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An Examination of the use of computer-based formative assessments

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ABSTRACT

The purpose of this quantitative, correlational study was to investigate the computer-based formative assessment (CBFA) practices of core academic teachers within a one-to-one computing environment to better understand the relationships between CBFA usage rates of teachers and their perceptions of instructional technology. Survey data were collected from 261 academic teachers (63% response rate), which quantified teacher CBFA usage rates. The major findings of the study indicated that there were statistically significant correlations between CBFA usage rates and teacher comfort with technology, teacher belief in technology, and teacher autonomy. Significant differences in CBFA usage rates were found between different subjects, class levels, and grade levels. The findings provide insight into how teachers utilize CBFA in their classrooms to aid in developing targeted professional development to support teachers in using technology to formatively assess students. Future research into the effectiveness of increased CBFA usage could demonstrate how student achievement may be related to increased use of this instructional tool.

1. Introduction

Of the many instructional methods that teachers choose to use in the classroom, formative assessment has been shown to increase student achievement and motivation (Andersson & Palm, 2017; Cauley & McMillan, 2010; Faber et al., 2017; Hendriks et al., 2019; Green, 2019; Meusen-Beekman et al., 2016). The use of formative assessment within the classroom can be an effective method of monitoring and adjusting instruction if used with frequency and fidelity (Andersson & Palm, 2017; Ozan & Kincal, 2018). While research is readily available and the importance of using formative assessment during the instructional phase is well documented, in practice, teachers are not using formative assessment adequately to realize the full impact of the practice (Cotton, 2017; Missett et al., 2014; Wiliam, 2011). Furthermore, even after teachers are exposed to formative assessment, often there remains, "a disconnect between research and practice" (Box et al., 2015, p. 957). Formative assessment requires timely analysis of student data to determine the current level of understanding of each student in the classroom (Greenstein, 2010). Facing the restrictions of the typical classroom teacher to gather student assessment data and make adjustments in real time, this process can be difficult to implement frequently with all students and may explain the disconnect (Box et al., 2015).

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Teachers continue to struggle to maximize the potential of formative assessment within their classrooms for a variety of reasons such as external pressures some teachers feel to cover material or teach to the test rather than implementing formative assessments regularly (Box et al., 2015). As a result, formative assessment theory does not always translate into teacher formative assessment practice in the classroom (Cotton, 2017; Missett et al., 2014).

Inexpensive personal computing devices have advanced technology access in classrooms (Molnar, 2014). Coupled with the widespread availability of interactive web-based applications known as Web 2.0 Tools has increased the formative assessment options in the classroom (Bower, 2016; Singer, 2017). Many school systems have taken advantage of this opportunity by purchasing networked computing devices for each student (Fleischer, 2017; Kennedy et al., 2016; Zheng et al., 2016). This one-to-one computing access has been shown to have positive effects on achievement in the areas of science, writing, mathematics, and English when teachers utilize the technology for instructional purposes (Zheng et al., 2016). In schools with a one-to-one networked computer ratio and ready access to Web 2.0 tools, Computer-Based Formative Assessment (CBFA) is a readily available option.

Although access has improved, teachers face barriers such as their technology self-efficacy, their level of technology professional development, and the need for ongoing technology support; overcoming these barriers has been reported to be essential for successful technology integration in the classroom and may be related to the frequency of technology usage by teachers (Blackwell et al., 2014; Heath, 2017; Hsu, 2016; Kopcha, 2012; Minshew & Andersson, 2015). When teachers perceive Web 2.0 tools as useful to facilitate student learning and have a high level of self-efficacy, their intentions to use the tools in their classrooms have been shown to translate into action (Sadaf et al., 2016).

The purpose of this study was to investigate the CBFA practices of core academic teachers within a one-to-one computing environment to better understand the relationships between teacher usage rates of CBFA in their classrooms and their attitudes toward technology. Prior studies are limited on the investigation of the relationships of teacher-specific and class-specific factors that influence frequency of CBFA usage in a one-to-one setting (e.g., subjects, academic ability levels) and thus there exists a gap in the literature, which warrants further research. While many studies have investigated the barriers to teacher use of technology, no research was found that has specifically investigated teacher use of CBFA and how different factors may be related to the frequency of CBFA usage by teachers in one-to-one computing settings and thus, this study is intended to close this gap. Therefore, two overarching research questions guided this study. The first research question was: Which Computer-Based Formative Assessments (CBFA) applications are middle school and high school academic teachers using in a one-to-one networked environment to formatively assess student learning? The second research question was: Are there differences in average CBFA usage rates across teacher and course-specific factors in a one-to-one computing setting?

2. Background

The review of the literature includes the impact of formative assessment on student achievement, one-to-one computing, and the effects of computer-based feedback and CBFA.

2.1. Formative assessment and student achievement

The frequent use of formative assessments has been shown to have a significant positive impact on student motivation and learning (Cauley & McMillan, 2010). Formative assessment allows students to have control over their own learning experience and teachers to be provided with information to meet their students' needs (Green, 2019). Formative assessment is different from summative assessment in that it typically occurs during the instructional portion of the lesson to guide the instructional decisions (Wiliam, 2011), rather than at the conclusion to measure student mastery (Cauley & McMillan, 2010). Despite the impact that it has on student achievement, many teachers still face barriers implementing formative assessment in their classrooms (Andersson & Palm, 2017; Cotton, 2017; De Lisle, 2016). These barriers include access to professional development on the use of formative assessments, their perceptions concerning student ability, and time constraints to conduct formative assessments coupled with providing immediate feedback to all students (Box et al., 2015; Foster, 2019; Green, 2019; Powell & Kusuma-Powell, 2015). Research has shown that these barriers can be addressed through targeted professional development (Andersson & Palm, 2017), and by providing teachers with autonomy and support from school leadership (Birenbaum et al., 2011, De Lisle, 2016; Hollingworth, 2012). Additionally, districts must provide professional learning that is relevant and considered by those who receive as purposeful. Purposeful professional learning has been defined as "continuous, job-embedded professional learning that is designed to meet a specific need identified within an annual process of a systematic comprehensive needs assessment" (McBrayer et al., 2018, p. 31).

2.2. One-to-one computing

Inexpensive computing devices such as the Google Chromebook have recently entered the market as an alternative to computer laboratories/laptops and has been rapidly gaining popularity in many school systems due to their low cost (Molnar, 2014). As a result, many systems are purchasing one device for every student to use daily (Fleischer, 2017; Kennedy et al., 2016; Zheng et al., 2016). This increased access to technology on a day-to-day basis has been shown to lead to changes in teacher behavior toward technology integration that favors more student-centered learning (Varier et al., 2017).

One-to-one computing environments provide benefits to the students by increasing motivation and engagement in learning when they have their own device (Fleischer, 2017; Lindsay, 2016; Varier et al., 2017). Teachers have also reported increased access to and use of formative assessment applications through online tools (Varier et al., 2017). When teachers use one-to-one access for formative

assessment purposes, strong positive gains in academic performance have been reported (Sheard & Chambers, 2014). Educators are able to spend minimal time and effort in collecting data on individual characteristics of students, such as performance or knowledge, allowing extended time and of focus on instruction (Tomasik et al., 2018; van Groen & Eggen, 2020).

2.3. Effects of computer-based feedback

The effectiveness of computer-based feedback derives from the immediacy of the feedback provided to the student on the quality of their responses, which in turn allows the student to make adjustments to their behaviors to advance their learning (Ozan & Kincal, 2018; Varier et al., 2017). Feedback can be public, with all students getting the correct answer at the same time, or private, with the student getting the information on their own device (Alcoholoda et al., 2016). Feedback from formative assessments can reinforce students' current work ethic, provide them with explicit learning goals, monitor progress towards goals, and spark motivation, which in turn can improve overall student learning (Ozan & Kincal, 2018; Tomasik et al., 2018; van van Groen & Eggen, 2020). In order for feedback to be effective, students must find it useful and apply the feedback (Maier et al., 2016). The potential for computer-based formative assessment to provide stronger academic gain over paper-and-pencil assessments has been demonstrated (Alcoholoda et al., 2016).

2.4. Computer-based formative assessments (CBFA)

The two primary goals of formative assessment are to assess the current level of each individual student, and then provide individualized instruction or feedback based on that data (Ozan & Kincal, 2018). Additionally, CBFA devices allow students to use a handheld device to select a multiple choice or true/false answer, which is then submitted to the teacher's computer. The teacher could display the correct answer as well as a distribution of answers to the classroom. With the emergence of one-to-one computing along with many free-to-use online tools, access to CBFA applications is an option from a variety of devices, such as mobile phones, laptops, or tablets (Fuller & Dawson, 2017; Shute & Rahima, 2017).

3. Methodology

This quantitative, correlational study investigated the types of CBFA used in six middle schools and three high schools within one mid-sized suburban Georgia school district and explored the variables that correlate to the teacher's frequency of CBFA use in their classrooms as well as differences in CBFA usage rates across several variables. The instrument utilized was a 38-item researcher developed questionnaire (Appendix B). This instrument quantified the frequency of each teacher's use of CBFA in their classroom and collected data on variables that had been shown to impact teacher use of technology and formative assessments. To ensure the alignment of the questions selected, all questions were aligned to existing research on instructional technology and formative assessment as well as the research questions guiding this study. To ensure content validity and reliability of the constructs used in this study, existing scales from two prior validated studies were used during instrument development (Reinhart & Banister, 2009; Vangrieken et al., 2017). An electronic questionnaire created with Qualtrics was employed to obtain self-reported answers from the study participants. These teachers were contacted through the use of the school system email distribution lists and resulted in a response rate of 63% (280 responses).

Of primary interest to this study was the number of days in the prior five days that the teacher had chosen to use a CBFA with students during class time. To account for the different levels of classes that the teacher may had been teaching (advanced or gifted, collaborative, or on-level classes), an overall average of CBFA usage was examined. Additionally, teacher demographic information and class specific information were collected. Teachers were also asked to report on which specific CBFA Web 2.0 tools that they had used in the prior 30 days (See Appendix A). Finally, teachers were asked to describe why they may have chosen to use CBFA at different rates with their classes at different academic levels, if they reported such a difference.

Using descriptive statistics, ANOVA, and *t*-test correlations, several variables were investigated related to teacher and course-specific factors as they compare to CBFA usage rates across class levels. To answer research question one, the first part of the data analysis sought to determine which CBFA applications teachers were utilized to formatively assess students over the prior 30 days. The researcher compiled a frequency tables to report on the number of participants that were using specific CBFA applications with their students. The researcher sorted this data by grade level and subject to determine what percentage of participants in each subject and grade level combination that were using each of the named applications. Descriptive statistics were used to quantify usage rates for the different subjects and grade levels.

To answer research question two, the researcher used ANOVA along with descriptive statistics to determine if prior research findings related to differences in student-level and class-level technology usage by teachers was also found in this one-to-one setting specific to CBFA usage rates. Prior to using ANOVA, the homogeneity of the variance was tested using Levene's test (Conover et al., 1981). This analysis was used to determine if there were any differences in mean CBFA usage across eight teacher and course specific factors measured in the study for each of the three different levels of classes taught (advanced/gifted, on-level, or collaborative) as well as the teacher average CBFA usage. These eight factors included: years of teaching experience, subject taught, grade level taught, professional development in the use of formative assessments, professional development in the instructional technology, collaboration on formative assessment usage, and collaboration on instructional technology. Additionally, the researcher coded responses to the open-ended question concerning the reasons why certain teachers may have reported using CBFA at different rates with different academic levels. Data were reported in narrative form by theme.

4. Results

To address the first research question pertaining to the CBFA usage, four frequency tables were created for each of the four academic subjects at the middle school and high school levels to indicate how many teachers reported that they had utilized each CBFA application within the prior 30 days. Overall results indicated that teachers from all four subject areas across both grade levels were using a wide variety of CBFA applications with their students. The three most commonly reported CBFA applications used by teachers in the study were Google Forms Quiz used by 77% of the teachers, followed by Kahoot! (Kahoot.com) at 61%, and then Quizlet Live (quizlet.com/live) at 51% of the teachers based on usage of this application in the prior 30 days. Google Forms Quiz was reported as either the first or second most commonly used CBFA application reported in all subjects at both the high school and middle school levels and was ranked first for each of the four subjects overall. The highest reported use of a single CBFA application by any one group was the application IXL for mathematics (www.IXL.com) used by 97.4% of the middle school mathematics teachers in the study. The group with the least reported overall use of CBFA applications was the high school mathematics teachers, with 18.9% of them reporting they had not used any CBFA applications with their students over the prior 30 days. The most used application for this group was Google Forms Quiz used by 62.2% of the teachers. High school social studies teachers and science teachers also reported lower CBFA usage rates compared with the other groups in the study, with 13.3% and 5.9% of these teachers respectively reported using no CBFA applications with their students in the prior 30 days. Kahoot! was reported as one of the most used applications in each of the eight subject and grade level groups. It was ranked first for high school social studies teachers with 80.0% of them reporting use of the application. For overall use across the four subjects, Kahoot! was ranked either the 2nd or 3rd most frequently reported application. Among the self-reported CBFA applications that were reported that were not available as a selection on the questionnaire, CK12 (www.ck12.org) was the highest ranked application reported by any group. Science teachers at the high school and middle school levels reported using this program at 19.4% and 51.6% respectively. See Table 1 through 4.

4.1. CBFA usage rates compared across demographic factors

The second research question addressed the differences in average CBFA usage rates across teacher and course-specific factors in a one-to-one computing setting. These specific factors addressed include subject, years of experience, grade level, professional development, teacher collaboration, and teacher reported reasons for differing usage rates.

4.2. Differences in CBFA usage rates by subject

A one-way ANOVA was used to determine if differences in mean CBFA usage rates existed for each level of class as well as the overall average teacher CBFA usage rate for each academic subject. These results indicated that there was a statistically significant difference in mean CBFA usage rate at the 0.05 level for the teacher average use of CBFA for teachers that taught different subjects. English teachers were using CBFA at statistically significant higher rates than mathematics teachers. English teachers also demonstrated the highest CBFA usage rates overall, followed by social studies teachers, then science teachers, and the lowest rate of CBFA usage was reported by mathematics teachers. The analysis across the three different class levels indicated that there was no statistically significant difference in CBFA usage rates for different subjects for the advanced/gifted classes, for the collaborative classes, or for the

Table 1
CBFA applications used by sixty-two English teachers.

Application Name	High School			Middle School		
	n	Percent	n	Percent	n	Percent
Google Forms Quiz	25	83.3	28	87.5	53	85.5
Kahoot!	22	73.3	19	59.4	41	66.1
Quizlet Live	16	53.3	18	56.3	34	54.8
GCA Item Bank	9	30.0	23	71.9	32	51.6
Quizizz	8	26.7	20	62.5	28	45.2
IXL	3	10.0	23	71.9	26	41.9
No Red Ink	16	53.3	9	28.1	25	40.3
USATESTPREP	3	10.0	21	65.6	24	38.7
Formative	10	33.3	14	43.8	24	38.7
GimKit	8	26.7	13	39.4	21	33.3
CommonLit	7	21.2	3	9.4	10	16.1
Actively*	1	3.3	4	12.1	5	7.9
STAR Reader*	3	10.0	0	0	3	4.8
ReadWorks*	1	3.3	2	6.3	3	4.8
Read Theory*	1	3.3	2	6.3	3	4.8
Socrative	1	3.3	1	3.1	2	3.2
PearDeck*	0	0	2	6.3	2	3.2
None Used	1	3.3	0	0	1	1.6

Note. * Denotes items that were written responses offered by participants. Responses are from 30 high school English teachers and 32 middle school English teachers.

Table 2
CBFA applications used by seventy-six mathematics teachers.

	High School		Middle School		Total	
Application Name	n	Percent	N	Percent	N	Percent
Google Forms Quiz	23	62.2	31	79.5	54	71.1
IXL	12	32.4	38	97.4	50	65.8
Kahoot!	13	35.1	23	59.0	36	47.4
USATESTPREP	9	24.3	27	69.2	36	47.4
Quizizz	8	21.6	25	64.1	33	43.4
Quizlet Live	10	27.0	18	46.2	28	36.8
GCA Item Bank	5	13.5	19	48.7	24	31.6
Formative	4	10.8	15	38.5	19	25.0
Prodigy	0	0	14	35.9	14	18.2
GimKit	0	0	10	25.6	10	13.0
None Used	7	18.9	1	2.6	8	10.5
DeltaMath*	5	13.5	0	0	5	6.6
Desmos*	1	2.7	3	7.7	4	5.3
Socrative	4	10.8	0	0	4	5.3
Edgenuity*	2	5.4	1	2.6	3	3.9
Plickers	0	0	3	7.7	3	3.9
Albert.io*	2	5.4	0	0	2	2.6

Note. * Denotes items that were written responses offered by participants. Responses are from 37 high school mathematics teachers and 39 middle school mathematics teachers.

Table 3
CBFA applications used by sixty-five science teachers.

	High School		Middle School		Total	
Application Name	n	Percent	n	Percent	n	Percent
Google Forms Quiz	26	76.5	23	74.2	49	75.4
Kahoot!	19	55.9	22	71.0	41	63.1
Quizlet Live	12	35.3	21	67.7	33	50.8
USATESTPREP	5	14.7	27	87.1	32	49.2
Quizizz	11	32.4	18	58.1	29	44.6
Formative	13	38.2	15	48.4	28	43.1
GCA Item Bank	5	14.7	18	58.1	23	35.4
CK12*	6	19.4	16	51.6	22	33.8
GimKit	3	8.8	16	51.6	19	29.2
Socrative	6	19.4	2	6.5	8	12.3
NearPod	2	5.9	4	12.9	6	9.2
Plickers	2	5.9	2	6.5	4	6.2
AP Classrooms*	4	11.8	0	0	4	6.2
Edgenuity*	2	5.9	0	0	2	3.1
None Used	2	5.9	0	0	2	3.1

Note. * Denotes items that were written responses offered by participants. Responses are from 31 high school science teachers and 34 middle school science teachers.

on-level classes. While not significant, mean CBFA usage rates across subjects for advanced/gifted, on-level, and collaborative classes indicated a very similar pattern of usage as found with the teacher overall average usage. For teachers that participated in this study at each of these class levels, English teachers reported the highest mean in all three class levels followed by social studies teachers while mathematics teachers reported the lowest usage rates for the advanced/gifted and on-level classes. Finally, science teachers had the lowest mean usage rate for the collaborative classes. The results of this analysis can be found in Table 5.

4.3. Differences in CBFA usage rates by years of experience

Results of the ANOVA analysis of CBFA usage rates by years of teacher experience found that there was no statistically significant difference in mean CBFA usage by years of experience for teachers of advanced/gifted classes, for on-level classes, for collaborative classes, or for teacher average CBFA usage. While not statistically different, a consistent pattern of usage rates by years of experience was found by comparatively examining the mean CBFA usage rate across class levels for the three experience levels. Findings indicated that for advanced/gifted, on-level, and teacher average usage rates, teachers that had between one to five years of experience were using CBFA at the highest mean rate, followed by teachers with six to 10 years of experience, and those with more than 11 or more years using CBFA at the lowest rate. The one exception to this finding was found for teachers in collaborative classrooms where the mean CBFA usage rates for this class level indicated that teachers with six to 10 years of experience had the highest rate, followed by teachers with 11 or more years, and teachers with one to five years demonstrating the least usage. Results of this analysis are noted in

Table 4
CBFA applications used by fifty-eight social studies teachers.

	High School		Middle School		Total	
Application Name	n	Percent	n	Percent	n	Percent
Google Forms Quiz	20	66.7	25	89.3	45	77.6
Kahoot!	24	80.0	18	64.3	42	72.4
Quizlet Live	16	53.3	23	82.1	39	67.2
USATESTPREP	11	36.7	20	71.4	31	53.4
Quizizz	11	36.7	20	71.4	30	51.7
GimKit	12	40.0	18	64.3	30	51.7
GCA Item Bank	11	36.7	17	60.7	28	48.3
Formative	10	33.3	10	35.7	20	34.5
NearPod	3	10.0	9	32.1	12	20.7
Gallopade*	1	3.3	3	10.7	4	6.9
None Used	4	13.3	0	0	4	6.9
AP Classrooms*	3	10.0	0	0	3	5.2
Socrative	2	6.7	1	3.6	3	5.2
Plickers	0	0	2	7.1	2	3.4
Active Classroom*	2	6.7	0	0	2	3.4

Note. * Denotes items that were written responses offered by participants. Responses are from 30 high school social studies teachers and 28 middle school science teachers.

Table 5
ANOVA results and descriptive statistics for class levels of CBFA usage by subject.

Subject	Mean	SD	n		Mean	SD	n	
	Advanced/Gifted classes				Collaborative classes			
English		2.49	1.34	45		2.46	1.43	39
Mathematics		1.63	1.62	43		2.16	1.70	51
Science		2.00	1.43	36		2.08	1.40	39
Soc. Studies		2.23	1.55	39		2.33	1.46	39
Source	SS	df	MS	F	SS	df	MS	F
CBFA	17.41	3	5.80	2.62	3.63	3	1.21	.525
Error	352.21	159	2.22		377.87	164	2.30	
On-Level classes					Teacher AVG CBFA			
English		2.42	1.27	45		2.46	1.30	62
Mathematics		1.86	1.80	65		1.78	1.71	76
Science		2.09	1.49	55		2.14	1.40	65
Soc. Studies		2.29	1.45	51		2.28	1.38	58
Source	SS	df	MS	F	SS	df	MS	F
CBFA	9.97	3	3.32	1.40	17.54	3	5.85	2.71*
Error	503.97	212	2.38		554.92	257	2.16	

*$p < .05$.

Table 6.

4.4. Differences in CBFA usage rates by grade level

Results of the *t*-test analysis of CBFA usage rates by teachers that taught either middle school or high school found that there was a statistically significant difference at the 0.01 level in mean CBFA usage rates for the advanced/gifted courses, the on-level courses, and for the teacher average CBFA usage rates for the grade level taught. Middle school teachers in advanced/gifted and on-level courses were using CBFA with a significantly higher frequency than the high school teachers in the same class levels. There was no significant difference in mean CBFA usage rates for middle school and high school teachers in collaborative classes. While not statistically significant, the mean CBFA usage for middle school teachers in collaborative classes was higher than the CBFA usage for high school teachers in collaborative classes as reported for the other class levels. Results of this analysis can be found in Table 7.

4.5. Differences in CBFA usage rates by professional development

Results of the *t*-test analysis of CBFA usage rates by teachers that had professional development on either instructional technology or formative assessment usage within the prior 12 months found that there was no statistically significant difference at the 0.05 level in mean CBFA usage rates for teachers that had professional development in either instructional technology or formative assessment for advanced/gifted classes, for on-level classes, for collaborative classes or for teacher average CBFA usage. While significant differences

Table 6
ANOVA results and descriptive statistics for class levels of CBFA usage by years of experience.

Years of Exp		Mean	SD	n		Mean	SD	n
	Advanced/Gifted Classes				Collaborative Classes			
1 to 5		2.37	1.21	27		2.16	1.50	26
6 to 10		2.12	1.68	26		2.36	1.53	36
11 or more		2.02	1.54	110		2.23	1.52	106
Source	SS	df	MS	F	SS	df	MS	F
CBFA	2.71	2	1.35	.59	.59	2	.30	.13
Error	366.91	160	2.30		380.91	165	2.31	
	On-Level Classes				Teacher AVG CBFA			
1 to 5		2.43	1.50	37		2.32	1.40	44
6 to 10		2.26	1.59	42		2.29	1.56	47
11 or more		2.02	1.54	137		2.05	1.48	170
Source	SS	df	MS	F	SS	df	MS	F
CBFA	5.70	2	2.85	1.19	3.75	2	1.87	.85
Error	508.13	213	2.39		568.71	258	2.20	

*p < .05.

Table 7
T-test results and descriptive statistics for class levels of CBFA usage by teacher grade level.

	Grade level						95% CI for Mean Difference		
	Middle			High					
	M	SD	n	M	SD	n		t	df
Adv/Gifted	2.41	1.58	79	1.80	1.39	84	.15, 1.07	2.61*	161
On-Level	2.42	1.47	117	1.81	1.58	99	.20, 1.02	2.94*	214
Collab.	2.38	1.51	107	2.02	1.50	61	-.11, .84	1.52	166
T. AVG	2.45	1.47	130	1.84	1.44	131	.25, .96	3.37*	259

*p < .01.

for professional development were not found, consistent patterns of mean CBFA usage did appear for professional development on technology as well as formative assessment. Teachers reported professional development usage of technology with higher mean CBFA usage rates for each of the three class levels as well as the teacher average CBFA usage rate. Results of this analysis can be found in Table 8. The results for professional development on formative assessment usage indicated that teachers that reported professional development on formative assessment were found to be using CBFA less often for each of the three class levels as well as the teacher average CBFA usage. CBFA usage rates do not appear to be related to professional development received by the teacher within the prior 12 months on the use of either instructional technology or formative assessment. Results of this analysis can be found in Table 9.

4.6. Differences in CBFA usage rates by teacher collaboration

Results of the *t*-test analysis of CBFA usage rates by teachers that have collaborated with other teachers on either instructional technology or formative assessment usage within the prior 30 days found that there was no statistically significant difference at the 0.05 level in mean CBFA usage rates for teachers that collaborated with other teachers in the past 30 days in either instructional technology or formative assessment for advanced/gifted classes, for on-level classes, for collaborative classes or for teacher average CBFA usage. While a significant difference was not found, a pattern of mean CBFA usage was noted for collaboration on technology as well as formative assessment. Results indicated that teachers that had collaborated with other teachers on technology in the prior 30

Table 8
T-test results and descriptive statistics for class levels of CBFA usage by professional development on technology.

	Professional development on technology						95% CI for mean difference		
	No			Yes					
	M	SD	n	M	SD	n		t	df
Adv/Gifted	1.87	1.35	47	2.18	1.57	116	-.82, .21	−1.18 161	
On-Level	1.96	1.54	72	2.23	1.55	144	-.71, .17	−1.22	214
Collab.	2.18	1.59	50	2.28	1.48	118	-.60, .41	-.39	166
T. AVG	1.99	1.46	83	2.21	1.49	178	-.61, .16	.26	259

*p < .05.

Table 9
T-test results and descriptive statistics for class levels of CBFA usage by professional development on formative assessment.

	Professional development on formative assessment						95% ci for mean difference		
	No			Yes					
	M	SD	n	M	SD	n		t	df
Adv/Gifted	2.09	1.42	54	2.09	1.56	109	-.50, .50	.00	161
On-Level	2.26	1.51	76	2.07	1.57	140	-.24, .63	.87	214
Collab.	2.41	1.47	58	2.16	1.53	110	-.23, .73	1.02	166
T. AVG	2.28	1.42	90	2.07	1.52	171	-.17, .59	1.07	259

*p < .05.

days had higher mean CBFA usage rates in their advanced/gifted classes, on-level classes, collaborative classes as well as the teacher average CBFA. For collaboration on formative assessment usage with the last 30 days, a similar pattern emerged with advanced/gifted, on-level, and teacher average CBFA all indicating higher mean CBFA usage for teachers that had collaborated on formative assessments. It is also noted that collaboration on these two topics appear to be commonplace in this district, with 81.6% reportedly collaborating on using instructional technology, and 90.8% of teachers reporting that they had collaborated with other teachers on formative assessment. Results of this analysis can be found in Table 10 and Table 11.

4.7. Teacher reported Reasons for different usage rates

To further explore the differences in CBFA usage across class levels, an open-ended question collected teacher responses on why they may have reported different usage rates for the different levels of classes that they taught. A total of 59 responses were submitted for this question. Of these 11 teachers indicated that they only taught one level of class during this semester or their responses could not be coded based on the information that was provided. The remaining 48 qualitative responses were coded by theme based on the reasons given. Five major themes emerged as reasons given: the needs of the class or students in the class, the need for repetitive practice for certain groups, behavioral concerns with using technology, a lack of instructional time, and a lack of applications to use with specific classes.

4.7.1. The needs of the class or student

The most often cited reason for using CBFA at different rates for different class levels (advanced/gifted, on-level, or collaborative) was the needs of individual students or the class as a whole. This reason was cited by 37.5% of teachers reporting. These teachers often referred to the need to differentiate the lesson, which led to varying needs for technology usage. For example, one of the responses given by a teacher noted, "I have found that certain activities are better on paper or by having physical copies of things, and students get burned out on technology." Another teacher supported differentiating based on individual student abilities by stating, "The students are either at a different pace, or prepping for separate assignments, etc."

4.7.2. Repetitive practic

The second most reported reason was the need for more repetitive practice with certain classes. This reason was cited by 27.1% of teachers' reporting. These teachers stated that they used CBFA more often with lower ability level classes due to the need for more repetitive practice with those students as opposed to the more advanced students. One teacher supported this by stating, "I try to use formative assessments more frequently for my collaborative and general courses to make time to reteach/remediate when necessary."

Additionally, teachers viewed students in the more advanced classes as more motivated learners that could grasp concepts more quickly without the need for additional formative assessments or extrinsic motivation. For example, one teacher noted, "I do use more with general level classes as it holds their attention more. In advanced courses there is an intrinsic need to complete the coursework regardless of interest level."

4.7.3. Behavioral concern

Behavioral concerns were found to be a theme reported by 14.6% of the respondents. Several of these teachers felt that the access to

Table 10
T-test results and descriptive statistics for class levels of CBFA usage by collaboration with other teachers on technology.

	Collaboration on technology						95% CI for mean difference		
	No			Yes					
	M	SD	n	M	SD	n		t	df
Adv/Gifted	2.06	1.28	34	2.10	1.57	129	-.62, .53	-.14	161
On-Level	1.76	1.38	42	2.23	1.57	174	-.99, .05	−1.77	214
Collab.	2.18	1.36	28	2.26	1.54	140	-.71, .54	-.27	166
T. AVG	1.98	1.33	48	2.18	1.52	213	-.67, .26	-.86	259

*p < .05.

Table 11
T-test results and descriptive statistics for class levels of CBFA usage by collaboration with other teachers on formative assessment.

	Collaboration on formative assessment						95% CI for mean difference		
	No			Yes					
	M	SD	n	M	SD	n		t	df
Adv/Gifted	1.93	1.33	15	2.11	1.53	148	-.99, .64	-.43	161
On-Level	1.95	1.28	20	2.16	1.57	196	-.92, .51	-.57	214
Collab.	2.36	1.08	14	2.24	1.55	154	-.72, .95	.28	166
T. AVG	1.88	1.24	24	2.17	1.51	237	-.92, .26	-.93	259

*$p < .05$.

technology was a distraction for the lower-level classes and thus teachers limited the use of technology. For example, one teacher reported, "I have found that for my general and collab classes, technology use is not all it was supposed to be, and in many cases actually detrimental. Students with attention issues do MUCH better with paper tests, quizzes, and even assignments." Another supported this argument by stating, "Some of my students struggle staying focused, even with technology. I have to mix it up so that classroom management stays a priority."

4.7.4. Lack of time

Of the teachers, 12.6% indicated that they did not have the time to use CBFA with their students. Teachers reported that they did not have time to use it with advanced classes due to the faster pace of the coursework, with one teacher stating, "In my collab class, I run out of time because I have to take longer to explain a new concept or task."

Opposingly, the other three stated that they did not have time to use it with lower-level classes due to the longer time it takes to teach their lessons. For example, one teacher illustrated this by reporting, "I have more time in my on-level class than I do for the advanced/gifted groups so I feel I can incorporate a larger variety of formative assessment techniques."

4.7.5. Lack of applications

Finally, 8.3% of the teachers stated that with certain class levels, there were limited CBFA applications that were created for the classes that they taught. Teachers cited the lack of pre-made resources for upper-level courses as the predominate reason. The following response highlights this: "The availability of technology resources such as IXL, and USATESTPREP are not available for all content areas." Additionally, another teacher noted the specific lack of diversity of helpful applications in their field, "AP Calculus, there are not many readily available (quizizz is okay for some but not Calculus BC). I do not have time to make them. I like to use materials that I find readily available."

4.8. Limitations

This study was limited to a self-report questionnaire collected in a single school district and exclusively focused on core academic teachers at the middle and high school levels. For this reason, the generalizability of the results may not reflect practices at the elementary level or the practices of teachers in other school districts. While the sample size for this study was acceptable at a rate of 63.0%, it is recognized that utilizing a sample of teachers that voluntarily opted to complete the survey may not fully represent all teachers in the population and it is possible that teachers with little interest in instructional technology may not have participated at the same rate as other teachers. Additionally, the data collected represented a snapshot of CBFA usage, professional development, and collaboration during only part of the academic year and may not reflect everyday usage.

5. Discussion

The study found that in this one-to-one computing setting, academic teachers at the middle school and high school levels were using varied CBFA applications. There were significant differences in the frequency that teachers were using CBFA with their students in different class levels (advanced/gifted, on-level, collaborative) based on student need and teacher perceptions. Several factors appear to have been related to teacher choice to use CBFA more frequently with their students at different class levels including the subject that they taught and the grade level at which the teacher taught.

While access to technology appears to no longer be a barrier with the ever-growing number of interactive Web 2.0 tools available, student-centered instructional changes have been shown to occur in the classroom, which includes teachers using the technology to formatively assess student learning (Bower, 2016; Varier et al., 2017). Additionally, the ease with which teachers could formatively assess student learning, provide instant feedback as well as motivate students, were noted as primary reasons for the change in formative assessment practices. An overwhelming majority of teachers from all subjects were found to be regularly using a wide variety of CBFA applications with their students, with Google Forms Quiz (77%), Kahoot! (61%), and Quizlet Live (51%) being the three most common. The widespread use of CBFA observed is likely due to the ease of access to the technology and of the applications, with these three noted applications being available for teachers and students at no cost and including simple user-friendly interfaces for teachers to create their own content.

Patterns of mean CBFA usage were observed for the following factors: years of experience, professional development or

collaboration in formative assessment and/or technology. These results were not consistent with prior research that found differences in either formative assessment usage or technology usage for years of experience (Blackwell et al., 2014), professional development (Hollingworth, 2012) or collaboration (Birenbaum et al., 2011). These results imply that in this one-to-one setting with access to the technology so readily available, all teachers regardless of experience, professional development or collaboration were using CBFA at similar rates.

Significant differences were found for CBFA usage rates for subjects taught and grade level of the teachers. Different technology usage patterns for different subjects were noted in two of the studies referenced (Hsu, 2016; Keane, 2012). While these studies simply noted that different subjects used technology for different purposes, the current study sought to quantify any statistical differences among the four academic subjects in their frequency of use of technology for the purpose of providing CBFA to their students in different class levels. The mean CBFA teacher average usage rates for each subject indicated that English teachers had the highest average usage rate, followed by social studies teachers, science teachers, and mathematics teachers. Although the mean CBFA usage rates for mathematics teachers were lower than the other three subjects, a statistically significant difference was found only between English and mathematics teachers. This result is consistent with findings from prior research indicating that teachers were likely to use technology during English instruction (Hsu, 2016). One possible explanation for this outcome could be related to the ease of use of the CBFA applications to create content for English classes versus content for mathematics classes. Assessments in English classes can generally be created using text-based questions, whereas in mathematics classes the questions often require special symbols and formatting. The difficulty to create mathematical questions and the lack of access to paid content-specific applications may have contributed to the less frequent use of certain CBFA applications.

While technology usage was pervasive at all levels, there were differences in the types of uses of technology found between levels (Ruggerio & Mong, 2015). Consistent with results of this study which indicated that middle school teachers are using CBFA significantly more often with their students overall and this difference is also present in their advanced/gifted and on-level courses. There was, however, no significant difference in usage in collaborative classes. Based on the qualitative responses given by the teachers in this study, there are two proposed reasons for the differences found in CBFA usage rates between these middle school and high school teachers. The first may be due to the differences in course lengths between grade levels, with middle school classes being year-long and the majority of high school classes being semester long. With the compressed schedule at the high school level, teachers may not feel they had time to incorporate CBFA as often with their students. The second reason may relate to the teacher perceptions on the motivational benefit of frequent CBFA usage with their students. As the use of instructional technology has been shown to be an academic motivator for most students, teachers at the middle school level may be using CBFA more often with their students to maintain interest and motivation, while teachers at the high school level may not feel the need to use these motivational tools with as much frequency. However, teachers addressed the effectiveness of computer-based feedback based on the immediacy of the feedback, which is consistent with research that denotes this allows students to make adjustments to their thoughts and behaviors to advance their learning in real-time (Ozan & Kincal, 2018).

6. Implications for practice

Formative assessment usage and instructional technology usage each face unique barriers in the classroom. Researchers have found that professional knowledge on the use of formative assessment and instructional technology is instrumental to both practices (Andersson & Palm, 2017; Kopcha, 2012). The perceptions of teachers play a significant role in the use of these practices in the classroom (Box et al., 2015; Hew & Brush, 2006; Minshew & Andersson, 2015). These findings of this study reinforce the understanding of teacher beliefs in shaping the frequency of CBFA usage and can assist school leaders in developing support systems to enhance this instructional practice via professional development.

This study found evidence that collaboration with other teachers on instructional technology and formative assessment was pervasive in this district. In this one-to-one computer to student ratio environment, and based on these findings, school leaders should encourage teacher collaboration in the area of formative assessment and instructional technology as well as provide purposeful professional develop to support these initiatives. Minshew and Andersson (2015) indicated that professional development in the area of technology needed to be subject-specific and should ensure that teachers are able to make a connection with the use of technology and their classroom practice. In this current study, significant differences in CBFA usage rates were found among teachers between different subject areas and different grade-levels. These findings support the notion that CBFA professional development for teachers should be subject-specific related to the needs of the specific target audience and should establish a clear connection between the use of the technology and the academic goals of the teachers' courses.

Furthermore, several teachers indicated they used CBFA more often with less advanced classes in the belief that more advanced students did not need as much practice and were more intrinsically motivated. Conversely, some teachers also reported that they used CBFA less often with their collaborative students due to behavioral concerns while using CBFA with them. School leaders should provide specific guidance on the frequency of the use of CBFA with students in all classes regardless of ability level. The use of frequent formative assessments has been shown to benefit all students (Black & Wiliam, 1998) and teachers may be missing an opportunity to enhance student learning for their students by using CBFA less often. Teachers should also be encouraged to alternate the type and frequency of use of CBFA applications that they use with their students, especially in collaborative classes. Varier et al. (2017) noted that the novelty of a technology seemed to be a significant motivator with students and increased engagement. Subject-specific targeted teacher collaboration and professional development may assist teachers, specifically if teachers consider it purposeful, collaborative, and sustainable (McBrayer et al., 2018).

7. Recommendations for future research

This study has added to the growing body of research on CBFA and the factors that influence use of CBFA by teachers with students of different ability levels in a one-to-one technology setting. Due to the findings of the current research study, this researcher makes the following three recommendations for future research:

1. The study could be replicated and expanded to additional school districts across the state or in other states that are using personal computing devices in a one-to-one ratio to generalize the results.
2. This research focused exclusively on the CBFA usage rates of teachers over a one-week period of time. Future research could expand on this by extending the data collection period over several weeks or months to get a more accurate picture of CBFA usage over the course of the year to examine differences in usage rates at different points in the school year.
3. This research focused exclusively on CBFA usage rates as they relate to teacher and class factors. Future research could examine the effectiveness of increased CBFA usage to improve student achievement across the three class levels (advanced/gifted, on-level, collaborative) and using the same teacher and class factors.
4. Further research may be needed to determine if it is more beneficial for student learning and limit technology burnout if teachers utilize a single application repetitively or a variety of applications. However, due to the continuously evolving profession of teaching, the challenges teachers are facing are continuously changing, specifically with evolving technological innovations (Salenko et al., 2020).

8. Conclusion

This research has confirmed prior research findings and found a statistically significant positive correlation between CBFA usage rates and teacher comfort with technology as well as CBFA usage rates and teacher perceived benefit of using technology. This research study has also illustrated that teacher beliefs about the needs of their students are impacting their decisions to use CBFA with their students. Significant differences in CBFA usage rates were found between different subjects, class ability levels, and grade levels. These findings support the idea that differences in teacher beliefs about student learning are related to the frequency of computer-based formative assessments usage by teachers. As school leaders plan for professional development around instructional technology, awareness of these differences in CBFA usage can be instrumental in crafting targeted learning to address the different perceptions of their teachers toward instructional technology.

In all subjects in both middle school and high school, a majority of teachers reported that they are using CBFA with their students. While the frequency of use of CBFA has been shown to be dependent on different factors, teachers in all subject areas are using a wide variety of applications with their students. As new applications become available, it is important for teachers and school leaders to continue to research and learn about these applications. While several studies have shown that when students use one-to-one technology, they are generally more motivated and engaged and this may be linked to the novelty of the technology. With increased use of the same CBFA applications, there is the risk that this novelty will wane resulting in less interest from the students. Additionally, teachers indicated that they were changing technology usage patterns due to student inattention when using CBFA. This implies that teachers should continually seek out new CBFA applications and ways to incorporate them into their classrooms in order to avoid student application fatigue. Teacher perceptions toward technology were indeed influencing CBFA usage patterns and in turn, school leaders with an understanding of these attitudes and beliefs should effectively support the individual needs of their teachers' use of this powerful instructional tool.

Credit author statement

Sullivan: Investigation, Data curation, Methodology, Formal analysis, Writing- Original Draft, Visualization. McBrayer: Conceptualization, Supervision, Visualization, Writing- Reviewing and Editing. Miller: Conceptualization, Supervision. Fallon: Writing-Reviewing and Editing.

Appendix A. Web 2.0 formative assessment applications

Name of Web 2.0 Tool	Description	Web address
Plickers	An application that uses printed numbered cards with letter choices, A, B, C, and D. When teachers pose a question, each student holds up their response card with their choice at the top. The teacher uses a handheld device with a camera to scan the room to capture responses. The teacher can then visit the website to view responses.	https://plickers.com
Poll Everywhere	The teacher creates an online account. Students visit the teacher site via a mobile device. Questions are posed by the teacher during class and students type in responses in multiple choice or free response form. The teacher can view results instantly.	https://polleverywhere.com
Nearpod	The teacher creates a slideshow and inserts questions. Students answer questions as the slideshow is presented. The pacing can be student-led or teacher-led.	https://nearpod.com

(*continued on next page*)

(*continued*)

Name of Web 2.0 Tool	Description	Web address
Formative	The teacher can create digital assignments. Students answer questions as multiple choice, free response, true-false, open-ended, or drawings. Teachers can see results instantly as the students progress and provide feedback.	goformative.com
Quizizz	Students play live quiz games. Each student's computer displays the questions and choices. A leader board keeps track of student progress compared to the rest of the class.	quizizz.com
Quizlet Live	A team-based question and answer game. Students work in teams to answer questions and compete against other teams in the class. Teamwork is required as no one student can see all of the questions. A running leader board presented to the class shows the team progress toward winning the game.	quizlet.com

Appendix B. Survey instrument

Directions.

All individual responses in this questionnaire will remain anonymous. Please answer each question as accurately as possible. The results of this questionnaire may be used to improve practices in our district related to instructional technology.

The questionnaire consists of 38 questions and should take approximately 10 min.

Computer-Based Formative Assessment (CBFA) refers to any classroom use of technology to collect information from students. Immediate feedback is given to the students on the quality of the information they provided, either by the teacher, another student, or by a computer program.

Some examples include: *CK12, Clickers, Formative, GCA Item Bank, Google Forms Quiz, IXL, Kahoot, Quizlet Live, Quizizz, NearPod, No Red Ink, Plickers, Prodigy, Poll Everywhere, Socrative, USATESTPREP,* there are others that you may be using ….

For questions 1–3, please answer NA if you do not currently teach this type of class.

1. For your advanced or gifted classes: In the last 5 class days, on how many days did you use a CBFA with these classes? (NA, 0, 1, 2, 3, 4, 5)
2. For your collaborative classes: In the last 5 class days, on how many days did you use a CBFA with these classes? (NA, 0, 1, 2, 3, 4, 5)
3. For your on-level classes: In the last 5 class days, on how many days did you use a CBFA with these classes? (NA, 0, 1, 2, 3, 4, 5)
4. How many years of teaching experience do you have including this year? (Richards, 2005) (1–5 years, 6–10 years, >11 years)
5. What subject do you primarily teach? (English, Science, Math, SS)
6. What is the grade level that you primarily teach? (MS, HS)
7. Have you been provided any training or professional development on the use of formative assessments in the last 12 months? (Yes/No)
8. Have you been provided any training or professional development in the use of instructional technology in the last 12 months? (Yes/No)
9. During the last 30 days, have you discussed with other teachers, any methods that one could use to formatively assess student learning? (Yes/No)
10. During the last 30 days, have you discussed with other teachers how to use instructional technology in the classroom? (Yes/No)
11. Do you currently teach at least two classes that have a state-mandated standardized test at the end of the course? (Yes/No)

For the next set of questions, select the response that best fits your level of agreement to the given statement.
Strongly Agree = 4, Agree = 3, Disagree = 2, Strongly Disagree = 1.
Construct 1: Comfort with Technology (Reinhart & Banister, 2009)

12. I feel comfortable about my ability to work with instructional technologies.
13. Learning new technologies is confusing for me. (Reversed)
14. I get excited when I am able to show my students a new technology application or tool.
15. I get anxious when using new technologies because I may not know what to do if something goes wrong. (Reversed)
16. I enjoy finding new ways that my students and I can use technology in the classroom.
17. I am confident with my ability to troubleshoot when problems arise while using technology.
18. Learning new technologies that I can use in the classroom is important to me.
19. I am confident in trying to learn new technologies on my own.

Construct 2: Perceived Benefit in using Technology in the Classroom (Reinhart & Banister, 2009)

20. Computer technology allows me to create materials that enhance my teaching.
21. Computer technologies help me be better organized in my classroom.
22. My students get excited when they use technology in the learning process.
23. Technology can be an effective learning tool for students.
24. Using technology to communicate with students allows me to be more effective in my job.

Construct 3: Technology Vision and Support (Reinhart & Banister, 2009)

25. A vision for technology use in our school is clearly communicated to the faculty.
26. Curriculum support is available in my building to assist with technology integration ideas.
27. My building principal encourages faculty to integrate technology in the classroom.
28. Technology support is available in my building to assist with troubleshooting.
29. My colleagues are committed to integrating technology in the classroom.

Construct 4: Teacher Autonomy (Vangrieken et al., 2017)

30. I am able to select assignments for my students on my own.
31. I am free to select the teaching methods and strategies that seem most appropriate to me.
32. I have the freedom to design and prepare lessons in my own way.
33. I am allowed to assess my students as I want.
34. I have the freedom to use and adapt classroom management strategies in a way that seems most appropriate to me.
35. I have the freedom to use Chromebooks and other technology in a flexible way in my lessons.
36. Select all of the CBFA applications that you have used with your students during class in the last 30 days. Select from this list.

CK12, Clickers, Formative, GCA Item Bank, Google Forms Quiz, IXL, Kahoot, Quizlet Live, Quizizz, NearPod, Playposit, Plickers, Poll Everywhere, Prodigy, Socrative, USATESTPREP, None used in the last 30 days.

37. List all other CBFA not listed in 36, which you have used with your students in class in the last 30 days. Please separate each entry with a comma.
38. If you reported in Q1, Q2, and Q3 that you are using CBFA at different rates over the last 5 days for different class levels (advance/gifted, on-level, or collaborative classes), please describe the reasons for the different usage rates.

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