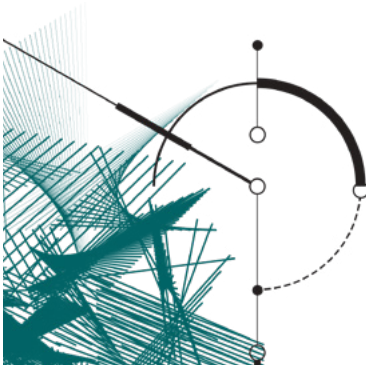


Notes in Brief

The aims of this study were to determine faculty's ability to accurately and reliably categorize exam questions using Bloom's Taxonomy, and if modified versions would improve the accuracy and reliability. Faculty experience and affiliation with a health sciences discipline were also considered. Faculty at one university were asked to categorize 30 sample exam questions using either Bloom's Taxonomy or one of two modified versions of Bloom's Taxonomy. Overall accuracy improved when a modified version of Bloom's Taxonomy was used. Collapsing the six categories of Bloom's into three (knowledge; comprehension and application; analysis, synthesis, and evaluation) showed higher levels of accuracy than when each category was collapsed with its neighbor. There was no difference between health science and nonhealth science faculty in accuracy. Overall interrater reliability was low regardless of experience or health science affiliation.

AUTHORS

Adam C. Welch, Pharm.D.
East Tennessee State University

Samuel C. Karpen, Ph.D.
East Tennessee State University

L. Brian Cross, Pharm.D.
East Tennessee State University

Brandie N. LeBlanc, Pharm.D.
Vanderbilt University Medical Center

A Multidisciplinary Assessment of Faculty Accuracy And Reliability with Bloom's Taxonomy

Published in 1956, Bloom's Taxonomy is a hierarchy of six categories (knowledge, comprehension, application, analysis, synthesis, and evaluation) that can be used to classify the depth of students' learning (Bloom, 1956; Krathwohl, 2002). While the taxonomy has maintained its hierarchal structure it has undergone several revisions and extensions including application in the affective and psychomotor domains, and, in 2002, a revision to better align the levels with their intended outcomes (Krathwohl, 2002). Due to its ability to classify the depth of learning, Bloom's Taxonomy can be applied when creating learning objectives for a course or when creating assessments but only to the extent of the accuracy and reliability of faculty use (Adams, 2015). Several findings call into question faculty ability to apply Bloom's Taxonomy. For example, faculty sometimes misalign their course objectives with the difficulty of exam questions. Misalignment commonly occurs when expectations of learning are at a higher level than the assessment questions that are written (i.e. the test is too easy; Momsen, Long, Wyse, & Ebert-May, 2010; Jideani & Jideani, 2012). Furthermore, faculty may not be formally trained in educational pedagogy (George, 2016; Engle et al., 2014).

Several colleges, especially in the health sciences, use an electronic platform to create, deliver, and assess exam questions. (ExamSoft For Your Program, 2017). This electronic testing platform allows for individual exam questions to be tagged to a particular outcome. Bloom's Taxonomy serves as one of those outcomes on this platform. By tagging questions to Bloom's faculty can identify potential areas of student weakness and consider curriculum changes if needed (Terry, 2016). However, this form of assessment is only effective if the faculty member can appropriately distinguish between the levels of Bloom's Taxonomy.

This study aimed to determine the accuracy and reliability of faculty's ability to use Bloom's Taxonomy to categorize sample exam questions. A secondary aim was to determine if other factors would have an effect on accuracy and reliability, such as having experience

CORRESPONDENCE

Email
welcha1@etsu.edu

with Bloom's Taxonomy or using a modified version of Bloom's. In fact, several collapsed versions of Bloom's Taxonomy have been described in the literature (Cecilio-Fernandes, Kerdijk, Jaarsma, & Tio, 2016; Igbaria, 2013; Kibble & Johnson, 2011; Phillips, Smith, & Straus, 2013). This study was completed at East Tennessee State University (hereby referred to as institution), an R3 doctoral university located in the southeast (Carnegie, 2017). Since this institution contains several health sciences colleges, another secondary aim was to assess whether being a member of a health sciences discipline would have an effect on accuracy and reliability.

Methods

This study aimed to determine the accuracy and reliability of faculty's ability to use Bloom's Taxonomy to categorize sample exam questions. A secondary aim was to determine if other factors would have an effect on accuracy and reliability, such as having experience with Bloom's Taxonomy or using a modified version of Bloom's.

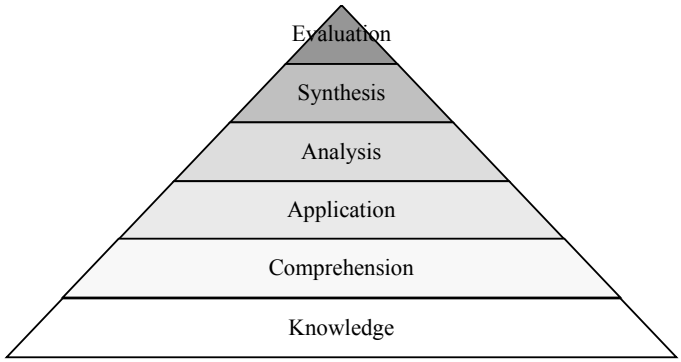
Three versions of the thirty-minute online survey were developed in Formstack (Formstack–Indianapolis, IN) and fielded to all faculty at the institution. This study was approved by the institutional review board. There were 1,202 faculty included in the sample. Academic Health Sciences Center (AHSC) faculty included nursing, public health, physical therapy, medicine, and clinical/rehabilitative health sciences. Non-AHSC participants were faculty from colleges of education, arts and sciences, business and technology, graduate and continued studies, and the honors college. The surveys were fielded for two weeks and email reminders were sent every four days.

Each version of the survey required participants to categorize 30 sample exam questions according to Bloom's 1956 Taxonomy. This taxonomy, rather than the 2002 revision, was used because it is included in the exam management software (Vandre & Ermie, 2017) used by several colleges at institution. The exam questions, which were written to be clear examples of each level of Bloom's Taxonomy, were taken from the teacher resources section of the University of California at Berkley's Center of Teaching and Learning Web site (University of California–Berkeley, 2015). See Table 1 for a subset of the questions used in the survey and their corresponding Bloom's levels. Participants were given one of three versions of the survey. The first version of the survey required participants to categorize each sample exam question to one of the original six levels of Bloom's Taxonomy (knowledge, comprehension, application, analysis, synthesis, and evaluation), hereafter known as Original. The second and third versions collapsed the categories by combining them into three categories. The three versions were called Original, Collapse One, and Collapse Two. Figure 1 outlines the original and modifications to Bloom's Taxonomy that were used in this study.

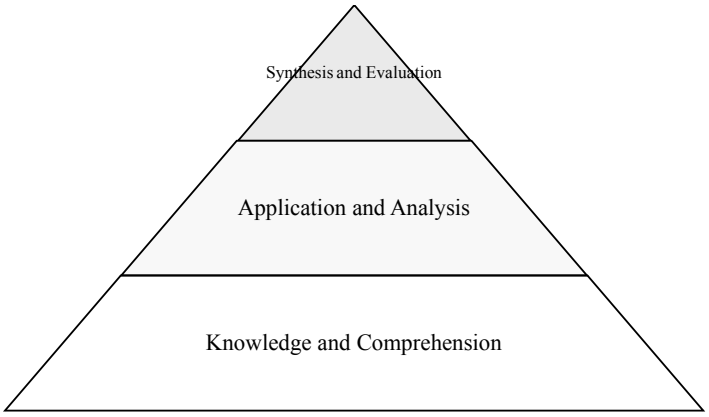
In all versions participants indicated whether or not they believed that they had categorized each item correctly. The Collapse Two version was based on Karpen and Welch (2016) who found that faculty tended to categorize knowledge items accurately but tended to confuse comprehension with application and analysis, synthesis, and evaluation with one another. The Collapse One version was based on other researchers who had merged each level of Bloom's with its neighbor (Plack et al., 2007; Gonzalez-Cabezas, Anderson, Wright, & Fontana, 2015). We sought to determine which collapsed scheme produced more accurate and reliable responses. Before categorizing the 30 items participants were provided with a brief explanation of Bloom's Taxonomy that included a description of each level and a corresponding example.

After categorizing the 30 sample exam questions participants estimated the number of items that they categorized correctly, reported their primary department affiliation, and reported how frequently they used Bloom's Taxonomy on a six-point scale (1=*Never* to 6=*At least once per week*; see Tables 2 and 3 for a demographic description of the sample). Krippendorff's alpha was used to determine the interrater reliability of the participant's classification. For this, greater than .600 is considered substantial and greater than .800 is considered almost perfect (Landis & Koch, 1977; Krippendorff, 1970).

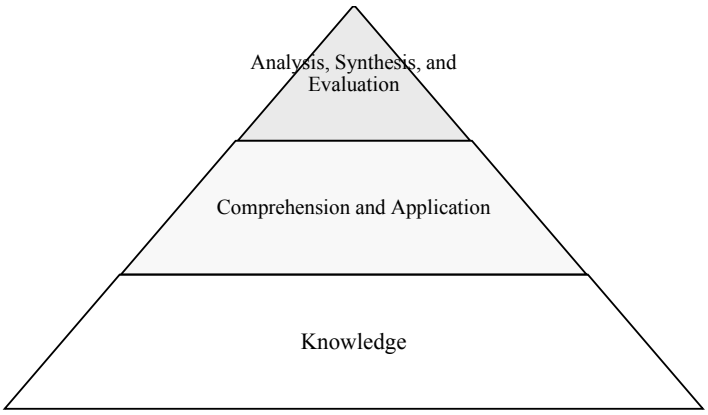
Figure 1. Original and collapsed versions of Bloom's Taxonomy used in this study.



Original—Bloom's Taxonomy. Of note, more recent versions of the taxonomy use the following terms in order: remember, understand, apply, analyze, evaluate, and create (Krathwohl, 2002).



Collapse One—Each category collapsed with its neighbor, thus creating three categories.



Collapse Two—A unique collapsing of the original categories into three categories.

Table 1

Example questions used in the three surveys

	Original	*Collapse One*	*Collapse Two*
Define short term memory	Knowledge	Knowl/Comp	Knowledge
What are the five sections of a research report?	Knowledge	Knowl/Comp	Knowledge
In one sentence give the point of a written passage.	Comprehension	Knowl/Comp	Comp/App
Describe in prose what is shown in graph form.	Comprehension	Knowl/Comp	Comp/App
Apply shading to produce depth in a drawing.	Application	App/Analysis	Comp/App
Determine the volume of an irregularly shaped object.	Application	App/Analysis	Comp/App
Given an argument for the abolition of guns, enumerate the positive and negative points presented.	Analysis	App/Analysis	Analysis/Synth /Eval
Identify the assumptions underlying a geometric proof.	Analysis	App/Analysis	Analysis/Synth /Eval
Write a logically organized argument in favor of a given position.	Synthesis	Synth/Eval	Analysis/Synth /Eval
Given two opposing theories, design an experiment to compare them.	Synthesis	Synth/Eval	Analysis/Synth /Eval
Given an argument for any position, enumerate the logical fallacies in that argument.	Evaluation	Synth/Eval	Analysis/Synth /Eval
In a given clinical situation, determine best treatment and predict the main effects and possible side effects.	Evaluation	Synth/Eval	Analysis/Synth /Eval

Results

There were 131 participants responding to the survey (10.9%) with 56 affiliated with colleges in the AHSC. Participants were given one of three versions of the survey: Original survey had 46 participants, Collapse One had 42, and Collapse Two had 42 participants. One participant was dropped due to incomplete information.

Interrater reliability

Interrater reliability for the Original version was α=.308 [95% CI (.341–.419)]. The Collapse One reliability was α=.423 [95% CI (.324–.515)] and Collapse Two was α=.426 [95% CI (.328–.524)]. Within each version Krippendorff's alpha was determined for frequent Bloom's Taxonomy users (participants who use Bloom's Taxonomy at least several times per semester), novices (participants who had not used Bloom's Taxonomy prior to the survey), AHSC faculty (nursing, public health, physical therapy, medicine, and clinical/rehabilitative health sciences), and nonAHSC faculty (arts and sciences, business and technology, education, graduate studies, and honors college). Alphas by version and subgroup are displayed in Table 4. The difference between the frequent users and novices was not significant for any version. Likewise, health science affiliation did not result in any statistical change in reliability. For all versions and all subgroups Krippendorff's Alpha was below the preferred threshold of .800.

Table 2

Participants' college affiliation

	Number	Percent of Sample
Arts & Sciences	36	27.5%
Business & Technology	12	9.2%
Clinical and Rehabilitative[1]	11	8.4%
Education	24	18.3%
Graduate Studies	1	0.8%
Honors College	1	0.8%
Medicine[1]	25	19.1%
Nursing[1]	14	10.7%
Public Health[1]	7	5.3%

[1] College affiliated with the Academic HealthSciences Center (AHSC)

Table 3

Participants' identified demographics for each survey version

	Department		*Usage*	
	Health Science	Non-Health Science	Novice	Non-Novice
Original	38.3%	61.7%	34.0%	66.0%
Collapse One	50.0%	50.0%	40.5%	59.5%
Collapse Two	40.5%	59.5%	33.3%	66.7%

Table 4

Interrater reliability expressed as α (95% CI)

	Overall	*Novices*	*Frequent Users*	*Health*	*Nonhealth*
Original	.308(.341-.419)	.356(.317-.397)	.448(.358-.537)	.379(.339-.418)	.392(.353-.430)
Collapse One	.423(.324-.515)	.350(.247-.451)	.398(.298-.492)	.393(.294-.491)	.451(.355-.547)
Collapse Two	.426(.328-.524)	.374(.271-.477)	.531(.428-.633)	.440(.341-.535)	.406(.303-.507)

Accuracy

Overall accuracy (the percent of items classified correctly) was 60.6% for the Original, 67.6% for Collapse One, and 77.6% for Collapse Two. Collapse Two yielded significantly higher accuracy than Collapse One $t(82)=4.46$, $p<.001$. Novices and nonnovices (participants who had used Bloom's Taxonomy prior to the survey) performed similarly in each version. Since the accuracy analyses required a larger sample size than the interrater reliability analyses - which only require two cases—frequent users could not be used; consequently, participants who had some prior experience with Bloom's Taxonomy were combined into one group: nonnovices. Health science participants' level of accuracy did not differ from nonhealth science participants' level of accuracy in any version (see Table 5 for a summary of the overall accuracy results).

Table 5

Accuracy of categorizing questions based on Bloom's Taxonomy based on demographic groups

	Overall	*Novices*	*Non-Novice*	*Health*	*Non-Health*
Original	60.6%	60.0%	61.4%	58.3%	61.9%
Collapse One	67.6%[1]	65.5%	69.6%	67.3%	68.6%
Collapse Two	77.6%[1]	75.0%	78.9%	78.9%	76.7%

1 – When comparing versions with three categories Collapse Two participants attained significantly higher accuracy levels than Collapse One participants ($p<.001$) using a Z test for proportions.

Accuracy for each Bloom's category varied substantially. In the Original participants were able to categorize Knowledge (85.9%) and Application (76.2%) items more accurately than any other type of item. Comprehension and Analysis items were the most difficult for participants to categorize at 40.9% and 45.1% accuracy, respectively. Table 6 summarizes the responses of participants.

Table 6

Original. Accuracy of responses for correct question category for Original version of Bloom's Taxonomy

		Actual Question Classification					
		Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Responses	Knowledge	**85.9%**	1.7%	0.4%	6.8%	0.0%	0.4%
	Comprehension	12.0%	**40.9%**	6.4%	14.9%	2.1%	3.1%
	Application	0.9%	21.7%	**76.2%**	13.6%	18.3%	7.8%
	Analysis	0.4%	17.9%	10.2%	**45.1%**	11.5%	24.4%
	Synthesis	0.4%	15.7%	5.1%	6.0%	**60.0%**	8.6%
	Evaluation	0.4%	2.1%	1.7%	13.6%	8.1%	**55.7%**

Note. Correct responses are bolded.

Accuracy in the Collapse One is shown in Table 7. Participants categorized 63.1% of Knowledge/ Comprehension items, 72.4% of Analysis/Application items, and 68.7% of Synthesis/Evaluation items correctly.

Table 7

Collapse 1. Accuracy of responses for correct question category for Collapse One version

		Actual Question Classification		
		Knowl/Comp	App/Analysis	Synth/Eval
Responses	Knowl/Comp	**63.1%**	10.7%	2.6%
	App/Analysis	27.4%	**72.4%**	28.7%
	Synth/Eval	9.5%	16.9%	**68.7%**

Note. Correct responses are bolded

Accuracy in Collapse Two is shown in Table 8. Participants categorized 92.3% of Knowledge items correctly, 71.9% of Comprehension/Application items correctly, and 69.5% of Analysis/Synthesis/Evaluation items correctly.

Table 8

Collapse 1. Accuracy of responses for correct question category for Collapse Two version

	Collapse Two	*Actual Question Classification*		
		Knowledge	Comp/App	Analysis /Synth/Eval
Responses	Knowledge	**92.3%**	5.0%	3.9%
	Comp/App	6.7%	**71.9%**	26.5%
	Analysis/Synth/Eval	0.9%	23.1%	**69.5%**

Note. Correct responses are bolded

Self-Assessment

More experienced participants over-estimated their ability to a greater extent than less experienced participants. Thus, experience using Bloom's Taxonomy may have a larger impact on perceived ability than on actual ability.

Absolute bias—the degree to which performance estimates differ from actual performance—was used as an index of self-assessment. In this study absolute bias is the difference between the proportion of items that participants believed that they categorized correctly and the proportion of items that they actually categorized correctly. In the Original version participants estimated that they categorized 68.0% of the items correctly and actually categorized 60.6% correctly, difference -7.4%, $t(46)=3.11$, $p=.003$. No absolute bias was observed in the two Collapsed versions. Collapse One participants estimated that they categorized 67.9% correctly and actually categorized 67.6% correctly, difference -0.3%, $t(42)=1.17$, $p=.247$. Collapse Two participants estimated that they categorized 74.8% correctly and actually categorized 77.6% correctly, difference 2.8%, $t(42)=1.10$, $p=.277$.

When all three surveys were combined to allow for adequate sample size—a repeated measures ANOVA with frequency of usage (Non-novice vs. novice) or health science affiliation (Non-health sciences vs. health sciences) as the between-subjects factor and predicted vs. actual percent correct as the within-subjects factor—they revealed that non-novice participants over-estimated their performance to a greater extent than novices, $F(1,128)=5.55$, $p=.020$. Non-health science participants showed significantly more optimistic absolute bias than health science participants, $F(1,128)=7.77$, $p=.006$ (see Table 9).

Table 9

Self-predicted accuracy based on participation demographic using repeated measure analysis of variance

Participant	Predicted Correct	Actual Correct	Difference: Actual–Predicted
Non-Novice[1]	74.8%	69.8%	-5.0% [$t(83)=2.89$, $p=.005$]
Novice	64.3%	66.1%	1.8% [$t(46)=.780$, $p=.439$]
Non-Health Science[2]	74.5%	68.7%	-5.8% [t(74)=3.35, p=.001]
Health Science[2]	66.1%	68.1%	2.0% [$t(54)=.880$, $p=.383$]

1 – Non-Novices made up 64.0% of the Non-Health Science group and 64.3% of the Health Science group.

2 - Including frequency of usage as a covariate did not alter these results.

Discussion

In line with Karpen and Welch (2016), interrater reliability was low in both the original and collapsed versions for both health science and non-science participants. Additionally, more experienced Bloom's users did not have significantly better reliability or accuracy than less experienced Bloom's users. Although, regarding accuracy, experience with Bloom's was analyzed nominally (yes or no) and did not necessarily equate to training. Overall, this study suggests that Collapse Two yields higher accuracy results than Collapse One. It is possible that faculty in any discipline think of assessments, regardless of nomenclature, as trichotomous: easy, medium, and hard questions. Collapsing categories, however, may dilute the data for assessment purposes. For example, combining Comprehension and Application may hide a desired distinction in abilities. If the original six-category hierarchy is desired by faculty then perhaps some alternative to collapsing, such as faculty development, may be useful.

Being able to assess a student's level of learning by an exam question relies on a faculty member's ability to accurately and reliably identify that level of learning. In this study the accuracy and reliability of categorizing Bloom's Taxonomy to exam questions were low.

Knowledge and application-level questions were categorized most accurately, perhaps because knowledge is the most basic category on the taxonomy; it represents a simple transfer of information. Application questions may have higher accuracy due to familiarity. They are commonly used in the health sciences—which represented a large portion of this study's sample (Blanco, Capello, Dorsch, Perry, & Zanetti, 2014). However, it is also suggested that multiple choice questions in general, cannot assess cognitive processes beyond knowledge recall (Scully, 2017).

Overall, participants overestimated their ability to use Bloom's Taxonomy. In both collapsed versions, however, the perceptions were similar to the outcomes, as fewer categories should make for easier accuracy estimation (Phillips et al., 2013). More experienced participants overestimated their ability to a greater extent than less experienced participants. Thus, experience using Bloom's Taxonomy may have a larger impact on perceived ability than on actual ability. Health science and non-health science participants also differed in their estimation accuracy such that health science participants more accurately estimated their performance than non-health science participants.

Conclusions

Being able to assess a student's level of learning by an exam question relies on a faculty member's ability to accurately and reliably identify that level of learning. In this study the accuracy and reliability of categorizing Bloom's Taxonomy to exam questions were low. Faculty are hired because of knowledge and expertise in a particular field and teaching abilities may come secondary to research or practice abilities in that field (Blanco et al., 2014; Ehrlich & Fu, 2012; Robinson & Hope, 2013). Using a collapsed version of Bloom's Taxonomy may be one way to improve accuracy in identifying learning. This approach may be useful to faculty of various disciplines and varying degrees of familiarity with Bloom's Taxonomy. However, collapsing Bloom's Taxonomy minimizes its distinction abilities. Faculty development may serve as one method to better understand their exam question hierarchy, though faculty development is challenging with pressures and demands on faculty (Szybinski & Jordan, 2010). Further research is needed to better identify ways to improve college faculty's abilities to identify levels of student learning through exam questions.

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