more likely to litter when they observe a lot of other litter on the ground, even though they know that littering is against the official rules. Messages such as "Many people litter. Don't be one of them!" may have the paradoxical effect of increasing littering because it suggests a descriptive norm that littering is common among fellow citizens (Cialdini, Reno, & Kallgren, 1990). Given that students are likely to relate to each other better than they do their teacher and that they care a lot about what their peers think of them, giving and receiving explanations to peers often leads to particularly strong learning.

Finally, beyond the cognitive benefits of peer instruction expressed above, peer instruction may allow a greater number of students to mentally wrestle with the material. In a large class, time limits preclude most students from explaining their ideas to the teacher. Peer instruction gives every student time to verbalize their thoughts. Further, students who may be hesitant to volunteer their ideas in front of an entire class may be more likely to voice their ideas and argue for their answer when debating with a single, fellow student. In fact, we have ongoing research that compares learning from peer instruction with a class-wide discussion of problems. This research suggests that peer instruction supports student learning better than class-wide discussion. Further, other current research suggests that peer instruction is most beneficial when students work in pairs. As the size of the group increases, students take less responsibility for answering the question, engage with the material less deeply, and forget the information more quickly.

Benefits of Peer Instruction Beyond Our Study

Other research shows that peer instruction benefits the application of learning to new problems. For example, Smith et al. (2009) examined peer instruction in college biology classes. Students' accuracy improved from about 50% correct before discussion to 70% correct following discussion. Then, students were asked to answer a new, similar question on their own. Students showed that they could apply their knowledge learned during peer discussions to new problems. On new problems that were approximately as difficult as the original problems, students answered about 75% of the new problems correctly on their own (much better than the 50% correct they achieved originally on their own). That study shows that students were able to transfer what they learned during peer instruction to solving new problems on their own, which is a difficult and remarkable feat! Further, we have some preliminary data which shows that peer instruction helps students remember the information for a longer time than just answering a question on their own or having a class-wide discussion.

There are countless variations to the general procedures of peer instruction that can be adapted to a specific teacher's preferences. For example, in classes where students answer the questions via digital clickers, some teachers opt to show the distribution of the class's answers before peer discussion (Nielsen, Hansen-Nygård, & Stav, 2012; Perez et al., 2010). Some teachers grade the accuracy of student answers for correctness (James, 2006), while other teachers use answering as a simple measure of participation. Some instructors use multiple-choice questions during peer instruction, while others administer short answer questions or complex problems. Some teachers choose to use peer instruction as a bell work problem at the beginning of every class to refresh students' minds about material covered in prior classes, while others choose to use it in the middle of class to break up lecture and emphasize key ideas.

Peer instruction can be implemented in many different ways and still promote student learning. We strongly advocate that peer instruction have at least the following components: 1) a requirement that students answer the question first on their own so that they can retrieve relevant knowledge by themselves and take responsibility for their answer (they thereby have made a commitment upon entering the discussion phase), 2) discussion with a partner, so that they can verbalize their reasoning, hear a partner's reasoning, and possibly debate the partner, and 3) after submission of the final answer, clarification and justification of the correct answer so that misconceptions or incorrect answers are addressed (debate can help students prepare to learn from an explanation).

Peer instruction is a more specific strategy than "think-pair-share" (e.g. Kaddoura, 2013). Think-pair-share can have multiple correct answers and does not necessarily encourage students to debate or challenge each other. A key feature of peer instruction is that students need to argue and justify their own reasoning when arguing in favor a correct answer. This set-up likely works best when there is only a single correct answer in order to foster debate among partners.

Peer instruction has broader learning benefits than just improving conceptual learning. Centering classroom activities around peer instruction (and away from didactic lectures) improves student retention in difficult courses (Lasry, Mazur, & Watkins, 2008), increases passing rates (Porter, Bailey-Lee, & Simon, 2013), improves student attendance (Deslauriers, Schelew, & Wieman, 2011), and bolsters student engagement (Lucas, 2009) and attitudes toward their course (Beekes, 2006).

Research shows that these benefits of peer instruction can be found in many different domains, including physics (Mazur, 1997), biology (Knight, Wise, & Southard, 2013), chemistry (Brooks & Koretsky, 2011), physiology (Cortright, Collins, & DiCarlo, 2005), calculus (Lucas, 2009), computer science (Porter et al., 2013), entomology (Jones, Antonenko, & Greenwood, 2012), and philosophy (Butchart, Handfield, & Restall, 2009). We believe that the benefits of peer instruction would extend even more broadly and likely benefit learning regardless of the domain of the content. Further, benefits of peer instruction have been found in many different student populations, from students in high school (Cummings & Roberts, 2008) to those in private universities (Lasry et al., 2008).

Peer instruction has shown learning benefits in a wide range of domains, with many types of questions, and across varied kinds of learners. Incorporating some peer instruction throughout classes is a relatively simple, flexible, and quick method for encouraging student participation and learning. Teachers can and should incorporate peer instruction into their teaching toolkit because peer instruction encourages students to process information deeply, test their ideas, and derive new knowledge.

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References

Beekes, W. (2006). The ‘‘millionaire” method for encouraging participation. *Active Learning in Higher Education*, 7, 25–36. https://doi.org/10.1177/1469787406061143

Brooks, B.J., Koretsky, M.D. (2011). The influence of group discussion on students' responses and confidence during peer instruction. *Journal of Chemistry Education*, 88, 1477–1484.

Brown, A. L., & Palincsar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick(Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 393-451). Hillsdale, NJ: Erlbaum.

Butchart, S., Handfield, T., & Restall, G. (2009). Using peer instruction to teach philosophy, logic and critical thinking. *Teaching Philosophy*, 32, 1–40. https://doi.org/10.5840/teachphil20093212

Chi, M. T. H., De Leeuw, N., Chiu, M., & Lavancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, 18 (3), 439-477. https://doi.org/10.1016/0364-0213(94)90016-7

Cialdini, R. B. (2007). Descriptive social norms as underappreciated sources of social control. *Psychometrika*, 72 (2), 263-268.

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology, 58*(6), 1015–1026. https://doi.org/10.1037/0022-3514.58.6.1015

Cortright, R.N., Collins, H.L. & DiCarlo, S.E. (2005) Peer instruction enhanced meaningful learning: ability to solve novel problems. *Advances in Physiology Education* **29**, 107–111. https://doi.org/10.1152/advan.00060.2004

Cummings, K. & Roberts, S. (2008). A study of peer instruction methods with school physics students. In C. Henderson, M. Sabella, & L. Hsu (Eds.), *Physics Education Research Conference* (pp. 103–106). College Park: American Institute of Physics.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science*, 332, 862–864.

Henderson, C., & Dancy, M. H. (2009). The impact of physics education research on the teaching of introductory quantitative physics in the United States. *Physical Review Special Topics: Physics Education Research*, 5(2), 020107.

James, M. C. (2006). The effect of grading incentive on student discourse in peer instruction. *American Journal of Physics*, 74(8), 689–691. https://doi.org/10.1119/1.2198887

Jones, M. E., Antonenko, P.D., & Greenwood, C. M. (2012). The impact of collaborative and individualized student response system strategies on learner motivation, metacognition, and knowledge transfer. *Journal of Computer Assisted Learning*, 28(5), 477-487. **https://doi.org/10.1111/j.1365-2729.2011.00470.x**

Kaddoura, M. (2013). Think pair share: A teaching learning strategy to enhance students' critical thinking. *Educational Research Quarterly*, 36 (4), 3-24.

Knight, J. K., Wise, S. B., & Southard, K. M. (2013). Understanding clicker discussions: Student reasoning and the impact of instructional cues. *CBE-Life Sciences Education*, 12, 645-654.

Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: from Harvard to the two-year college. *American Journal of Physics*, 76(11), 1066–1069. https://doi.org/10.1119/1.2978182

Lucas, A. (2009). Using peer instruction and i-clickers to enhance student participation in calculus. *Primus*, 19(3), 219-231. https://doi.org/10.1080/10511970701643970

Mazur, E. (1997). Peer instruction: A user's manual. Upper Saddle River, NJ: Prentice Hall.

Nielsen, K.L., Hansen-Nygård, G., & Stav, J. B. (2012). Investigating peer instruction: how the initial voting session affects students' experiences of group discussion. *ISRN Educ 2012*, article 290157.

Noddings, N. (1985). Small groups as a setting for research on mathematical problem solving. In E. A. Silver (Ed.), *Teaching and learning mathematical problem solving* (pp. 345-360). Hillsdale, NJ: Erlbaum.

Perez, K.E., Strauss, E.A., Downey, N., Galbraith, A., Jeanne, R., Cooper, S., & Madison, W. (2010). Does displaying the class results affect student discussion during peer instruction? *CBE Life Sciences Education*, 9, 133–140. https://doi.org/10.1187/cbe.09-11-0080

Porter, L., Bailey-Lee, C., & Simon, B. (2013). Halving fail rates using peer instruction: a study of four computer science courses. In: SIGCSE '13: Proceedings of the 44th ACM Technical Symposium on Computer Science Education, New York: ACM Press, 177–182.

Schultz, W.P., Nolan, J.M., Cialdini, R.B., Goldstein, N.J., and Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, 18(5), 429–434. https://doi.org/10.1111/j.1467-9280.2007.01917.x

Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. *The Journal of the Learning Sciences*, 4, 321–354. https://doi.org/10.1207/s15327809jls0403_3

Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., Su, T.T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science*, 323, 122–124.

Trouche, E., Sander, E., & Mercier, H. (2014). Arguments, more than confidence, explain the good performance of reasoning groups. *Journal of Experimental Psychology: General, 143,* 1958–1971. https://doi.org/10.1037/a0037099

Tullis, J. G. (2018). Predicting others' knowledge: Knowledge estimation as cue-utilization. *Memory & Cognition*, 46, 1360-1375. https://doi.org/10.3758/s13421-018-0842-4

Tullis, J. G., & Goldstone, R. L. (2020). Why does peer instruction benefit student learning? *Cognitive Research: Principles and Implications*. 5:15. https://doi.org/10.1186/s41235-020-00218-5

Vygotsky, L. S. (1981). The genesis of higher mental functioning. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 144-188). Armonk, NY: Sharpe.