What the Research Says: Using eInstruction's CPS™ to Support Effective Instruction

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A Summary of Independent Research

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IESD WHITE PAPER

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INTRODUCTION

Over the past few years, student response systems–also referred to as classroom response systems or audience response systems–have become widely used in higher education and are now also being used in an increasing number of K-12 classrooms (Beatty & Gerace, 2009, pp. 146-147). A substantial body of evidence supports the use of such systems and specific instructional practices that are facilitated by using these systems.

The purpose of this white paper is to summarize key points in that evidence and describe how eInstruction's CPS™ student response system can be used in research-based ways to support effective instruction. This paper draws on research related to:

- Use of student response systems in K-12 and higher education
- Effective questioning techniques used by teachers
- The value of feedback to students as part of the formative assessment process
- Changing student misconceptions
- Modifying teaching in response to formative assessment data

COMMON INSTRUCTIONAL USE MODELS FOR CPS™

Common instructional models for using the CPS™ system that align to research described in this paper include the following:

- Ask questions prior to a class discussion to identify prior knowledge and possible misconceptions
- Ask questions during a class discussion or activity to monitor student understanding and adjust instruction as needed
- Display class responses and use the display as a basis for discussion
- Intersperse class discussions and presentations with questions to emphasize important content, add interactivity, and engage student attention

ABOUT THIS WHITE PAPER

This white paper includes the following informative sections:

- An executive summary presenting key findings from the body of research
- Separate sections presenting more detailed research results related to:
  - Research on student response systems
  - Teacher questioning
  - Student engagement
  - Value of feedback
  - Student preconceptions and misconceptions
  - Modifying teaching in response to formative assessment data
- Conclusion

EXECUTIVE SUMMARY—KEY FINDINGS

Research presented in the sections that follow supports the following findings:

- Research on student response systems suggests that they promote learning when coupled with appropriate pedagogical methodologies (Fies &Marshall, 2006; Kay & Knaack, 2009; Penuel et al., 2007; Roschelle et al., 2004a, 2004b).

- Student response systems such as CPS™ offer effective support for research-based teacher questioning strategies (Black & Wiliam, 1998b; Crooks, 1988; Ellis, 1993; Gall & Rhody, 1987; Wilen, 1987).

- Use of student response systems such as CPS™ can make classroom lessons more interactive, thereby raising student interest and engagement (Fies & Marshall, 2006; Gall & Rhody, 1987; Kay & Knaack, 2009; Penuel et al., 2007; Roschelle et al., 2004a, 2004b).

- Student response systems such as CPS™ offer effective support for students to receive focused, timely feedback as part of the process of formative assessment, of the type that has been shown to improve learning (Bangert-Drowns et al., 1991; Barron et al., 1998; Black & Wiliam, 1998a, 1998b; Kay & Knaack, 2009; National Research Council, 2000; Tierney & Charland, 2007; Vye et al., 1998).

- Student response systems such as CPS™ provide powerful tools for addressing student preconceptions and misconceptions through the use of formative assessment, with important research-based implications for student learning (Abrahamson, 2006; National Research Council, 2000).

- Student response systems such as CPS™ facilitate frequent, timely formative assessment that can be used to guide adjustments to teaching–an instructional practice that has been found to have a powerful impact on student learning (Barootchi & Keshavarz, 2002; Black & Wiliam, 1998a, 1998b; Dori, 2003; Fies & Marshall, 2006; National Research Council, 2000; Nunes, 2004; Penuel et al., 2007; Roschelle et al., 2004a, 2004b; Tierney & Charland, 2007; Vendlinski & Stevens, 2002). This includes use of formative assessment to support differentiated instruction (Hall, 2002; Tomlinson, 2000).

RESEARCH ON STUDENT RESPONSE SYSTEMS

Reviewing the body of direct research on student response systems (SRS) such as CPS™, most of it from higher education, Fies and Marshall (2006) reported, "There is great agreement that [student response systems] promote learning when coupled with appropriate pedagogical methodologies.... The literature also indicates that [SRS]-supported environments lead to greater learning gains than traditional learning environments" (p. 106). More specifically, they cited an analysis of 26 classroom network studies by Roschelle et al. (2004a, 2004b) that found evidence of the following (see Fies & Marshall, 2006, p. 103):

- "[G]reater student engagement" (16 studies)
- "[I]ncreased student understanding of complex subject matter" (11 studies)
- "[I]ncreased student interest and enjoyment" (7 studies)
- "[H]eightened discussion and interactivity" (6 studies)
- "[I]ncreased student awareness of individual levels of comprehension" (5 studies)
- "[I]ncreased teacher insight into student difficulties" (4 studies)

Additional information provided by Roschelle et al indicates that this body of research should be considered suggestive rather than conclusive.

Out of 16 implementation studies examined directly by Fies and Marshall, the most common outcomes were as follows (see Appendix, p. 107):

- "Higher participation, more engagement" (9 studies)

- "Instructor more aware, more responsive instruction" (7 studies)
- "Students self-monitor understanding, understand more" (7 studies)
- "Better communication" (6 studies)
- "More interest, more enjoyment (fun)" (6 studies)
- "More formative assessment" (5 studies)

Summarizing results of previous higher education research on student response systems, Kay and Knaack (2009, p. 383) identified similar benefits:

- "[S]tudent attitudes toward [student response systems] are very positive."
- "[S]tudents are more engaged in the content presented..., participate more..., and pay more attention to concepts presented."
- "[U]sing [student response systems] improves the feedback cycle between instructor and students with the rapid, anonymous, collection and presentation of all student responses to questions asked."
- "Many higher education students report that they learn more when [student response systems] are used.... [T]here is substantial qualitative and quantitative evidence to suggest that learning performance increases as a direct result of using [student response systems]."

K-12 RESEARCH

Penuel and colleagues (2007) surveyed 584 elementary and secondary educators across multiple grade ranges and subject areas on their use of eInstruction's Classroom Performance System, of which CPS™ is the latest version. When asked about the effects of the system, teachers awarded a mean score between 4 (agree) and 5 (strongly agree) on a scale of 1-5 for each of the following statements (see Table 2, p. 334):

- "The CPS™ helps me tell if the students understand a concept" (M = 4.38, SD = .62)
- "Class interactions resulting from using the CPS™ help student learning" (M = 4.24, SD = .71)
- "With the CPS™, students can quickly tell whether they are right or wrong" (M = 4.51, SD = .83)
- "I have better-quality information about students' understanding through the use of the CPS™" (M = 4.19, SD = .774)
- "By using the CPS™, I have more timely information about what students know" (M = 4.46 SD = .68)
- "I have been able to adapt instruction better to specific student needs or misconceptions by using the CPS™ (M = 4.05,SD = .79)
- "Doing activities with the CPS™ in class helps students get a better understanding of concepts" (M = 4.07, SD = .69)
- "Students are more actively engaged in a CPS™ class than in others" (M = 4.37, SD = .76)

The researchers also found that "[f]requent, broad users of the CPS™ were much more likely to perceive the CPS™ as conferring a range of benefits to themselves and to students" (p. 340). While the subjects of this study do not constitute a representative sample of all SRS-using teachers, these findings suggest that K-12 teachers who are using the Classroom Performance System™ perceive benefits from its use similar to those identified in higher education studies.

Kay and Knaack (2009) found similar results from a survey of 213 grade 10-12 students in science classes taught by seven teachers who made limited use of the eInstruction system. A majority of the students agreed with the following statements (see Table 1, p. 385):

- "Using clickers was a good way to test my knowledge" (74%; includes students who slightly agreed, agreed, and strongly agreed with the statement)
- "I was more engaged in the lesson when clickers were used" (70%)
- "I was more motivated when clickers were used" (63%)
- "I participated more than I normally would when clickers were used" (62%)
- "I would prefer to use clickers" (62%)

- "I liked seeing what other students in the class selected for answers" (56%)
- "Using clickers generated more class discussion" (53%)

Equally noteworthy was the difference in responses from students in classes where the system was being used for formative assessment versus those where it was being used for summative assessment. According to the researchers:

> Using [a student response system] for formative assessment was rated significantly more positively than using [a student response system] for summative assessment on all 11 Likert scale items in the... attitude scale. Using [a student response system] for formative assessment also resulted in significantly higher scores on most survey items when compared to a mixed approach (formative & summative). (p. 388)

IMPORTANCE OF INSTRUCTIONAL APPROACH

The difference in student attitudes reported by Kay and Knaack (2009) for formative assessment versus summative assessment uses of student response systems (reported above) underscores the fact that student response systems are tools for carrying out specific pedagogical approaches, and that the impact of such systems depends on the instructional strategies that are used. Beatty & Gerace (2009) advised, "[D]on't ask what the learning gain from [student response system] use is; ask what pedagogical approaches a [student response system] can aid or enable or magnify, and what the learning impacts of those various approaches are" (p. 147).

Penuel and colleagues (2007) similarly noted:

> Researchers who have studied student response systems in higher education share a belief that the technology alone cannot bring about improvements to student participation in class and achievement; rather, the technology must be used in conjunction with particular kinds of teaching strategies. (p. 318)

In keeping with this perspective, the remainder of this white paper describes specific instructional uses of student response systems, including the research supporting those uses.

TEACHER QUESTIONING

A synthesis of research related to teacher questioning found:

> Although some studies have produced conflicting findings, research strongly supports teachers' assumptions that asking questions contributes to the effectiveness of their instruction. Taken as a whole, studies conducted at all grade levels have indicated that both written and oral questions result in learning gains. (Ellis, 1993, pp. 2-3)

Gall and Rhody (1987, pp. 25-26) identified the following reasons that researchers have offered as to why questioning is effective:

1. Questions are motivating, and so they keep students on task.
2. Questions focus the student's attention on what is learned. A teacher's question is a cue to the student that the information required to answer the question is important.
3. Questions, especially thought questions, elicit depth of processing. Rather than reading the text passively, a good question requires the student to process the text actively and transform it into terms meaningful to him or her.
4. Questions activate metacognitive processes.... Thus, students become aware of how well they are mastering the curriculum content and whether they need to study it further.

5. Questions elicit further practice and rehearsal of the curriculum content.
6. If the student answers a question correctly, that is reinforcing, and the teacher may further reinforce the answer by praising or acknowledging it. If the student answers incorrectly, that can prompt the teachers to engage in reteaching.
7. Students' mastery of the curriculum is usually assessed by tests that consist of questions. Therefore, questions asked during instruction are consistent with the task requirement of tests.

Specific findings and recommendations related to effective questioning include the following:

- Different types of questions are appropriate for different instructional goals (Ellis, 1993, p. 3). For example, factual recall questions "have been found to be effective in reviewing material, assessing comprehension, and determining student preparedness" (p. 5). High-level "convergent" questions require students to "[look] for evidence to support, [give] reasons for behaviors or outcomes, and [draw] conclusions," prompting them to "extend their thinking by supporting assertions" (pp. 6-7). A third category, low-level "divergent" questions asking students "to think of alternate ways to do something," are suitable for use "as the first step in the problem-solving process or in a sequence of questions where students brainstorm possible solutions" (p. 7).

- Questioning should be frequent. Crooks (1988) summarized three research review essays as finding that "the frequency of teacher questioning has generally been shown to be positively related to student achievement" (p. 453).

- Questions should be directed toward, and answered by "as many students as possible (to encourage all toward active learning)" (Crooks, 1988, pp. 453-454; see also Ellis, 1993, p. 12, citing Wilen, 1987; Black & Wiliam, 1998b, pp. 143-144).

USE OF CPS™ TO SUPPORT EFFECTIVE TEACHER QUESTIONING STRATEGIES

Student response systems such as CPS™ are fundamentally technologies to support efficient simultaneous questioning of students. In the case of CPS™:

- Answer formats that are supported by the system include multiple-choice, multiple-answer, yes/no, true/false, ranking, and advanced-numeric and text-entry capabilities (e.g., for short-answer questions).
- Questions can be set in advance or created spontaneously.
- Questions can be used to collect data of many different types, such as factual knowledge, opinions, predictions, evaluations, and higher-order thinking.
- Answers can be recorded for grading purposes or not, at the teacher's discretion.

Student response systems are thus well suited to supporting frequent, unobtrusive questioning, using a variety of question types that can be answered simultaneously by all students.

STUDENT ENGAGEMENT

As noted previously, questioning is inherently motivating and focuses students' attention on learning (Gall & Rhody, 1987, pp. 25-26). In light of this, it is hardly surprising that improved student interest, motivation, and engagement are among the most common outcomes reported by studies of student response systems (Fies & Marshall, 2006; Kay & Knaack, 2009; Penuel et al., 2007; Roschelle et al., 2004a, 2004b).

USE OF CPS™ TO INCREASE STUDENT ENGAGEMENT

Student response systems such as CPS™ provide opportunities to make classroom lessons more interactive, thereby raising student interest and engagement. Students can be queried, not just for assessment purposes, but also to answer opinion questions and provide anonymous classroom survey data as a basis for discussion.

- Questions can be directed to all students, with individual tracking to encourage participation.
- Student responses are quick, silent, and largely unobtrusive, involving little disruption to the flow of class instruction.

VALUE OF FEEDBACK

Based on their review of 250 research studies addressing formative assessment across multiple ages and subject areas, Black and Wiliam (1998b) stated, "Feedback has been shown to improve learning when it gives each pupil specific guidance on strengths and weaknesses" (1998b, p. 144). Specifically, they cited a meta-analysis of 58 experiments on "'test-like events' (e.g., evaluation questions in programmed learning materials, review tests at the end of a block of teaching, etc.)" (1998a, p. 36, citing Bangert-Drowns, Kulik, Kulik, & Morgan, 1991), which found the following:

- "Feedback was most effective when it was designed to stimulate correction of errors through a thoughtful approach to them in relation to the original learning relevant to the task" (Black & Wiliam, 1998a, p. 36). Along similar lines, the authors of How People Learn, a synthesis of research on learning across the subject areas that incorporates findings from psychology, child development, the study of learning transfer, anthropology, and neuroscience, noted that "[f]eedback is most valuable when students have the opportunity to use it to revise their thinking as they are working on a unit or project"—in short, when the feedback is timely (National Research Council, 2000, p. 141, citing Barron et al., 1998; Black & Wiliam, 1998a; Vye et al., 1998).

- "[F]eedback was more effective when the feedback gave details of the correct answer, rather than simply indicating whether the student's answer was correct or incorrect" (Black & Wiliam, 1998a, p. 51).

- "[P]roviding feedback in the form of answers to the review questions was effective only when students could not 'look forward' to the answers before they had attempted to answer the questions themselves" (Black & Wiliam, 1998a, p. 51).

Controlling for the second and third bullets "eliminated almost all of the negative effect sizes that Bangert-Drowns et al. [1991] found, yielding a mean effect size across 30 studies of 0.58" (Black & Wiliam, 1998a, p. 51), which is generally considered among researchers to indicate an effect of practical significance. This speaks to the importance of teachers' effective feedback techniques in their use of the CPS™ system.

A review of 30 secondary-level peer-reviewed empirical research articles related to formative assessment published between 2000 and 2005 found similar positive effects for feedback. According to Tierney and Charland (2007):

While these studies do not give indication of the relative merits of... different methods of feedback, positive consequences are generally seen. Feedback is described as an effective means of scaffolding learning... and encouraging greater student autonomy (pp. 12-13).

USE OF CPS™ TO PROVIDE FEEDBACK TO STUDENTS

Student response systems such as CPS™ enable students to receive focused, timely feedback.

- Student responses are aggregated and reported to the teacher, allowing the teacher to focus discussion and instruction on incorrect responses shared by large numbers of students.
- Questions can be designed to provide immediate, focused feedback to individual students via the LCD screen on their CPS™ clicker in response to the specific answer they gave.

As noted above, Kay and Knaack (2009) identified improvements to "the feedback cycle between instructor and students" as one of the benefits of student response systems in higher education (p. 383).

STUDENT PRECONCEPTIONS AND MISCONCEPTIONS

The importance of addressing student preconceptions and misconceptions is described in How People Learn. One of the "key findings" of How People Learn was that "[s]tudents come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom" (National Research Council, 2000, pp. 14-15).

Based on this finding, the authors recommended formative assessment as a strategy for "[t]eachers [to] draw out and work with the preexisting understandings that their students bring with them," stating: "The use of frequent formative assessment helps make students' thinking visible to themselves, their peers, and their teachers. This provides feedback that can guide modification and refinement in thinking" (p. 19).

USE OF CPS™ TO ADDRESS PRECONCEPTIONS AND MISCONCEPTIONS

Student response systems such as CPS™ provide powerful tools for addressing student preconceptions and misconceptions. This is illustrated by the example of George Webb, an early practitioner who used such systems in a university physics class:

> [O]n introducing a new topic, he would often very carefully choose a question that had an obvious answer based on everyday nonphysicist thinking, but which was invalid. When over 90% of the class chose this answer and found out that they were all wrong, they suddenly became interested and were more than ready to listen to the first part of the lecture (Abrahamson, 2006, p. 4).

Student response systems such as CPS™ facilitate the process of addressing student preconceptions and misconceptions by:

- Providing a means to frequently query all students mid-instruction
- Making responses simultaneous, so students can't be influenced by other students' responses
- Allowing responses to remain anonymous, so students aren't embarrassed by "wrong" answers
- Presenting the range and distribution of opinions in graphic format (e.g., through projected bar graphs and pie charts of student responses)

MODIFYING TEACHING IN RESPONSE TO FORMATIVE ASSESSMENT DATA

Black and Wiliam defined as formative assessment as "all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged" (1998a, pp. 7-8). In their aforementioned review of 250 research studies related to formative assessment (Black and Wiliam, 1998a, 1998b), their general finding was that "innovations that include strengthening the practice of formative assessment produce significant and often substantial learning gains" (1998b, p. 140), with typical effect sizes ranging from 0.4 to 0.7 (1998b, p. 141)—a level of gains they characterize as "quite considerable, and... amongst the largest ever reported for educational interventions" (1998a, p. 61).

Formative assessment was particularly valuable for low-achieving students in the studies reviewed by Black and Wiliam. They found that "[w]hile formative assessment can help all pupils, it yields particularly good results with low achievers by concentrating on specific problems with their work and giving them a clear understanding of what is wrong and how to put it right" (pp. 142-143).

The value of formative assessment as a tool to guide instruction was similarly noted by the authors of How People Learn:

> Formative assessments—ongoing assessments designed to make students' thinking visible to both teachers and students—are essential. They permit the teacher to grasp the students' preconceptions, understand where the students are in the "developmental corridor" from informal to formal thinking, and design instruction accordingly. In the assessment-centered classroom environment, formative assessments help both teachers and students monitor progress (National Research Council, 2000, p. 24).

A recent review of empirical research on formative assessment endorsed Black and Wiliam's findings, stating, "The teachers in many of these studies benefit from sustained support in learning how to use assessment to inform teaching" (Tierney & Charland, 2007, pp. 13-14). Specific positives mentioned by these researchers included:

> the possibility of responding to the needs of an individual learner..., adjust unit plans... or shift curricular goals.... Assessment information provided by students can be "invaluable" (Nunes, 2004, p. 333) for teachers, and it can be used intentionally to improve the relevance and effectiveness of instruction (e.g., Vendlinski & Stevens, 2002). Improvements in student learning are linked to greater use of assessment information by teachers (Barootchi & Keshavarz, 2002; Dori, 2003), and improvements in student engagement are also suggested as teachers are able to "design future instructional strategies, materials and activities that are more meaningful and valuable to the learners" (Nunes, 2004, p. 333), (pp. 14-15).

USE OF CPS™ TO GUIDE ADJUSTMENTS TO TEACHING

As noted above in the section on Research on Student Response Systems, more informed instruction on the part of teachers is one of the most frequently cited results of research studies, and is a benefit noted by teachers in using such systems (Fies & Marshall, 2006; Penuel et al., 2007; Roschelle et al., 2004a, 2004b).

Student response systems such as CPS™ facilitate frequent, timely formative assessment that can be used to guide adjustments to teaching. In particular, features of these systems make it possible to take a quick snapshot of the understanding of all students in the class. This information is immediately available to guide instruction, without the need to wait for grading after class. Additionally:

- Information about individual student responses, available within the management software and accessible through system reports, provides information to teachers that can be used to differentiate instruction. Leading experts on differentiating instruction recommend incorporating ongoing assessment by teachers as a key element in implementing differentiated instruction (Hall, 2002; Tomlinson, 2000).
- Resources such as the ExamView® question banks that accompany all major textbooks make it easy to incorporate questions that match the instructional focus of planned lessons.

CONCLUSION

Student response systems such as CPS™ represent a valuable potential resource for educators at many levels. Research on such systems suggests that they promote learning when coupled with appropriate pedagogical methodologies. In particular, student response systems such as CPS™ offer effective support for research-based teacher questioning strategies. Such systems can also make classroom lessons more interactive, thereby raising student interest and engagement. As part of a system for frequent formative assessment, student response systems facilitate focused, timely feedback; provide tools for teachers to identify and correct their students' preconceptions and misconceptions; and help guide adjustments to teaching–all practices that have been found to positively impact student learning.

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