2018-05

Problem-based learning: Mathematical knowledge, assessment and competencies

Koh, Kim

Problem-Based Learning, Mathematical Knowledge, Assessment, and Competencies

Kim Koh, Olive Chapman, Ali Abidi, Zulay Diaz

Werklund School of Education

University of Calgary Postsecondary Conference on Teaching and Learning
May 2, 2018

The Global Context

- The rapidly changing, global workplace has led to a high demand for graduates who possess not only excellent disciplinary knowledge, but also additional competencies that reflect their ability to think out of the box and to work independently as well as with others in solving complex problems – Students as Creators, Drivers, Innovators, and Collaborators.

- Hence, developing students' competencies across the curriculum has become a priority in many higher education institutions (Anderson, 2017) and instructors are urged to infuse competence-based learning into the courses they teach and to adopt innovative pedagogical approaches that provide university students with authentic learning experiences to develop and master competencies.

The Alberta Context

- “Provincial curriculum is the starting point for teachers to apply their professional judgement to plan and design equitable student learning experiences that capitalize on students’ engagement and motivation by taking into account their interests, abilities, preferences and backgrounds, as well as local contexts. Such learning experiences broaden perspectives and enable students to create opportunities, challenge the status quo, take initiative to achieve their dreams, and take action to create a better world. Through the study of subjects that reinforce literacy and numeracy and develop competencies through learning outcomes, students use their abilities to communicate respectfully, synthesize ideas, collaborate with others, think critically and solve complex problems” (Alberta Education, 2017).

- The American Association of Colleges for Teacher Education (AACTE) and the Partnership for 21st Century Skills (2010):

  "New teacher candidates must be equipped with 21st century knowledge and skills and learn how to integrate them into their classroom practice for our nation to realize its goal of successfully meeting the challenges of this century" (p. 3)

- The inclusion of 21st century knowledge and skills formally into teacher preparation programs is of paramount importance.

- Teacher preparation programs play an essential role not only in helping all student teachers learn how to design curriculum and assessment that align well with the 21st century standards, but also in developing their professional competencies.

- Biggs (1999): the importance of aligning learning goals/outcomes (curriculum), teaching and learning activities (pedagogy) , and assessment tasks (assessment).

- If we intend our student teachers to be assessment literate—be competent in the design and use of innovative assessment methods to enable K-12 students in Alberta to master disciplinary knowledge and to develop competencies, we instructors need to model exemplary pedagogical and assessment practices to student teachers.

UNIVERSITY OF CALGARY

- In this interactive session, we intend to initiate a dialogue on how problem-based learning (PBL), a learner-centered pedagogical approach, can be used to maximize authentic learning opportunities for undergraduate students (i.e., student teachers) to develop their mathematical knowledge, assessment literacy, and professional competencies (e.g., critical thinking, creativity and innovation, complex problem solving, self-directed learning, collaboration, and communication).

Problem-Based Learning

- Problem-based Learning (PBL) has long been touted as an effective pedagogical approach to promote undergraduate students' authentic learning and development of disciplinary knowledge and professional competence.

- It has been widely used in the fields of medicine, nursing, engineering, and social sciences.

- In line with social constructivist learning theory, PBL is characterized by students' collaborative engagement in solving real-world, ill-defined problems that are embedded within authentic assessment tasks (Barrows, 1986; Barrows & Tamblyn, 1980; Biggs, 1999; Koh & Tan, 2016).

Ten Principles for the Design of PBL Curricula

- Barrows (1986):
  - Students must have responsibility for their own learning (Self-Directed Learning)
  - The problem scenarios/simulations used in PBL must be ill structured and enable independent inquiry (Critical Thinking)
  - Learning should be integrated from a wide range of disciplines or subjects (Disciplined Inquiry/ Transdisciplinary Inquiry)
  - Student collaboration is essential (Collaboration)
  - What students learn during their self-directed learning must be applied to the problem with reanalysis and resolution (Critical Thinking and Problem Solving)

Assessment in PBL

- Biggs (1999): the importance of aligning curriculum objectives, teaching and learning activities, and assessment tasks in PBL
  - "The essential feature of a teaching system designed to emulate professional practice is that the crucial assessments should be performance-based, holistic, allowing plenty of scope for students to input their decisions and solutions" (p. 210)
- The use of authentic assessment tasks (i.e., performance assessments that are authentic) to promote student learning and mastery of professional competencies in higher education is essential in an era of competency-based education across the globe.

Four Features of Authentic Assessment

- Wiggins (1989):
  - Authentic tasks truly represent performance in the field – contextualized, complex intellectual challenges. Students' own research or application of knowledge in messy, ill-structured tasks promotes critical thinking, problem solving, innovation and creativity
  - Explicit performance criteria and standards as presented in the form of well-developed rubrics
  - Self-assessment – a formative assessment or assessment for learning promotes students' self-directed learning and lifelong learning
  - Students are expected to present and defend their work to a real audience → communication, confidence

The Five Problems and Three Learning Tasks in EDUC 456 Winters 2016 and 2017

Problem	Learning Tasks (Authentic Assessments)
Developing an Assessment Tool Box: Considering Balance and Purpose	Learning Task 1: Part 1 – Individual Work: Assessment Glossary
Assessment for Learning	Learning Task 1: Part 2 – Group Work: An Infographic on the Concepts of Assessment of Learning, Assessment for Learning, and Assessment as Learning
Developing High Quality Assessment Tasks	Learning Task 2: Part 1 – Group Work: Review, Critique, Redesign or Design of A Performance Assessment and Its Associated Rubrics
Developing High Quality Rubrics to Enhance Student Learning	Learning Task 2: Part 2 – Individual Work: A Written Paper on Your Review, Critique, Redesign or Design of A Performance Assessment and Its Associated Rubrics
Grading and Reporting	Learning Task 3: Part 1 – Group Work: Deconstructing and Analyzing A Report Card Learning Task 3: Part 2 – Individual Work: A Formal Written Report for Advocating the Use of Your Group's Report Card at the School District Level

UNIVERSITY OF CALGARY

An Example

Grade 6 Mathematics Authentic Assessment

Identify Learning Outcomes

Three Essential Questions:

- What do I want my students to learn within this topic/lesson/unit?
- What can my students currently understand and do (perform)?
- What do I want my students to understand and be able to do based the Big Ideas and specific outcomes in the mathematics programs of study?

Guidelines for Quality Assessment Design (Koh, 2011)

Determining the Purposes and Functions of your Assessment

- Will you intend to use the assessment for teaching and assessing higher-order learning outcomes?
- Will you use the assessment information for diagnostic, formative and/or summative assessment?
- Will there be self- and/or peer-assessment to take place in the process of learning?

Identifying Learning Goals/Objectives/Intentions/Outcomes

- What are the types of knowledge, concepts, skills, processes, values, attitudes (or learning outcomes/content standards in the syllabus) you intend your students to learn and demonstrate through this assessment?

Selecting the Type of Authentic Assessment

- Is the authentic assessment a project/performance task/class discussion/reflection journal/online forum, etc.?
- Will you assess both written work and oral presentation?
- What is the time frame for the completion of the assessment tasks?
- Will the assessment tasks involve students in individual work and/or group/pair work?
- To what extent will students be given control over the task parameters (e.g., choice over questions, length of responses, use of procedures/ tools/ resources, etc.)?

UNIVERSITY OF CALGARY

Contextualizing the Assessment Tasks

- What real-world issues and problems can help contextualize the assessment tasks?
- Does the context of assessment give personal meaning and value beyond the classroom so as to engage students in the completion of the tasks?

Determining the Criteria of the Rubrics

- What criteria, related to the identified goals/objectives/ intentions/outcomes, will be used to evaluate student products or performances and processes?
- How many levels of performance will be used to describe the performance standards?
- Will you prepare exemplars to exemplify each level of performance?
- Will your students be allowed to negotiate the criteria with you?

Criteria for Authentic Intellectual Quality

- Newmann and Associates (1996), authentic assessments provide students with ample opportunity to engage in high quality intellectual work.

- Three broad criteria for authentic intellectual work:
  - Construction of Knowledge: using or manipulating knowledge as in analysis, interpretation, synthesis, and evaluation, rather than only reproducing knowledge in previously stated forms.
  - Disciplined Inquiry: gaining in-depth understanding of limited topics, rather than superficial acquaintance with many, and using elaborated forms of communication to learn and to express one's conclusions.
  - Value Beyond School: the production of discourse, products, and performances that have personal, aesthetic, or social significance beyond demonstration of success to a teacher.

Newmann & Associates' (1996) Criteria for Authentic Intellectual Work	Koh's (2011) Criteria for Authentic Intellectual Quality (AIQ)
Construction of Knowledge	• Depth of Knowledge (Factual Knowledge, Procedural Knowledge, Advanced Concepts) • Knowledge Criticism (Presentation of Knowledge as a Given, Comparing and Contrasting Information, Critiquing Information) • Knowledge Manipulation (Reproduction, Organization, Interpretation, Analysis, Synthesis, and/Evaluation, Application/Problem Solving, Generation or Construction of Knowledge)
Disciplined Inquiry	• Extended Communication (Oral and Written)
Value Beyond School	• Making Connection to Real World beyond the Classroom

- Student Work Sample

UNIVERSITY OF CALGARY

Mathematics knowledge for teaching

- **Specialized content knowledge (SCK)**
  - Knowing alternative meanings/approaches/interpreta-tions of a mathematics concept or procedure [65−18]
- **Knowledge of content and teaching (KCT)**
  - Knowing instructional advantages of different repre-sentations; what mathematical representations to use with students and which of those representations are likely to be understood and misunderstood by students
- **Knowledge of content and students (KCS)**
  - Knowing the ways students understand the content; students' mathematical thinking and alternative approaches [65 – 18 = 53]

Which of these students is using a method that could be used to multiply any two whole numbers?

a.
$$\begin{array}{r} 35 \\ \times\ 25 \\ \hline 125 \\ +\ 750 \\ \hline 875 \end{array}$$

b.
$$\begin{array}{r} 35 \\ \times\ 25 \\ \hline 175 \\ +\ 700 \\ \hline 875 \end{array}$$

c.
$$\begin{array}{r} 35 \\ \times\ 25 \\ \hline 25 \\ 150 \\ 100 \\ +\ 600 \\ \hline 875 \end{array}$$

Which of these do you think students learning this form of addition will have the most difficulty doing?

(A)	523	(B)	593	(C)	586	(D)	586
	+ 25		+ 25		+ 25		+325

(e)	**523**	(f)	**523**	(g)	**523**
	+25		+25		+25
	748		948		48

UNIVERSITY OF CALGARY

a. 47	b. 16	c. 56	d. 35
+ 86	+ 48	+ 78	+ 46
123	91	1214	171

- A teacher provided the following situation in her third-grade class:
- ***I was at a store and I saw that chocolate kisses come in bags of 42. I wanted to share these kisses among 7 people. How many kisses would each person get?***
- Following are the steps Pat told his teacher he had performed mentally to solve the problem. The teacher's follow-up questions confirmed that Pat's steps reflected a deep understanding of the problem situation.
- 4 x 10 = 40
- That is three 4s too many, so I have 12 left over.
- 12 + 2 = 14
- 14 ÷ 2 = 7
- 4 + 2 = 6. So 42 ÷ 7 = 6

- How does each of Pat's steps make mathematical sense in this context?
- Use Pat's approach to solve 56 ÷ 8

TIMSS fraction item

TIMSS is an international set of tests on mathematics and science which is given every four years to a sample of students in grades 4 and 8.

Here is one item on fractions: TIMSS--2011; Item M 052228

- Which shows a correct method for finding 1/3 – 1/4?
- A (1 – 1)/(4 – 3)
- B 1/(4 – 3)
- C (3 – 4)/(3*4)
- D (4 – 3)/(3*4)

	A	B	C	D
Average	25.4	26.0	9.4	37.1

	A		B		C	D
Average	25.4		26.0		9.4	37.1
Korea	2.7	6.9	4.2	86.0		
Singapore	4.8	5.5	6.5	83.1		
Taipei	2.9	7.7	7.0	82.0		
Hong Kong	4.0	8.7	10.0	77.0		
Japan	15.4	11.1	8.2	65.3		
Russia	12.3	18.8	4.8	62.8		
Australia	30.2	21.9	12.8	33.8		
US	32.5	26.1	10.7	29.1		
England	24.5	32.8	11.0	28.2		
Finland	42.3	29.5	8.7	16.1		
Quebec	27.3	23.0	13.0	33.0		
Ontario	27.7	22.4	14.0	32.5		
Alberta	34.7	23.7	12.3	27.8		

Name: Jeffrey

A. $3\frac{3}{8} - 1\frac{1}{2} = 2\frac{1}{8}$

B. $4\frac{2}{6} - 2\frac{1}{2} = 2\frac{1}{6}$

C. $2\frac{5}{6} - 1\frac{2}{3} = 1\frac{1}{6}$

D. $6\frac{1}{3} - 2\frac{4}{6} = 4\frac{2}{3}$

E. $4\frac{7}{8} - 1\frac{1}{4} = 3\frac{5}{8}$

F. $5\frac{3}{4} - 2\frac{1}{4} = 3\frac{2}{4}$

G. $3\frac{2}{3} - 1\frac{5}{6} =$

H. $7\frac{2}{9} - 3\frac{1}{3} =$