Journal of
Problem
Based
Learning
in Higher Education

JPBLHE: Early view

The Use of a Digital Problem-Based Learning Module in Science Methods Courses

Peter Rillero and Ying-Chih Chen *

ABSTRACT

Teacher education in Problem-Based Learning (PBL) is requisite for improving and increasing K-12 PBL implementations. A free, online PBL module entitled "Design a Problem-Based Learning Experience" was developed for preservice and inservice teachers. This article describes how the module is used in preserve teacher science methods courses, experiences before and after the module use, and the perceptions of sixty-two teacher candidates (TCs) after module completion. The results revealed that TCs generally had positive attitudes about the module. TCs in elementary level courses had significantly higher rating than secondary level courses. Graduate TCs also rated significantly higher than undergraduate students. Analysis of interview data revealed three features of the PBL module: (1) it is concise and organized, (2) it provides effective and practical examples, and (3) it provides interactive and rigorous videos to engage learners. Potential ways to improve the online PBL are discussed.

Problem-Based Learning (PBL) can integrate diverse subjects with meaningful experiences. With exploration preceding explanation, PBL provides paths to realize state science standards, Next Generation Science Standards (McConnell, Parker, & Eberhardt, 2018; NGSS Lead States, 2013), and the Common Core mathematics standards (Nariman & Chrispeels, 2015). The approach advances a vital outcome of education: the abilities to recognize and solve problems.

PBL implementation requires different teacher roles in the instructional process (Bridges, 1992). Our Teachers College has embraced the goal of preparing teachers with the knowledge, abilities, and mindsets to effectively implement PBL. This article describes (a) the use of a PBL module in our science methods courses, (b) experiences before and after the module, and (c) preservice teachers' views of the module.

* Peter Rillero, Mary Lou Fulton Teachers College, Arizona State University
Email: rillero@asu.edu
Ying-Chih Chen, Mary Lou Fulton Teachers College, Arizona State University
Email: ychen495@asu.edu

PROBLEM-BASED LEARNING

Dewey's (1938) conceptions of knowledge being bound with activity provided a theoretical basis for PBL. Challenging the prevailing lecture and memorize method, PBL was launched in the 1970s at McMaster University as medical students learned content and clinical reasoning abilities by identifying symptoms in real patients, simulated patients, or written case studies; diagnosing medical conditions; and proposing treatments (Barrows, 1996; Barrows & Tamblyn, 1980; Zubaidah, 2005). From medical education, PBL entered other professional education programs (Beck & Lindvang, 2015; Cottell, 2010; Gould & Sadera, 2015).

PBL in K-8 Grades

Passage into grades K-12 necessitated a broader view, from foci on clinical skills or problem-solving for a single profession to preparing younger learners for many life possibilities (Marle et al., 2012; Torp & Sage, 2002). Studies of K-12 implementations are limited and frequently have conflicting results (Wirkala, & Kuhn, 2011). However, a recent systematic literature review for elementary science education, involving control-groups with PBL as the independent variable, provided evidence that grades K-8, science, PBL experiences foster academic achievement, knowledge retention, conceptual development, and improved attitudes (Merritt, Lee, Rillero, & Kinach, 2016).

PBL and English Language Learners

The population of English Language Learners (ELLs) in U.S. schools has increased steadily over the past thirty years (Shin & Kominski, 2010). When students struggle with the language in which academic content is delivered, their academic success is jeopardized (Wright, 2015). PBL can help all students, but especially ELLs who face additional obstacles, develop language and content knowledge with strategic scaffolding (Rillero & Hernandez, 2016). Yet, teachers may not believe active learning strategies should be used with ELLs. For example, Kelly describes results of a pretest and posttest after an ELL methods course (2017): "overall findings showed that preservice teachers viewed teaching ELLs as a teacher implementing direct instruction in basic literacy to passive students at both the beginning and end of the course." Teachers need to understand how to implement active learning approaches, such as PBL, to benefit ELLs and all learners.

TEACHERS AND PBL

PBL environments have free-flowing elements, nevertheless, “teachers must be intentional in the design of the learning environment and the enactment of support strategies” (English & Kitsantas, 2013, p. 130). In moving away from teacher-centered instruction, a challenge is finding balance between supports for students and autonomous work (Pepper, 2009); this challenge exists for both new and experienced teachers (Strevy, 2014). Being able to hold back instructor input is important for creating a space for student learning (McConnell, Parker, & Eberhardt, 2018). Many teachers struggle with letting go, letting students make mistakes as they work to solve a problem; others may swing to the opposite extreme, embracing student struggle but withholding too much assistance (Pourshafie & Murray-Harvey, 2013). For example, an implementation in a college of education, instructors were reluctant to give assistance, assuming students should be independent learners (Koh & Tan, 2016), resulting in students not asking instructors for assistance.

The need for PBL teacher education is deepened as most inservice and preservice teachers have not experienced PBL as learners and might not have PBL implementers to observe (Lehman, et al., 2006; Strevy, 2014). Important teacher characteristics for effective PBL implementation include skills, attitudes, and knowledge (Pourshafie & Murray-Harvey, 2013).

THE PBL MODULE

Our Teachers College received a grant to prepare our undergraduate and graduate preservice teachers (whom we call Teacher Candidates (TCs)) to work with English Language Learners and implement PBL through an approach called Problem-Based Enhanced Language Learning (Rillero, et al., 2017). Grant recipients teamed with the Sanford Design project to develop a free, online PBL module for preservice and inservice teachers entitled “Design a Problem-Based Learning Experience” (Rillero & Camposeco, 2018). A distributed white paper presented our operational definition of PBL for discussion and agreement: **Problem-based learning is an instructional approach where learners grapple with meaningful problems and collaboratively work toward their resolution.** A detailed description of the module creation process is presented by Rillero and Camposeco (2018).

The module is freely available at https://modules.sanfordinspire.org/modules/design-problem-based-learning-experience/. The launch page features an introductory video, learner outcomes, and a downloadable (a) Coaching Guide, (b) Module Resource, and (c) Transcript.

Learners start the module after a brief registration process. The chapters in the module are as follows:

1. **Introduction**: The definition, required mindsets, and benefits of PBL.
2. **Designing an experience**: Three steps of PBL and corresponding criteria for each.
   a. **Establish the problem**: Identify a problem that has real-life application and is meaningful to students.
   b. **Create the experience**: Learners plan for how students will collaborate and share their solutions.
   c. **Evaluate**: Learners identify academic and social outcomes for the experience. They also plan formative and summative assessment opportunities
3. **Tips for Getting Started**: Learners select videos of subject-matter experts explaining different tips for planning their first problem-based learning experience.
4. **Bears on a Boat**: An annotated PBL lesson plan is viewed that explains how each criterion and step are met.
5. **Evaluate a PBL Experience**: After a self-assessment, learners have the choice of either evaluating a PBL experience or proceeding to the conclusion.

After chapter completion, learners take a six-question assessment that requires a 100% score for a completion certificate, with retakes possible. We assign the module as an out-of-class experience. The submission of their certificate confirms the TCs have explored the module.

PRE- AND POST-MODULE EXPERIENCES

Few of our teacher candidates (TCs) have experienced PBL as learners. Thus, before assigning the module, we have them participate in a PBL experience as though they were elementary or secondary students. The PBL experience varies in methods classes but “Bears in a Boat” (Rillero, Thibault, Merritt, & Jimenez-Silva, 2018) is often used in the elementary course and PBL with pendulums (Rillero & Hernandez, 2016) is frequently used in the secondary course.

After the module, TCs have experiences designing and implementing PBL in our methods courses, in subsequent methods courses, and during their student teaching. Our sequences of experiences are presented in Figure 1.

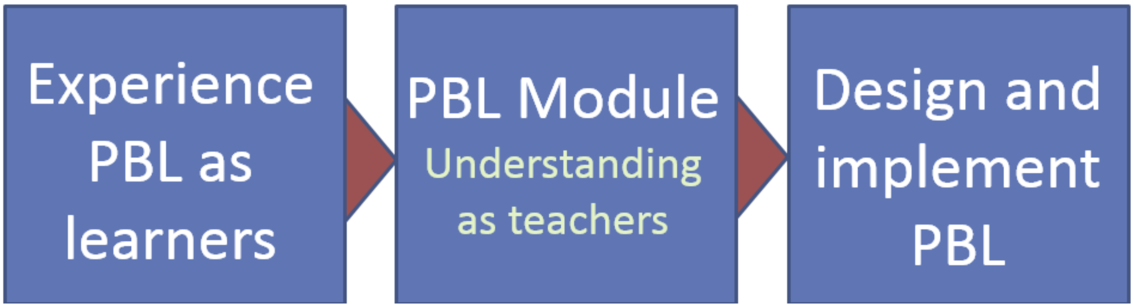

Figure 1. The module in context of other PBL experiences.

METHODS CLASS EVALUATION OF MODULE

Instrument and Populations

The following sources of data provided insights into TCs' perceptions of the module: (a) a survey administered shortly after the module completion and (b) interviews with selected students. The survey consisted of 16 Likert items and two opened-ended questions. Each Likert item is rated using a 1 (strongly disagree) to 5 (strongly agree). The two open-ended items were as follows:

(A) What are the best aspects of this module? Please say why these are good

(B) What aspects of the module could be improved? Please say why.

We also conducted in-depth, semi-structured, clinical interviews (Patton, 2001) to elicit students' inner opinions toward the digital PBL module. Three students were randomly selected for the interviews. Each student was interviewed individually by the second author. The length of interview time was approximately thirty minutes. The semi-structured interviews served a means to triangulate data from two open-ended questions and the sixteen Likert items. Thus, the interviews focused on confirming or disconfirming participants' responses for the instrument and two open-ended questions.

We administered the survey to 62 TCs (preservice teachers) after module completion. The reliability based on Cronbach's alpha coefficients is 0.76, suggesting that the items have acceptable internal consistency.

Quantitative Results

The average age of participants is 23.92 years old, ranging from 20-42. Gender, course, and desired teaching level are presented in Table 1. The average total score for the 16 items is 64.5, ranging from 47 to 80. The average item score is 4.03 (SD=0.80). The lowest means (reported with SDs) were for the following two items: "The module challenged me to do my best work" (3.72, 1.05) and "The module was interesting" (3.76, 0.92). The highest means were for “The module was relevant for my future work” (4.55, 0.56) and “The module design was clear and coherent” (4.45, 0.56). The average time reported to complete the PBL module is 45.24 minutes, ranging from 10 minutes to 80 minutes. The mean scores and standard deviation for each subgroup are shown in Table 2.

Sample demographics: Participants’ Gender, Course Taking, and Desired Teaching Level

Category	Sub-category	N	%
Gender	Female	50	80.6
	Male	12	19.4
Course	Elementary education undergraduate preservice teachers	24	38.7
	Elementary Special Education undergraduate preservice teachers	13	21
	Elementary education graduate preservice teachers	5	8.1
	Secondary Education science preservice teachers	20	32.2
Desired teaching level	Early elementary (k-3)	25	40.3
	Upper-level elementary (4-6)	8	12.9
	Middle school (7-9)	14	22.6
	High School (10-12)	15	24.2
Course level I	Elementary	42	67.7
	Secondary	20	32.3
Course level II	Undergraduate	57	91.9
	Graduate	5	8.1
Total		62	100

Table 1

Sample Sizes, Mean Scores, and Standard Deviation for each Subgroup

Group		N	M	SD
Total		62	64.50	8.89
Gender	Female	50	65.00	8.64
	Male	12	62.42	10.00
Course Level I	Elementary	42	66.42	8.42
	Secondary	20	60.45	8.67
Course Level II	Undergraduate	57	63.61	8.61
	Graduate	5	74.60	5.22

Table 2

Comparing Groups on Quantitative Survey

A one-way analysis of variance (ANOVA) was conducted to analyze potential differences between sub-groups. Scores on the questionnaire were used as the dependent variable, with the sub-group as the independent variable. The statistical significance was determined at an alpha level of .05 for all statistical tests.

Results showed no significant difference between gender even though females rated the module slightly higher than males. Results showed that TCs who took elementary level courses had significantly higher rating than secondary level courses, $F(1, 61)=6.699$, $p < .05$. *Post hoc analysis* showed that Item 1 (The module learning outcomes were clear), 3 (The learning and teaching methods used were effective), 5 (The module challenged me to do my best work), 6 (The module increased my understanding of the topic), 7 (The module encouraged me to feel part of a community committed to learning), 12 (The module was relevant for my future work), 13 (The module was interesting), and 15 (My interests in the subject has increased as a consequence of this module) had significantly higher scores for the TCs in elementary level courses

Results showed that graduate TCs rated significantly higher than undergraduate students, $F(1, 61)=7.802$, $p < .01$. *Post hoc analysis* showed that Item 2 (The module design was clear and coherent); 4 (The workload for this module was reasonable), 5 (The module challenged me to do my best work), 6 (The module increased my understanding of the topic), 7 (The module encouraged me to feel part of a community committed to learning), 8 (The module met my expectations), and 13 (The module was interesting) had significantly higher scores in the group of graduate students.

As a comparison group, we also had experienced, certified teachers in a two-year old Science, Technology, Engineering, Art, and Mathematics (STEAM) compete the module and survey. There were nine teachers in this sample. The rationale for this comparison is that inservice teachers with their education and experience may better understand the value of teacher education tools. Results showed that inservice teachers had significantly higher scores than preservice teachers, $F(1, 70)=3.854$, $p < .05$. *Post hoc analysis* showed that Items 4, 8, and 13 had significantly higher scores in the group of inservice teachers.

Open-ended Questions & Semi-structured, Clinical Interviews

Constant comparative method (Strauss & Corbin, 1990) was utilized to identify regularities or patterns in the two open-ended questions from 62 students and semi-structured, clinical interviews from three students. Data analysis involved an iterative process of coding, displaying, reduction, verification, confirmation, and disconfirmation of data. The initial coding scheme was organized around two categories of students' perceptions of the PBL module and the potential ways to improve the PBL module. Within the two categories, additional sub-codes were employed to capture students' perceptions and opinions after they completed the exploration of the module. Patterns and themes emerging from the data were discussed and refined using investigator triangulation (Janesick, 1994). This process continued until major themes had been substantiated and refined.

Data analysis revealed six salient features of the use of PBL module. Features 1-3, shown in Table 3 are related to module effectiveness. Feature 4-6, shown in Table 4 are addressed the potential ways to improve the PBL module.

Effectiveness of the PBL Module

Feature 1: This module is concise and organized
Evidence from open-ended questions *-The layout is easy to follow, professional looking. AND the questions (a couple of) them were tricky so I felt as if I really needed to pay attention. It made me think!* *-The information is well structured making it easy to follow.* **Evidence from interview** *-I really liked how it was structured. I think it's a good practice and a good way to learn about the problem based learning.*
Feature 2: This module provides effective and practical examples to understand the implementation of PBL
Evidence from open-ended questions *-The scenarios provided practical examples connecting the concepts to classroom situations* *-It gives really good examples. I also liked how they incorporated actual teachers who have used this strategy and talked about how effective it is in their classroom.* **Evidence from interview** *-It's very sequential; we talk about different sections of it, and it gives really good examples.*
Feature 3: This module provides interactive and rigorous videos to engage learners
Evidence from open-ended questions *-The module was interactive. It asks me questions to check for understanding, which helps a lot. Input from professional in the field real world explanation.* *-Expert opinion videos, examples and elaborations on each topic, interactive questioning.* **Evidence from interview** *-I also liked how they incorporated actual teachers who have used this strategy and talked about how effective it is in their classroom.*

Table 3

Ways to Improve the PBL Module

Feature 4: Operational process can be improved, such as information seeking, back to previous learning portfolio
Evidence from open-ended questions *-I did not like that it was difficult to go back and find information.* *-Might there be an opportunity to go back into the module, while taking the test?* *- It didn't give an explanation when you selected an incorrect answer. It just said, "Incorrect."* **Evidence from interview** *- I think that I have to go back and watch the module again to be a little more clear on it. I mean I think the information was good, it's just when I went to answer the assessment I just didn't perform well. Maybe going back and watching the module again would be more helpful.*
Feature 5: More examples and opinions at/ from different grade levels and teachers
Evidence from open-ended questions *-I think there should have been more examples in all different types of science content and at different grade levels.* *-Making is more related to secondary ed. The examples were mostly around elementary science so it is not as relatable for secondary education teacher.* **Evidence from interview** *-I put my reflection was just having more content examples specific to my content, specific to my area, like secondary education, high school, kind of examples.*
Feature 6: Combine with sequential lessons to implement and design a PBL lesson
Evidence from open-ended questions *-I think that the whole PBL method is good but I think it would help to show what the entire process looks like in the classroom as an example of each step so the view can see a visual.* **Evidence from interview** *-I think that's a good way to introduce it. Then now you can dissect what each part looks like, show examples of lesson plans, and then actually have students make the lesson instead of the other way around, because I know we're doing it other sorts of classes.*

Table 4

DISCUSSION

TCs views of the PBL module are positive. For the 16-item survey, the mean score is 4.03 out of five. The highest evaluated item, relevancy for future work, is noteworthy, as our TCs do not always see the relevance of what they are learning. The second highest rated item was for the module design being clear and coherent. This may be due to the long and detailed process in the module development (Rillero & Camposeco, 2018) and is also reflected in the open-ended and interview responses of TCs. While all survey items were rated above the midpoint (three for the five-point scale), the lowest rated item was “The module challenged me to do my best work.” Striking the balance between frustration and challenge can be difficult to achieve for all students; the results suggest that some students might benefit from a higher challenge level. The second lowest rating was for “The module was interesting.” Future iterations of the module should strive for greater levels of interest.

TCs in elementary methods courses rated the module higher than TCs in our secondary education courses. Although there are different path options in the module, the main PBL described was for lower elementary students. This might have been a factor in the lower scores by secondary education students, which was suggested in the open-ended comments. Module revision should incorporate more secondary education options. The graduate students rated the module higher than undergraduate students. The reason for this is not clear but presumably their previous education and life experiences contributed to this higher evaluation score.

Experienced inservice teachers, in the second-year teaching in a district STEAM program, also completed the module and survey. This group rated the module significantly higher than the preservice teachers. The higher ranking by experienced teachers lends credibility to the module. The reasons for the higher ranking could be explored in future studies.

The PBL module is a start to enable future teachers to implement the method. We also engage students in a PBELL experience (Rillero, Thibault, Merritt, & Jimenez-Silva, 2018) and synergy between the module and the experience, leads to high-quality TC work as they develop and implement PBELL experiences. By focusing on PBL with language supports the preservice teachers develop abilities to make the experiences more beneficial for all students but especially ELLs.

CONCLUSION

The PBL module is used in our science methods courses as part of a comprehensive method for enabling future teachers to have the knowledge, skills, and mindsets to implement PBL. The module describes the benefits of PBL, steps for implementation, tips for getting started, and presents a rich description of a PBL experience. An assessment at the end synthesizes and evaluates learning. A certificate earned is presented as proof of completion. Our TCs generally have positive views of the module. Prior to learning from the module, the TCs experience PBL as though they were an elementary or secondary student. After the module, students have experiences designing and implementing PBL in their internship classrooms.

Acknowledgments

This work was supported in part by a U.S. Department of Education Teacher Quality Partnership (TQP) grant titled "Integrating STEM, Literacy, and Language to Prepare All Teachers to Teach English Language Learners: iTeach ELLs."

References

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. In L. Wilkerson & W. H. Gijselaers (Eds.), *Bringing problem-based learning to higher education: Theory and practice* (pp. 3-12). San Francisco: JosseyBass.

Barrows H. S., & Tamblyn R. M. (1980). *Problem-based learning: An approach to medical education*. New York: Springer Publishing Company.

Beck, B., & Lindvang, C. (2015). Problem Based Learning as a shared musical journey – Group dynamics, communication and creativity. *Journal of problem based learning in higher education, 3*. https://doi.org/10.5278/ojs.jpblhe.v3i1.1200

Bridges, E. M. (1992). *Problem-based learning for administrators*. Eugene, OR: ERIC Clearinghouse on Educational Management.

Cottell, P. G. (2010). Shreffler Stores, accounting issues related to consumer receivables, asset impairment, and discontinued operations: A Problem-Based Learning Unfolding Problem, *Issues in Accounting Education, 25*(4) 775-787

Dewey, J. (1938). *Experience and education*. London: Collier Macmillan.

English, M. C., & Kitsantas, A. (2013). Supporting student self-regulated learning in problem- and project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 7*(2). https://doi.org/10.7771/1541-5015.1339

Gould, K., & Sadera, W. (2015). Evaluation of health profession student attitudes toward an online nutrition education problem-based learning module. *International Journal on E-Learning, 14*(2), 181-198.

Janesick, V. J. (1994). The dance of qualitative research design. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research design* (pp. 209–219). Thousand Oaks, CA: Sage.

Jerzembek, G., & Murphy, S. (2013). A narrative review of problem-based learning with school-aged children: Implementation and outcomes. Educational Review, 65(2), 206-218.

Kelly, L.B. (2017). Preservice teachers' developing conceptions of teaching English learners. *TESOL Quarterly*. https://onlinelibrary.wiley.com/doi/full/10.1002/tesq.375

Koh, K., & Tan, C. (2016) Promoting reflection in pre-service teachers through problem-based learning: an example from Canada. *Reflective Practice*, *17*(3), 347-356. https://doi.org/10.1080/14623943.2016.1164683

Lehman, J. D., George, M., Buchanan, P., & Rush, M. (2006). Preparing teachers to use problem-centered, inquiry-based science: Lessons from a four-year professional development project. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1). https://doi.org/10.7771/1541-5015.1007

Marle, P. D., Decker, L. L., Taylor, V., Fitzpatrick, K., Khaliqi, D., Owens, J. E., & Henry, R. M. (2012). CSI-chocolate science investigation and the case of the recipe rip-off: Using forensic science to engage students. *Journal of Chemical Education*, *91*(3), 345-350.

McConnell, T. J., Parker, J. M., & Eberhardt, J. (2018). *Problem-based learning in the physical science classroom*, K-12. Alexandria, VA: NSTA Press.

Merritt, J. D., Lee, M. Y., Rillero, P., & Kinach, B. (2017). Problem-based learning in K-8 mathematics and science education: A literature review. *Interdisciplinary Journal of Problem-Based Learning*, 11(2). Available at https://dx.doi.org/10.7771/1541-5015.1674

Nariman, N., & Chrispeels, J. (2016). PBL in the era of reform standards: Challenges and benefits perceived by teachers in one elementary school. *Interdisciplinary journal of problem-based learning*, *10*(1). http://dx.doi.org/10.7771/1541-5015.1521

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press.

Patton, M. Q. (2001). *Qualitative research and evaluation methods.* Thousand Oaks, CA: Sage.

Pepper, C. (2009). Problem based learning in science. *Issues in Educational Research*, *19*(2), 128-141.

Pourshafie, T., & Murray-Harvey, R. (2013) Facilitating problem-based learning in teacher education: Getting the challenge right, *Journal of Education for Teaching*, *39*(2), 169-180.

Rillero, P., Koerner, M., Jimenez-Silva, M., Merritt, J., & Farr, W. (2017). Developing teacher competencies for problem-based learning pedagogy and for supporting learning in language-minority students. *Interdisciplinary Journal of Problem-Based Learning*. *11*(2).

Rillero, P., & Camposeco, L. (2018). The iterative development and use of an online problem-based learning module for preservice and inservice teachers. *Interdisciplinary Journal of Problem-Based Learning, 12(1).* https://docs.lib.purdue.edu/ijpbl/vol12/iss1/7/

Rillero, P. & Hernandez, J. (April/May 2016). Problem-based enhanced-language learning with Pendulums. *Science Scope*, *39*(8), 10-15.

Rillero, P., Thibault, M., Merritt, J., & Jimenez-Silva, M. (2018). Bears in a boat: Science content and language development through a problem-based learning experience. *Science Activities, 55*(1) http://dx.doi.org/10.1080/00368121.2017.1406323

Strauss, A., & Corbin, J. (1990). Open coding. In A. Strauss & J. Corbin (Eds.), *Basics of qualitative research: Grounded theory procedures and techniques* (2nd ed.), pp. 101–121). Thousand Oaks, CA: Sage.

Shin, H. B., & Kominski, R. A. (2010). *Language use in the United States: 2007.* Retrieved from http://www.census.gov/prod/2010pubs/acs-12.pdf

Strevy, D. (2014). Focus on teacher education: Project-based learning; is there a problem-based difficulty? *Childhood Education*, *90*(6), 462-465. https://doi.org/10.1080/00094056.2014.983026

Torp, L., & Sage, S. (2002). *Problems as possibilities: Problem-based learning for K-16 education*. Alexandria VA: Association for Supervision and Curriculum Development.

Wirkala, C., & Kuhn, D. (2011). Problem-based learning in K-12 education: Is it effective and how does it achieve its effects? *American Educational Research Journal*, *48*(5), 1157-1186. http://dx.doi.org/10.3102/0002831211419491

Wright, W. (2015). *Foundations for teaching English language learners: Research, theory, policy, and practice* (2nd ed.). Philadelphia, PA: Caslon Publishing.

Zubaidah, S. (2005). Problem-based learning: Literature review. *Singapore Nursing Journal*, *32*(4), 50-55.