Assessing Teaching Critical Thinking with Validated Critical Thinking Inventories: The Learning Critical Thinking Inventory (LCTI) and the Teaching Critical Thinking Inventory (TCTI)

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Abstract

Critical thinking is viewed as an important outcome of undergraduate education by higher education institutions and potential employees of graduates. However, the lack of clarity and inadequate assessment of critical thinking development in higher education is problematic. The purpose of this study was to develop instruments to assess the competence of faculty to develop critical thinking of undergraduate students as perceived by students and by faculty themselves. The measures of critical thinking teaching were developed in two phases. Phase I focused on development of critical thinking items while Phase II focused on initial validation of the critical thinking inventories. Six brief instruments were developed, all with high reliability and validity. Scale length ranged from 10 to 13 items. Four measures captured students' perceptions of learning critical thinking and constituted the Learning Critical Thinking Inventory (LCTI). Two scales were intended for faculty to assess their perceptions of the extent they facilitated learning critical thinking in their teaching, and these constituted the Teaching Critical Thinking Inventory (TCTI). The psychometric characteristics of the inventories meet high standards, the measures are sufficiently brief to make them suitable for repeated administration, and different parallel forms are of great value for multiple administrations.

Key Words: Critical thinking inventory, assess learning critical thinking, perceptions of learning critical thinking, evaluation of learning critical thinking, rapid assessment of learning critical thinking, critical thinking in higher education, validating measures on learning critical thinking.

I. Introduction

The development of students' critical thinking skills has been of great importance in education for the last thirty or more years. As early as 1980 the National Commission on Excellence in Education's publication *A Nation at Risk,* called for education reform to develop students' critical thinking skills (http://www2.ed.gov/pubs/NatAtRisk/index.html). More recently the Association of American Colleges and Universities (AACU, 2009) encouraged critical thinking that promotes civic engagement and focuses on real life problems. Despite this emphasis on critical thinking in higher education, there are no standardized instruments available to assess actual or perceived abilities of faculty to develop students' critical thinking skills. This article describes the development and initial validation of inventories to assess (a) student's perceptions of faculty's facilitation of their learning of critical thinking, and (b) faculty's perception of their teaching of critical thinking.

II. Literature Review

Critical thinking is viewed as an important outcome of undergraduate education by higher education institutions and potential employees of graduates. In a survey of institutions of higher education administered by AACU, critical thinking was identified as one of the common intended learning outcomes for all undergraduate students. The online 2008-2009 survey was sent to 906 member institutions and 433 or 48%

responded. The importance of critical thinking as an outcome was independently corroborated by business executives as one of five areas in need of increased emphasis by higher education institutions (AACU, 2009).

There is a link between higher education and critical thinking. The impact of higher education on critical thinking is often debated or the focus of study. For example, in a survey of 2,300 undergraduates at twenty-four institutions, Arum and Roksa (2011, pp. 36, 54) found that 45 percent of students failed to demonstrate significant improvement in critical thinking and complex reasoning during their first two years of college. The question arises of why, when the majority of students benefited from their first two years of college, a large group did not. Factors that directly contribute to critical thinking development in higher education were an area of scholarly emphasis in the 1990's, but more recently less attention has been given to this critical aspect. A recent search of the literature from 2005 – 2012 using the ERIC database and the key words of critical thinking and assessment or evaluation did not reveal any articles for review. Bensley and Murtagh (2012) support this finding in their discussion about the critical thinking literature containing few empirical studies on both skills and dispositions, with no studies thoroughly examining skills, dispositions and metacognition collectively. A manual review of references in the Bensley and Murtagh (2012) article did yield more recent articles for review. Therefore, this section summarizes the existing literature reviews, syntheses, and meta-analyses on critical thinking in higher education from 1987 to 2013.

Findings from a literature review on critical thinking facilitation by McMillan (1987), failed to uncover specific instructional or course conditions that enhanced critical thinking, but did support the general conclusion that college attendance improved critical thinking. In a more recent review, longer exposure to education was found to lead to higher critical thinking scores on standardized tests (Tsui, 1998). Also, the greatest gains in critical thinking happen during the freshman year and with full-time students (Tsui, 1998). However, critical thinking development does not happen without intentionality (Halpern, 1993) and a continuous concentration on the development of critical thinking (Bangert-Drowns and Bankert, 1990; Gellin, 2003). Pithers (2000) identified reflection and challenging current ideas as two strategies to enhance critical thinking. Most of the reviews and meta-analyses conducted the last 25 years, cited difficulties comparing individual studies because of differences in how critical thinking was defined and assessed (Bangert-Drowns & Bankert, 1990; Gellin, 2003; McMillan, 1987; Pithers, 2000; Tsui, 1998). However, a common theme from the reviews was that multiple experiences over time help to enhance students' critical thinking. It is therefore not a surprise that Halpern (1993) advocated a broad-based, cross-disciplinary approach to the development of critical thinking instead of a specific course approach. The overall effect of involvement in critical thinking across courses seems greater than the effect of any single activity on enhancing college students' critical thinking (Gellin, 2003).

The empirical literature shows that when critical thinking instruction is done well, students are more disposed to think critically and become more able thinkers (Halpern, 1993). However, the lack of clarity and inadequate assessment of critical thinking development in higher education remains problematic. Paul, Elder and Bartell (1997) interviewed 140 college faculty about their current knowledge and teaching practices related to critical thinking. Although 89% of the respondents indicated critical thinking was a primary objective of their instruction, only 19% could give a clear explanation of critical thinking and less than 10% could describe how to assess critical thinking or the development of critical thinking. Measures

Table 1 References Used to Create the Individual Critical Thinking Items

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to assess students' critical thinking skills and dispositions are available, including the Watson-Glaser Critical Thinking Appraisal (http://www.pearsonassessments.com/HAIWEB/Cultures/en-us/Productdetail.htm?Pid=015-8191-013), the California Critical Thinking Skills Test, and the California Critical Thinking Dispositions Inventory (http://www.insightassessment.com/). However, this is not the case for instruments intended to assess the aptitude of *faculty* to develop students' critical thinking abilities. The purpose of this study was to develop brief inventories to assess the competence of faculty to develop critical thinking of undergraduate students as perceived by students and by faculty themselves.

III. Methods

The critical thinking inventories were developed in two phases. The first was for

Table 2 Critical Thinking Themes

(1) The thinking process: Assists students to think about their thinking and improve the process of how learners think critically.

(2) The subject matter: Helps students to think critically about the subject matter, use the subject matter core concepts to think through issues and to address real world situations and problems.

(3) Clarity, logic and discipline: Assists students to be clear in their thinking, apply logic when reasoning out a position and think (on their feet) in a disciplined way.

(4) Multiple perspectives and "real" conclusions: Enables students to consider multiple perspectives in their subject matter and use critical thinking to arrive at conclusions they truly believe.

(5) Questions and illustrations: Helps students to know what good questions are when they learn and be able to identify good examples to illustrate their reasoning.

(6) Feelings and critical thinking: Enables students to explore their feelings when they think critically about the subject matter and appreciate the role of emotions in critical thinking.

(7) Dealing with evidence: Helps students to deal with contradictory evidence, to recognize the contradiction and arrive at a synthesis.

(8) Cultural diversity: Helps students realize how their perspectives are influenced by their own situation and identity, and assists them to recognize that others might have different experiences that shape their views.

(9) Noting connections and differences: Makes connections between concepts and issues related to subject matter and identifies differences.

(10) Model critical thinking: Demonstrates being explicit about assumptions, reasoning, inferences, being open to alternatives, and deciding on action.

(11) Respect, support and encourage learners: Shows respect to learners by, for example, listening attentively to their questions, being supportive of their efforts to learn and encouraging learners to take action based on their thinking.

(12) Real world problems: Applies critical thinking skills to real world problems.

(13) Engagement and reflection: Engages learners in learning and helps them reflect on their learning.

(14) Strategies and opportunities: Provides learners with strategies to become critical thinkers and opportunities to practice their skills.

(15) Regularly evaluate and give feedback: Regularly evaluates the critical thinking of learners and provides helpful feedback.

(16) Analyze, organize and test the soundness of ideas: Helps learners to organize ideas, analyze them and test the soundness of their own ideas and those of others.

the creation of critical thinking items, while the second looked at initial validation of the inventories. Although several theoretical frameworks exist for critical thinking, there are none available for the *teaching* of critical thinking. In the absence of a theory for teaching critical thinking, the creation of items was informed by approaches that prominent scholars have taken to teach critical thinking. The study was approved by the university's Institutional Review Board in 2011. During Phase I, specific themes were developed based on:

(1) the available literature on the teaching of critical thinking (See Table 1) and

(2) two workshops by experts on teaching critical thinking.

The themes were re-written as statements about faculty behaviors directed at facilitating critical thinking in students. For example, the statement for the theme of "subject matter" was "Helps students to think critically about the subject matter, use the subject matter core concepts to think through issues, and address real world situations and problems" (See Table 2).

The themes were sent to 39 experts on critical thinking. The 12 who responded (31%) were satisfied with the range of themes identified, and were helpful in adding richness to the description of some themes.

A list of 60 items was compiled to represent the themes. Two stem questions were used to elicit responses on a five-point Likert scale, from "Did not help me at all" to "Helped me greatly." They were: "The instructor or course helped me to ..." and "How often did the instructor ...?" Some items were refined after discussions with critical thinking experts and faculty. Nine (15%) of the items were stated negatively to minimize response set bias. The items were reviewed for readability by three undergraduate students (two female and one male). Minor changes were made to two items based on student comments. A cross-reference table in the form of a topical map of "items by dimension" was compiled to ensure that each theme of critical thinking was covered by at least three items. In the final tally, there were a total of 61 items in the Learning Critical Thinking Inventory (LCTI).

During Phase II, the LCTI was administered to undergraduates with at least one semester at the university. Analyses focused on determining whether the construct "learning critical thinking" comprises one or more dimensions. This validation study included factor analysis, internal consistency determination using Cronbach alpha, and validity analysis, relying on various item correlations and diagnostics. Additionally, a separate inventory for faculty was developed and validated.

IV. Student Validation Results for the LCTI

Invitations to complete the LCTI online were sent to 10,716 undergraduates, 367 of whom responded (3.4%). There were never more than 3 missing responses on any single item, and fewer than 1% (.25%) blank responses overall. In those cases, missing responses were replaced by the mean.

By doing a Principle Axis Factor Analysis (PAF) with a Varimax rotation of the 61 items, three factors were found to explain 63% of the variance. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .978, indicating that the sample size was adequate for the analysis. As Bartlett's test of sphericity was highly significant ($p<0.001$), it was concluded that the strength of the relationship among variables is strong and that it is appropriate to use factor analysis on the data.

The first factor consisted of 34 items, with loadings between .548 and .782. The second factor had 23 items with loadings between .384 and .759, and the third factor 5 items with loadings between 0.452 and 0.724. Reliability of the first and second factors was very high, 0.984 and 0.959 respectively. Except for one, all items with high loadings on the first factor correlated with the total scale score (>.60), which is an indicator of validity. Not one item, if deleted, would improve alpha. Of the 23 items comprising the second factor, 20 correlated highly with the total test score. The third factor had lower reliability, as indicated by a Cronbach alpha of .75, and it had lower than desirable inter item correlations, with the lowest correlation coefficient per item ranging between .233 and .382. Only one of the five items correlated higher than .60, and three items came in lower than .50 with the total scale score. All the items with high loadings on the third factor were negatively worded. The third factor was then eliminated from further analysis along with other items that had low corrected item-total correlations. Fifty-three items remained for further analysis, 33 with high loadings on factor one and 20 on factor two.

Before ceding that the solution involved two factors, other interpretations of the factor structure of the remaining items had to be considered. An alternative explanation was more plausible, namely, that the way the questions were phrased caused questions with similar formats to group together in the factor analysis. In factor analysis this is known as response set bias. The items forming each of

Table 3: Reliability, Validity and Correlation of the initial formats of the Learning Critical Thinking Inventory (LCTI)

Learning Critical Thinking Measures (Eigenvalues of single factor extracted, Variance Explained)	Reliability: Cronbach α	Validity: Mean corrected item-total correlation	Mean (SEM)	Pearson's Correlation
Learning Critical Thinking - A (12 items) (Eigenvalue=7.873, V.E.=65.61%)	.952	.769	3.732 (3.289)	A-B .967*
Learning Critical Thinking - B (12 items) (Eigenvalue=7.905, V.E.= 65.87%)	.952	.769	3.641 (3.265)	A-C .962* A-D .965*
Learning Critical Thinking– C (13 items) (Eigenvalue=8.379, V.E.= 64.46%)	.954	.764.	3.675 (3.330)	B-C .970* B-D .966*
Learning Critical Thinking– D (12 items) (Eigenvalue=7.809, V.E.=65.07%)	.951	.764	3.646 (3.285)	C-D .966*

*p<.001

the dimensions of LCTI corresponded with the following two stem questions: "The instructor or course helped me to: …""and "How often did the instructor…" Generally speaking, the first question attempted to measure the extent to which critical thinking was learned, and the second the frequency with which learning occurred. All of the items of the first factor were from the list of items under the first type question, and all the items that loaded on factor two were from the second type question. Items that loaded on both factors covered similar content, and there were no other obvious differences between these two groups of items.

Another approach to resolving the uncertainty is to do a second-order factor analysis using the two factors as the variables. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .50, which indicates that the sample size was adequate for the analysis. The Bartlett's test of sphericity was highly significant ($p<0.001$). Communality value was .738, and a scree plot clearly showed that the two items loaded on one factor and had an eigenvalue of 1.86. The factor loadings of both items were .926. This means that the two factors represent an overarching construct and provide further evidence that the two-factor solution may be due to response set bias. Since both approaches support the unidimensionality of factor 1 and factor 2 combined, it was decided to continue the analysis by establishing the psychometric characteristics of the 53-item inventory.

The 53-item measure was highly reliable (Cronbach alpha=.981). Developing a rapid assessment instrument for a large number of items can add to the response burden. Too many items make an instrument less suitable for multiple administrations and for omnibus-type evaluations of more than one measure. In an attempt to reduce the number of items without compromising reliability and validity, the 53 items of factor one were divided into four groups by allocating items systematically and alternately to four different formats, called LCTI A, B, C, and D. Form A had 14 items and the other formats 13. The rationale for this approach was this: If each scale had acceptable reliability and validity—and if each scale correlated highly with the others—then

Table 4: Reliability, Validity and Correlation of different formats of the final Learning Critical Thinking Inventory (LCTI) and Teaching Critical Thinking Inventory (TCTI)

Learning Critical Thinking Measures (Eigenvalues of single factor extracted, Variance Explained)	Reliability: Cronbach α	Validity: Mean corrected item-total correlation	Mean (SEM)
Learning Critical Thinking-A (11 items) (Eigenvalue=7.873, V.E.=65.61%)	.949	.771	3.748 (2.354)
Teaching Critical Thinking-A (11 items) (Eigenvalue=6.008, V.E.=54..61%)	.913	.706	4.007 (2.376)
Learning Critical Thinking-B (10 items) (Eigenvalue=7.905, V.E.= 65.87%)	.951	.792	3.707 (2.107)
Teaching Critical Thinking-B (10 items) (Eigenvalue=5.933, V.E.= 59.33%)	.920	.672	3.926 (2.248)
Learning Critical Thinking–C (13 items) (Eigenvalue=8.379, V.E.= 64.46%)	.954	.764.	3.675 (3.330)
Learning Critical Thinking–D (12 items) (Eigenvalue=7.809, V.E.=65.07%)	.951	.764	3.646 (3.285)

*p<.001

the various formats may be used as parallel format scales in rapid assessment. To increase reliability, one item was dropped from LCTI A, B, and D in subsequent internal consistency analysis. An additional item was deleted from Form A to ensure that all squared multiple correlations of items were higher than .5 and validity coefficients (corrected item-total correlation) higher than .60.

The scales were all found to be highly reliable and similar to each other, with scores ranging from .951 to .954. The validity of the results was also found to be much higher than the (high) standard of .60, with the mean-corrected item total correlation ranging from .764 to .769. The mean score of the four measures on the 1-5 Likert scale was 3.732, 3.643, 3.675 and 3.646 respectively. All four formats correlated significantly ($p<.001$) and highly with one another, having Pearson's correlations of at least .962. The standard error of measurement of the four scales was very similar, ranging between 3.265 and 3.330. In a factor analysis, the unidimensionality of each of the four scales was confirmed by relatively high eigenvalues of the only factor extracted (between 7.8 and 8.4) and a relatively high percentage of variance explained (between 64.5% and 65.9%) (See Table 3).

V. Faculty Validation Results for the TCTI

Forms A and B of the Learning Critical Thinking Inventory were administered by electronic survey to a sample of faculty. To reduce response burden on faculty, only two formats of the learning inventory (A and B) were included, and the wording of instructions was adjusted, for example, changing "*The instructor* helped me to think about *my* thinking" to "*I* helped my students to think about *their* thinking." The revised versions are referred to as the Teaching Critical Thinking Inventory (TCTI) Forms A and B.

The sampling frame consisted of 724 faculty who taught at least one course in the spring of 2011 and (to prevent survey

overload or saturation) who were not part of a university-wide survey on community engagement. A 20% response rate was obtained. One respondent opened the link but did not answer any questions, and another left 25% of the questions blank. Both were deleted from the database. Missing answers were otherwise only 0.13% and were evenly distributed across respondents, with no single respondent failing to answer more than one question. Missing data was replaced using item mean replacement.

A PAF of the 12 items of the TCTI-Form A revealed that a single factor explained 53% of the variance. The 12 items loaded on one factor, with an eigenvalue of 6.36. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .921, indicating that the sample size was adequate for the analysis. The Bartlett's test of sphericity was highly significant ($p<0.001$). The factor loadings were between .628 and .793. Reliability was 0.917. All but one item correlated highly with the total scale score (>.60). One item, "Better understand critical thinking related vocabulary," correlated 0.57 with the total scale score and had a low correlation (<.30) with one other item. By removing the first-mentioned item, validity was increased validity while reliability was compromised only slightly— 0.691 to 0.706 and 0.917 to 0.913, respectively. It was therefore decided to delete the item. The final 11 items loaded on one factor in a PAF, which explained 55% of the variance.

A PAF of the 12 items of the TCTI Form B identified one factor that explained 54% of the variance. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy was .916, indicating an adequate sample size for the analysis. As the Bartlett's test of sphericity was highly significant ($p<0.001$), it was concluded that the strength of the relationship among variables was strong and that factor analysis was appropriate for the data. The factor loadings were between .540 and .840. Reliability was 0.917. Only two items failed to correlate highly with the total scale score (>.60). The correlation of these two items wasn't consistently high with any other item (>.30). The two items were: "Model how to think by 'thinking out loud'" and "Better understand the role of emotions in critical thinking." The first of these two items differed from other items in the sense that it referred to a technique for improving critical thinking; all the other items focused more on the outcome of critical thinking. The second item, "Better understand the role of emotions in critical thinking," was the cause of some discussion, as not all experts agreed that it was a core component of critical thinking. It was therefore decided to delete the two items. Reliability of the 10-item inventory was 0.92 and not one item out of the set would improve alpha if deleted. The mean-corrected item total correlation was 0.672. The 10 items loaded on one factor in a PAF, which explained 59% of the variance.

Reliability of the Teaching Critical Thinking Inventory scales was high and similar, 0.91 and 0.92. Validity was also much higher than the high standard of .60, with mean-corrected item total correlations of .706 and .672 for Forms A and B respectively. The mean scores on the 1-5 Likert scales of Form A and Form B were 4.007 and 3.926 respectively. TCTI-A and TCTI-B correlated significantly ($p<.001$) and highly ($r=0.921$) with one another. The standard error of measurement of the two scales was similar at 2.376 and 2.248. In a factor analysis, the unidimensionality of each of the two scales was confirmed by a relatively high percentage of variance explained (55% and 59%).

VI. Aligning the Learning (LCTI) Scales with the Teaching (TCTI) Scales

The extent to which learners and faculty agree about the extent that critical thinking is facilitated in education is of great interest in assessment and evaluation. Since it would be preferable to use the same measure to assess perceptions of students and faculty,

it was decided to reduce the 12-item student Form A measure by one item and Form B measure by two items in order to have exactly the same items in both student and faculty scales. The reliability of the two measures decreased very slightly (Form A from .952 to .949 and Form B from .952 to .951). At the same time, however, the validity increased from .769 to .771 for Form A and from .769 to .792 for Form B (See Table 4).

Error scores for both final LCTI scales were also lower (Form A from 3.289 to 2.354; Form B from 3.265 to 2.107). The mean score of the 11-item LCTI Form A on the 1-5 Likert scale was 3.748, slightly lower than the TCTI Form A, which was 4.007. Mean scores for LCTI Form B and TCTI Form B were 3.707 and 3.926 respectively. For both forms, the faculty rated their ability to facilitate critical thinking more highly than the student population. Appendix A presents the Form A for both the LCTI and TCTI. Caution should be used, however, when interpreting this result, as not all the student respondents were taught by the faculty respondents; the samples were independent but overlapping.

VII. Conclusion

The purpose of this study was to provide initial reliability and validity data on a Critical Thinking Learning Inventory. The psychometric characteristics of the four parallel forms of LCTI and of the two forms of the TCTI meet high standards. Reliability and validity coefficients are very high, their error measures are small and similar, and the measures are sufficiently brief to make them suitable for repeated administration. The availability of different parallel forms is of great value for multiple administrations.

Item Response Theory (IRT) analysis in future studies with larger sample size should compare the sensitivity and difficulty of items in the various formats. Such an analysis will likely enable the construction of even shorter parallel scales with equivalent difficulty levels. In addition IRT analysis offers the advantage of investigating item bias for different populations.

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Teaching Critical Thinking Inventory-A (TCTI-A) for faculty

(Cronbach α=.91; Mean corrected item-total correlation=.71)

I helped my students to:

Did not help them at all — Helped them greatly

1 2 3 4 5

1. ____Think about their thinking
2. ____Know what clear questions are when they learn
3. ____Identify specific examples to illustrate their reasoning
4. ____Consider multiple perspectives in my subject matter
5. ____Make logical connections when studying subject matter
6. ____Understand that their prejudices or biases influence their thinking
7. ____Work through complexities in issues without giving up

When you teach, how often do you:

Not at all — Very often

1 2 3 4 5

8. ___Support students when they try to show good thinking?
9. ___Ask questions that helped students think more carefully?
10. ___Encourage students to apply their insights to new or other situations?
11. ___Make students feel engaged in class and learning?

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Appendix A
Learning Critical Thinking Inventory-A (LCTI-A) for students

(Cronbach α=.95; Mean corrected item-total correlation=.77).

The instructor or course helped me to:

Did not help me at all — Helped me greatly

1 2 3 4 5

1. ____Think about my thinking
2. ____Know what clear questions are when I learn
3. ____Identify specific examples to illustrate my reasoning
4. ____Consider multiple perspectives in my subject matter
5. ____Make logical connections when studying subject matter
6. ____Understand that my prejudices or biases influence my thinking
7. ____Work through complexities in issues without giving up

How often did the instructor

Not at all — Very often

1 2 3 4 5

8. ____Support us when we try to show good thinking
9. ____Ask questions that helped us think more carefully
10. ____Encourage us to apply our insights to new or other situations
11. ____Make me feel engaged in class and learning