Cognitive Diagnostic Assessment and the Learning Errors and Formative Feedback (LEAFF) Model

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Presentation for the 11th Annual MARCES/MSDE Event on Informing the Practice of Teaching Using Formative and Interim Assessment: A Systems Approach
Oct. 20-21, 2011, University of Maryland, College Park, USA
Acknowledgments

- Social Sciences and Humanities Research Council of Canada (SSHRC Grant No. 410-2011-0811)
- Centre for Research in Applied Measurement and Evaluation (CRAME)
The story is well known as are the statistics

Plethora of websites and videos on plight of student achievement, innovation & growth, and the public educational system

- *Waiting for Superman* in 2010 by David Guggenheim

- [http://www.youtube.com/watch?v=u9whOEr33UU](http://www.youtube.com/watch?v=u9whOEr33UU)
Informing Learning & Teaching Using Assessments
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- There are three tools we have to begin to address a solution:
  - These are tools to help shape student behavior and open opportunities for young people
  - Part of our accountability education system
Informing Learning & Teaching Using Assessments

- But we do not seem to know how to coordinate these tools
  - No Child Left Behind & Race to the Top
- It seems we are missing an ingredient in the mix – an affective aspect of learning – that might be necessary for any assessment to be a mirror of learning
- This affective aspect might spoil teaching and assessment:
  - *We teach* but many students fear making mistakes (Beilock & Carr, 2001; Cooper, 2007)
  - *We assess* but many students fear feedback and evaluation (Stiggins, 2008)
Audience Participation – Word Problem

- A cycle shop has a total of 36 bicycles and tricycles in stock. Collectively there are 80 wheels. How many bikes and how many tricycles are there?
Word Problem Solution

- One approach is:
  1) All 36 have at least two wheels for a total of $36 \times 2 = 72$ wheels
  2) There are 80 wheels in all, the eight additional wheels (80–72) must belong to 8 tricycles
  3) So there are $36 - 8 = 28$ bikes
Success from Apparent Failure

- Assuming we are right, how do we begin to tackle the fear?
  - How do we convince students that *making mistakes (apparent failure) is part of learning?* (Harmin & Toth, 2006)
  - How do we convince students that *assessment and feedback are not personal judgements but necessary aspects of learning?* (Daft, 2009)
- The answer is not to dispense with feedback or gloss over performance that needs to be corrected
- [http://youtu.be/0RP1sS8rMsQ](http://youtu.be/0RP1sS8rMsQ)
Success from Apparent Failure
Anatomy of Teaching

- Good teaching allows us to teach higher level thinking, problem solving, and innovation – and learning errors
  - Establishing a safe classroom environment that promotes learning
  - Sharing of learning outcomes/objectives to clarify the learning
  - Modeling questioning techniques
  - Communicating descriptive & formative feedback to clarify learning for students (Shute, 2008)
Anatomy of Learning

- Learning is risky because:
  - You *do not know* and are acquiring new knowledge and skills
  - Is time-consuming, involves deliberate practice, and feedback
  - Information-processing systems (brains) make mistakes as they converge on understanding and refining knowledge and skills
  - Mistakes help define the boundaries of new knowledge and skills
- Error represents a mistake, knowledge and skill gap, transitory failure, moment in time failure, and misconception that can be rectified
Anatomy of Assessment

- **Cognitive diagnostic assessment (CDA)** is based on learning scientific theory to **measure learning and achievement**
- **Formative assessment** is integrated with instruction to **provide information** to adjust teaching and facilitate student learning
- **Interim assessment** is administered during instruction to **measure acquisition of knowledge and skills** relative to goals
- **Summative assessment** is administered periodically to **measure** achievement at a given point in time
- **Balanced assessment** combines both summative and formative assessment to **collect information** about student learning and achievement
The objective of this presentation is to rethink how we coordinate teaching, assessment, and learning.

We propose that current practice in learning, teaching, and assessment does not emphasize or encourage students to feel free to make errors and, therefore, students:

(a) avoid making errors
(b) fail to explore the boundaries of new knowledge and skills
(c) misconstrue assessments (even formative) as a means of being judged

We need to rethink the role of errors and how they facilitate teaching, assessment, and learning.
Overview

- Summarize how learning errors/mistakes are conceptualized and addressed in CDA and formative assessments
- Describe errors and their role in learning
- Introduce the Learning Error and Formative Feedback (LEAFF) Model
- Conclude by discussing and summarizing key objectives and offering next steps and areas for further research
CDA and Formative Assessment

- Provide foundational information to teaching and learning
- CDA informs us where a student may be prone to making mistakes
- Formative assessment is an interactive process that allows for teachers to provide feedback to students and, in turn, modify their instruction to address learning errors
- CDA diagnoses errors and formative assessment provides us with a mechanism for remediating errors
Anatomy of Assessment

Cognitive Diagnostic Assessment

- CDA identifies/diagnoses knowledge and skills (errors)
- Formative assessment provides with a process to remediate errors in knowledge and skills
Four Elements of Formative Assessment

1. Identify the knowledge gap
2. Feedback
3. Student Involvement
4. Learning Progression
Identifying Knowledge Gap with CDA

- CDA helps to:
  - Assess prior knowledge and skill
  - Identify the knowledge and skill gap (Hattie & Timperley, 2007; Sadler, 1989)
- Gierl, Alves, & Majeau (2010) operationalized CDA using the Attribute Hierarchy Method
  - Grade 3 and 6 mathematics
Example of Operationalized CDA

- Grade 3 outcome “counting numbers, describing (extending) number sequences”
Four Elements of Formative Assessment

1. Identify the knowledge gap
2. Feedback (Formative – Shute, 2008)
3. Student Involvement
4. Learning Progression
Example of Formative Feedback

| Attribute Probability Estimates for Three Grade 3 Examinees with Different Total Scores |
|---------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Examinee                        | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     |
| Kevin Doe (4)                   | 0.97   | 0.96   | 0.84   | 0.07   | 0.01   | 0.00   | 0.00   | 0.00   |

### Skill: Apply skip counting by:

- Excellent
- Acceptable
- Needs Improvement

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Formative Feedback with FA

- Addresses the gap between *what student knows* and *what students need to know* to meet desired learning goals (Marsh, 2007)
- Is meaningful and timely feedback (Stiggins, 2007)
- Provides a roadmap in guiding the learning forward
- Is purposeful, directional, and informative in addressing learning error and creating safe environment
- Directs student’s future actions in productive ways (Wiliam, 2010)
Little Sarah (Alberta Assessment Consortium, 2006)
Interim Summary – Connecting CDA and FA

- Link between CDA and formative assessment as gateways to identifying and addressing errors
- We propose that CDA and FA also provide a process that begins to lessen the fear of making errors
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Errors and Role in Learning

- Why do we need to have a stronger learning focus on errors?
- How do we teach students to perceive errors as part of learning?
  - It is from making errors that real learning and success emerges (Stevenson & Stigler, 1992)
Definition of Error

- Straying from the existing standard through failure (Merriam-Webster, 2011)
- State or condition of being wrong in conduct or judgment (Oxford Dictionary, 2011)

- Based on these definitions we propose a learning error is a:
  - mistake
  - knowledge and skill gap
  - transitory failure
  - moment in time failure
  - misconception in the learning process that can be rectified
Error and Learning

- Negative connotation associated with making *error* is an impediment on student learning (Lorenzet, Salas, Tannenbaum, 2005)
  - The greatest fear reported by students is making a mistake in a whole class setting (Willis, 2010)
  - Consequence of fear of error is low participation, but participation is one of the keys to learning (Willis, 2010)
  - Students will avoid work instead of risking being wrong
Error and Fear

- Praise is a strategy used to encourage learning, however false praise can encourage children to fear mistakes (Dweck, 2008)

- We propose a need to embrace error in a more positive way in light of how we learn
  - Practice makes permanent
  - Brain-based learning
Practice makes Permanent (Willis, 2010)

- Consider an infant or a child learning to walk or ride a bike. These skills are acquired through error, guidance, instruction, and formative feedback.
Brain based learning

- “Neuroplasticity constructs neural networks [expectations about the world and environment], but without active participation and making mistakes, faulty networks will not be revised. That faulty foundation can severely restrict future learning” (Willis, 2010; Lawson, 2004)

- The brain learns by making mistakes, not by memorizing right answers (Jensen, 2008)

- Errors are a natural part of learning, we propose error is a critical part of the learning process
Errors and Learning Environments

- How can more positive attitudes be fostered about learning errors?
  - Safe learning environments
  - CDA correctly identifies students’ knowledge and skills
  - Formative assessment strategies provide an avenue for students to feel comfortable revealing and addressing learning errors
Error and Culture

Western culture interpret error as an indication of “failure in learning the lesson” (Stigler & Stevenson, 1991, pg. 44)

Eastern culture errors are an index of “what still needs to be learned” (Stigler & Stevenson, 1991, pg. 44)
We propose:

- Embrace learning errors as a critical part of learning process
- Acknowledge errors as “opportunities for learning” instead of “examples of failure”
Anatomy of Teaching, Learning, and Assessing

- Errors influence the refinement of teaching
- Errors should be an accepted component of the education process
- Errors are clarified through assessment
- Errors inform the learning process

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LEAFF Model

- The Learning Errors and Formative Feedback (LEAFF) Model builds on the anatomy of teaching, learning, and assessment – 3 parts
  - *Teacher instruction* (context & IVs) regarding role of errors in learning (Ohlsson, 1996; Schank, 1986)
  - *Students’ mental models and formative feedback* (cognition & emotion) related to the learning environment (Johnson-Laird, 2004)
  - *Observed performance* (DV*s) on assessments and effect of discussing errors and safe classroom environments
  - Few attempts to generate models of learning from errors (Ohlsson, 1996)
LEAFF Model

Teaching/instructional context

Students’ mental models and feedback

Hypotheses about student performance
Instruction

- **Pedagogical value of learning errors**
  - Schank's (1986) theory of failure-driven learning
    - failed expectations trigger tweaking – improved learning
  
- Ohlsson (1996) review of learning errors
  - learners must be aware of errors to learn
  - learners explain to themselves what went wrong
  - if the performance is incorrect, then the underlying knowledge and skills must be tweaked
Instruction

INSTRUCTION

Teacher – Discussion of anatomy of learning and necessity of errors/failures
CDA

Teacher – NO discussion of anatomy of learning and necessity of errors/failures (default)
Students’ Mental Models

- Individuals base inferences and actions on mental representations (Johnson-Laird, 2004)
  - Models include domain knowledge and skills disseminated in instructional context and emotional evaluation
    - Mastery goals if learning context is deemed safe
    - Performance goals if learning context is deemed unsafe
  - Feedback – formative or feckless – depends on the instructional context & not on the assessment
    - Formative feedback will positively influence mental models of learning and observed performance when safe to make errors
Students’ Mental Models

FORMATIVE FEEDBACK
Increasing instructional relevance for student

Mental model schema of learning risk alongside information processing of instructional lesson

Emotional evaluation of learning context – Is it SAFE?
YES or NO

YES – learning environment is SAFE
Mastery goals and display of learning errors

FECKLESS FEEDBACK
Decreasing instructional relevance for student

NO – learning environment is UNSAFE
Performance goals and avoidance of errors

Assessment Performance
Observed Performance

- Mental models influence transparency of learning on assessments
  - Implications on measured learning from different instructional context and associated mental models

Performance on any kind of assessment is more transparent

1. More errors on first order assessments (formative)
2. Greater student innovation and experimentation
3. Higher level thinking skills
4. Higher interest and motivation
5. Fewer errors on second, third-order assessments (interim & summative)

Performance on any kind of assessment is more opaque

1. Fewer errors on first order assessments (formative)
2. Lesser student innovation and experimentation
3. Lower level thinking skills
4. Lower interest and motivation
5. More errors on second third-order assessments (interim & summative)
Discussion

- What is our objective?
  - Improved student learning outcomes....

- How do we get there?
  - Assessment
  - Learning
  - Teaching
Discussion

- Assessment
  - CDA, formative, *interim*, and even summative must be mirrors of what students:
    - Have learned in the past
    - Are learning right now, and
    - Can be learning in the future
  - These mirrors must be psychometrically defensible but they also require that students allow their learning to be seen
Discussion & Conclusion

- Testing the LEAFF model – next steps
- Learning and Teaching
  - Learning is risky
  - Teachers cultivate safe classroom environments
    - Facilitate all assessment as mirror of student learning
    - Discuss importance of errors and role in learning
    - Shape healthy student mental models of learning
    - Facilitate student mastery orientations
Thank you.

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