NATIONAL ASSESSMENT OF EDUCATIONAL PROGRESS GRADE 12 PREPAREDNESS RESEARCH COLLEGE COURSE CONTENT ANALYSIS STUDY

FINAL REPORT

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EXECUTIVE SUMMARY

The National Assessment Governing Board is an independent, bipartisan organization that sets policy for the National Assessment of Educational Progress (NAEP). The Governing Board established the NAEP Program of 12th Grade Preparedness Research to assess what NAEP can report on the academic preparedness of 12th grade students entering college and job training. The Governing Board commissioned the Educational Policy Improvement Center in October 2012 to conduct the College Course Content Analysis (CCCA) study, which used course artifacts to identify the prerequisite knowledge, skills, and abilities (KSAs) in mathematics and reading that are necessary for students to be prepared to qualify for entry-level, credit-bearing courses that satisfy general education requirements.

The CCCA study was designed to answer the following research questions:

- What are the prerequisite KSAs in mathematics and reading to qualify for entry-level, credit-bearing courses that satisfy general education requirements?
- How do these prerequisite KSAs compare with the 2009 and 2013 NAEP mathematics and reading frameworks and item pools?
- How do these prerequisite KSAs compare with previous NAEP preparedness research, i.e., descriptions of minimal academic preparedness requirements produced in the Judgmental Standard Setting (JSS) research?
- How can these prerequisites inform future NAEP preparedness research?

Study Method

Phase 1: Establishing the Foundation for the Study

The initial phase included selecting a representative sample of institutions, collecting course artifacts, organizing the artifacts into course packets, and recruiting content reviewers and NAEP content experts.

Selecting a representative sample. One hundred fifty-one (151) institutions contributed 160 course packets, which included a syllabus, textbook, and class assignment or assessment (hereafter referred to as course artifacts). Half of the 160 packets addressed mathematics courses, and the other half addressed courses with substantial reading demands. To generate a nationally representative sample of institutions, the target sample was stratified by

- program type (two-year and four-year)
- size (small < 4,999 students; medium 5,000–9,999; or large > 10,000)
- geographic region (East or West)
- institutional control (private or public)

Collecting course artifacts and assembling course packets. The mathematics course titles included precalculus/calculus, college algebra, finite mathematics, and statistics. The courses with substantial reading demands included English literature, psychology, U.S. government, and U.S. history. Instructors who taught the included courses at the sampled institutions provided the course artifacts and verified that these artifacts met inclusion criteria. The course artifacts were compiled into course packets for the content analysis activities.

Recruiting content reviewers and NAEP content experts. Highly qualified college-level content experts, 16 in mathematics and 16 in reading, were recruited to conduct course content reviews. The content reviewers were postsecondary instructors who taught relevant introductory college courses. Another smaller group of doctoral-level content experts in mathematics and reading with specialized expertise and experience with the NAEP frameworks were engaged to provide guidance for the use of the NAEP frameworks within the overall study design.

Phase 2: Conducting Content Analysis Activities

The next phase included training and qualifying the content experts to conduct two content reviews, independent and group, as part of the convergent consensus process; summarizing the data into detailed content maps of the KSAs; and completing a generalizability study, as a measure of the consistency of the coding process.

Training and qualifying reviewers. The training began by inviting content reviewers to conduct a "holistic" review of the course packets prior to being introduced to the NAEP framework. This provided reviewers with the opportunity to identify prerequisite KSAs independent of NAEP frameworks. Subsequent reviewer trainings were conducted to address the NAEP framework, the coding scheme, decision rules, and review processes. Training also included trial reviews of a subset of the course packets and individualized feedback for each reviewer. Only reviewers who demonstrated an understanding of the materials and processes qualified to participate in the content reviews.

Independent and group content reviews. After training, the research project moved into the operational components of the study by facilitating two content expert reviews of the course packets: one independent review where reviewers individually applied a comprehensive coding scheme to the course packets, and one group review where the reviewers discussed their points of individual agreement and disagreement. Content reviewers also used a set of decision rules to support their identification of the prerequisite KSAs within each course packet. Decision rules are clarifying guidelines for pre-identified potential areas of ambiguity.

Summarizing the data and conducting reliability checks. The data collected from these reviews were summarized into content maps of the prerequisite KSAs for each course. Some prerequisite KSAs were not included within the NAEP framework objectives but were evident in the course packets. A generalizability study was conducted to evaluate coding reliability.

Phase 3: Conducting NAEP Expert Reviews

During the final phase, the NAEP experts used the content maps to develop narrative descriptions of the prerequisite KSAs necessary for students to be prepared for entry, without remediation, into credit-bearing entry-level courses. They then compared their narrative descriptions to NAEP item pools, borderline performance descriptions generated in previous research, and other content summaries captured in the Judgmental Standard Setting and Job Training Program Content studies. In these comparisons, NAEP experts analyzed correspondence between the CCCA KSAs and content assessed in the NAEP. Through a facilitated discussion, they provided insight via their NAEP framework expertise.

Study Process Results

The validity of the results is based on institutional representativeness, artifact sufficiency, and coding reliability. Analysis indicates that the sample of institutions submitting artifacts for courses with substantial reading demands is generally representative of the population of institutions. Institutions submitting artifacts for mathematics courses underrepresent small institutions and private institutions and overrepresent public institutions and large institutions. Post hoc analyses suggest that deviations from representativeness do not pose a serious threat to validity. Content reviewers deemed the artifacts sufficient to allow them to focus on what students are expected to be able to learn, what students are expected to be able to do to demonstrate learning, and the kinds of content the students will reference in order to learn. Results from the generalizability study indicate the CCCA findings are reliable, i.e., rating was consistent within course packets during the independent and group reviews.

Prerequisite KSA Findings and Conclusions

Prerequisite KSAs

The results from the study indicate that most of the prerequisite KSAs for both mathematics courses and courses that require extensive college-level reading are reflected in the NAEP frameworks. A KSA was considered prerequisite if a student is either expected or required to possess this knowledge, skill, or ability to be prepared for entry into the course. The prerequisite KSAs were mapped to the NAEP frameworks or they were included as non-NAEP additional KSAs. Any KSA identified in 75% or more of course packets within a subject area was considered to be a common prerequisite. Prerequisite KSAs found less frequently within course packets demonstrated the range of prerequisites present within the sample of course packets, and, by extension, likely to be present within courses taught across U.S. institutions.

Reading prerequisite KSAs. Some of the reading KSAs that are prerequisite to entering entry-level, credit-bearing college courses have substantial informational text reading demands, and some of the reading KSAs demand engagement with literary texts. KSAs common to both included the ability to locate or recall textually explicit information within and across texts and the ability to take different perspectives in relation to a text. Few differences were found in prerequisite KSAs among courses with substantial informational text reading demands. The key distinction between the courses with substantial informational text versus literary text reading demands was in the KSAs related to the ability to make complex inferences within and across texts; related KSAs were more commonly found to be prerequisite in courses dependent on informational texts rather than literary texts. However, courses within English literature were more likely than those with substantial informational text reading demands to have prerequisite KSAs relating to both informational and literary texts.

Mathematics prerequisite KSAs. The mathematics KSAs were mostly specific to a course title, i.e., there was not a single set of prerequisite KSAs that covered all entry-level, credit-bearing courses. The majority of prerequisite KSAs were represented in objectives within the NAEP framework's *Numbers and Operations* subject area. Prerequisite KSAs for precalculus/calculus and college algebra were notably different from those for finite mathematics and statistics—they were represented by the objectives within the *Variables, Expressions, and Operations and Equations and Inequalities* subtopics of the *Algebra* subject area of the NAEP framework, whereas there were fewer prerequisite KSAs from these subject areas for statistics and finite mathematics. Additional KSAs that were not found within the NAEP framework were identified as prerequisites. These related to the use of technology (e.g., calculators, online resources) and the ability to read and communicate in various modes about mathematics.

Comparison of Prerequisite KSAs to 2009 and 2013 NAEP Mathematics and Reading Frameworks and Item Pools

Reading prerequisite KSA comparison. The NAEP reading framework aligned well with the prerequisite KSAs identified in this study, especially in the cognitive domains of *Locate/Recall* and *Integrate/Interpret*. The prerequisite KSAs focused less on the ability to critique or evaluate, which may be what is covered within a college course and therefore not a prerequisite to entry into the course. The reading item pools represent fairly well the prerequisite KSAs noted in this study. The nature of the text excerpts in the 2009 and 2013 NAEP reading item pools did not, however, cover the range of texts that would be required in order to assess all of the prerequisite KSAs.

Mathematics prerequisite KSA comparison. The "big picture" of the mathematics frameworks was transparent to the NAEP experts when they envisioned the 4th, 8th, and 12th grade objectives side by side. After accounting for the pieces of NAEP objectives that were not considered relevant, some prerequisite KSAs are found in the 8th grade NAEP framework. Some additional KSAs identified by content reviewers were found by the NAEP experts to be implied within the NAEP frameworks and explicit in the frameworks for grades not referenced in this study. The CCCA prerequisite KSAs focused more heavily on application of mathematics (e.g., simulations, addressing real-world problems) than is evident in the item pools. The NAEP experts found the items to be skill-based and procedural in nature rather than applied. The CCCA content focused on application problems, which do match the NAEP framework, but the items do not reflect the same level of focus. Another main difference between NAEP mathematics and CCCA prerequisite KSAs is that many of the CCCA sampled courses did not have measurement or geometry objectives as prerequisite KSAs.

Comparison of Prerequisite KSAs to Previous NAEP Preparedness Research

Reading prerequisite KSA comparison. The CCCA prerequisite KSAs describe a depth of understanding and a level of cognitive demand that are beyond those described by the JSS minimum preparedness requirements. The NAEP experts portrayed the two sets of descriptions as concentric circles, with the JSS circle completely inside the CCCA circle. They concluded that the CCCA study, with the inclusion of the courses that relied heavily on informational texts as well as those relying primarily on literary texts, resulted in a narrative description that was broader and deeper than the JSS borderline performance descriptions (BPD).

The reading prerequisites identified in the CCCA study are more numerous and constitute more KSAs related to higher-order thinking skills than those described by the JSS descriptions of minimal preparedness. The specific NAEP objectives necessary for minimal preparedness from JSS were all subsumed by the prerequisites evident in CCCA course artifacts. For example, the JSS description included *offer evidence in support of*, but not judging, evaluating, and critiquing, which is subsumed by *offering evidence to support a claim*.

Mathematics prerequisite KSA comparison. The prerequisites identified for precalculus/calculus and college algebra are similar to the JSS description of the KSAs necessary for minimal preparedness for entry-level college mathematics courses. The prerequisites for finite mathematics and statistics, however, require fewer and less cognitively complex KSAs than are described by the JSS description.

Given the differences in evidence, process, and unit of analysis, dissimilarities between study findings were expected. The CCCA study identified prerequisite KSAs from the evidence contained in college course packets of artifacts. As a standard-setting process, the JSS study identified what minimally prepared college students need to know and be able to do to succeed in entry-level college mathematics courses and courses with substantial reading demands.

Informing Future NAEP Preparedness Research

Studies focusing on the prerequisites from a broader range of entry-level college courses might be useful at identifying differences in prerequisites for courses that use a variety of texts and text types. Of particular interest is the inclusion of courses that contain both significant mathematics and reading demands (e.g., economics) and the examination of the prerequisites related to both content areas.

Exploring prerequisites related to writing, graphical representations of information, and technology use could complement the content analyses of reading and mathematics KSAs that have been conducted on college and job training courses.

INTRODUCTION

This report describes the College Course Content Analysis (CCCA) study, one of a series of studies contributing to the National Assessment of Educational Progress (NAEP) Program of 12th Grade Preparedness Research sponsored and overseen by the National Assessment Governing Board, hereafter referred to as the Governing Board. The Governing Board is an independent, bipartisan organization authorized and funded by Congress to set policy and provide general oversight and direction for NAEP, commonly known as *The Nation's Report Card*. NAEP is the largest nationally representative and continuing assessment of what 4th, 8th, and 12th grade students know and can do in 12 academic subject areas.

NAEP Program of 12th Grade Preparedness Research

Since 2004, the Governing Board has been working to determine the feasibility of NAEP reporting on the academic preparedness of 12th grade students, relative to postsecondary education and job training programs. The Governing Board convened a seven-member technical panel in 2007 to assist in the planning of research and validity studies to determine how and what NAEP could report on the preparedness of 12th grade students (WestEd, 2010). The Technical Panel on 12th Grade Preparedness Research recommended a multimethod approach comprised of five separate areas of research, each targeting a major research question, as shown in Figure 1.

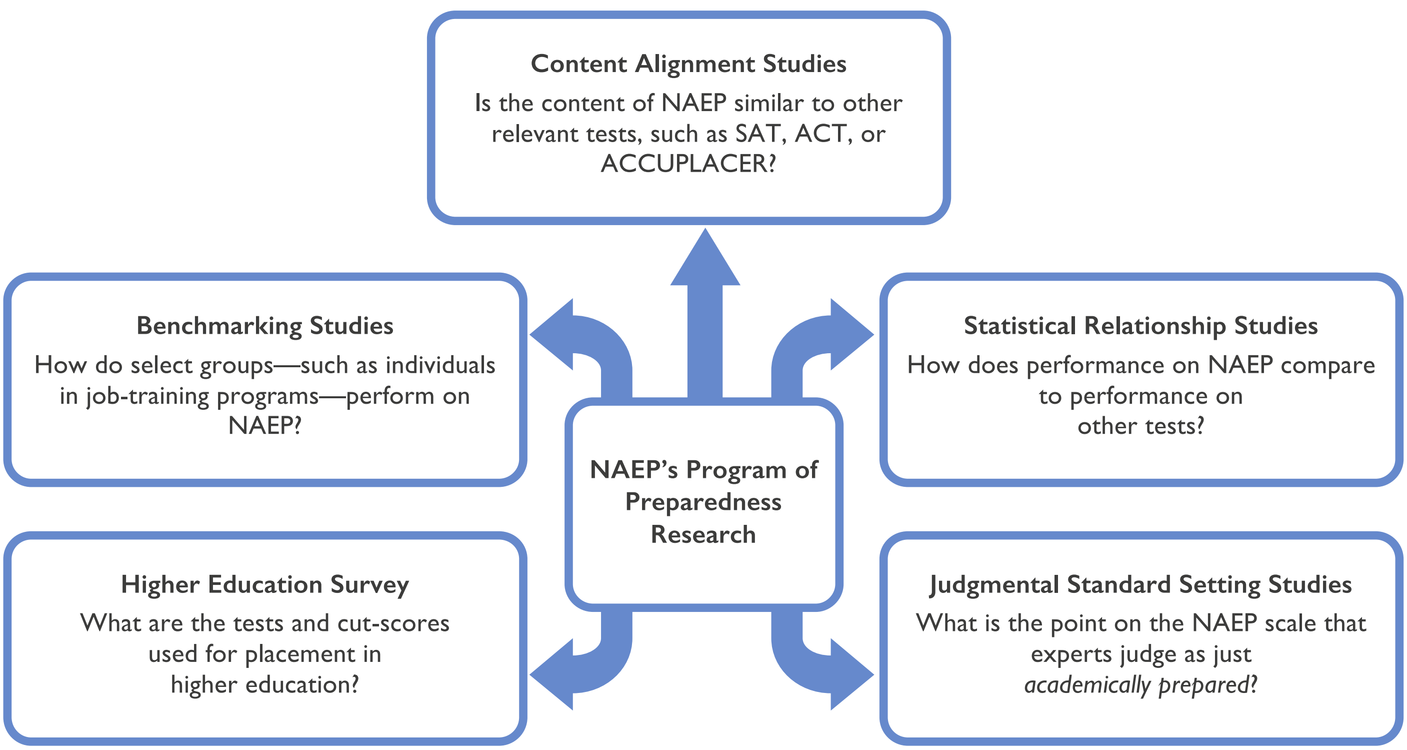

Figure 1. **NAEP's Program of Preparedness Research**

The Governing Board commissioned the Educational Policy Improvement Center (EPIC) to conduct a study to determine the relationship between the prerequisite knowledge, skills, and abilities (KSAs) in reading and mathematics that students need for entry-level college courses and the 12th grade NAEP reading and mathematics assessment content. Artifacts from entry-level college courses were reviewed to determine the KSAs necessary for students to be academically prepared for entry into these courses and the degree to which the 12th grade NAEP reading and mathematics frameworks aligned with the necessary prerequisite KSAs.

The CCCA study was designed to produce research findings that contribute to the overall NAEP Program of 12th Grade Preparedness Research and that can serve as validity evidence in relation to interpretations of the results from two previous preparedness studies—the Judgmental Standard Setting (JSS) study, implemented in 2011, and the Job Training Program Curriculum (JTPC) study, implemented in 2012. The JSS study followed a modified bookmarking, standard-setting process to identify the NAEP objectives that represented the mathematics and reading knowledge, skills, and abilities prerequisite to occupational job-training programs and entry-level college courses. The JTPC study used a modified Delphi method or *convergent consensus* process (Conley, 2006) to identify, through content analysis of course materials, the prerequisite KSAs of job-training program courses in the same five occupational areas explored in the JSS study.[1] The CCCA study also follows the convergent consensus approach to content analysis of course materials, but rather than five occupation areas, the CCCA study focuses on entry-level college courses, as represented by four course titles in mathematics and four course titles in courses with substantial reading demands. Course titles relevant to the NAEP mathematics framework included college algebra, finite mathematics, precalculus/calculus, and statistics. Titles relevant to the NAEP reading framework included English literature, psychology, U.S. government, and U.S. history.

[1] The five occupations were Automotive Master Technician; Computer Support Specialist; Heating, Ventilation, and Air Conditioning Technician; Licensed Practical Nurse; and Pharmacy Technician.

CCCA STUDY OVERVIEW

CCCA is a content analysis study with the primary purpose of identifying the KSAs needed for a student to be prepared to enter an entry-level college course, without remediation. The methodology relies on a formal, systematic approach using expert judgment to measure and validate content and conclusions that are challenging to measure, yielding rich and useful information. Confidence in the findings is dependent on review of the reliability and validity associated with the pillars of the methodology: the institutional representativeness from which the study artifacts were drawn, the sufficiency of the artifacts to allow determinations of applicability, and the intra- and interrater reliability of the reviewers.

Research Questions

The CCCA study addresses four research questions for both mathematics and reading:

1. What are the prerequisite knowledge, skills, and abilities (hereafter referred to as prerequisite KSAs) in mathematics and reading to qualify for entry-level, credit-bearing courses that satisfy general education requirements?
2. How do these prerequisite KSAs compare with the 2009 and 2013 NAEP mathematics and reading frameworks and item pools?
3. How do these prerequisite KSAs compare with previous NAEP preparedness research; i.e., the descriptions of minimal academic preparedness requirements produced in the JSS research?
4. How can these prerequisites inform future NAEP preparedness research; i.e., planning and analysis efforts relative to the 2013 12th grade NAEP mathematics and reading assessments?

To achieve the goal of CCCA study comparability with the previous JSS study, the CCCA study relied on the same NAEP frameworks used in JSS, collected course materials and syllabi from the same (2009) academic year and used 2009 NAEP 12th grade items for comparison. During the study, 2013 items were available and were included in the study.

CCCA Study Phases

The CCCA study began in October of 2012 and spanned eighteen months. The first phase lasted nine months and consisted of identifying the institutional sample, identifying and collecting artifacts, and recruiting content reviewers and NAEP experts. The second phase lasted four months and encompassed reviewer training, coding, data summarization, and group meeting activities. The final phase lasted six months and included NAEP expert review of coding from the group meeting activities, data analysis, and report development.

The three phases of the CCCA study are summarized below and illustrated in Figure 2:

1. Establishing the foundation for the study, including creating a representative sample of institutions, collecting artifacts, organizing them into course packets, and selecting content reviewers and NAEP experts.
2. Conducting content analysis activities including training and qualifying content reviewers, convening a series of coding events using the convergent consensus content review process, summarizing the data into detailed content maps of the KSAs, and completing a generalizability study (G-study).

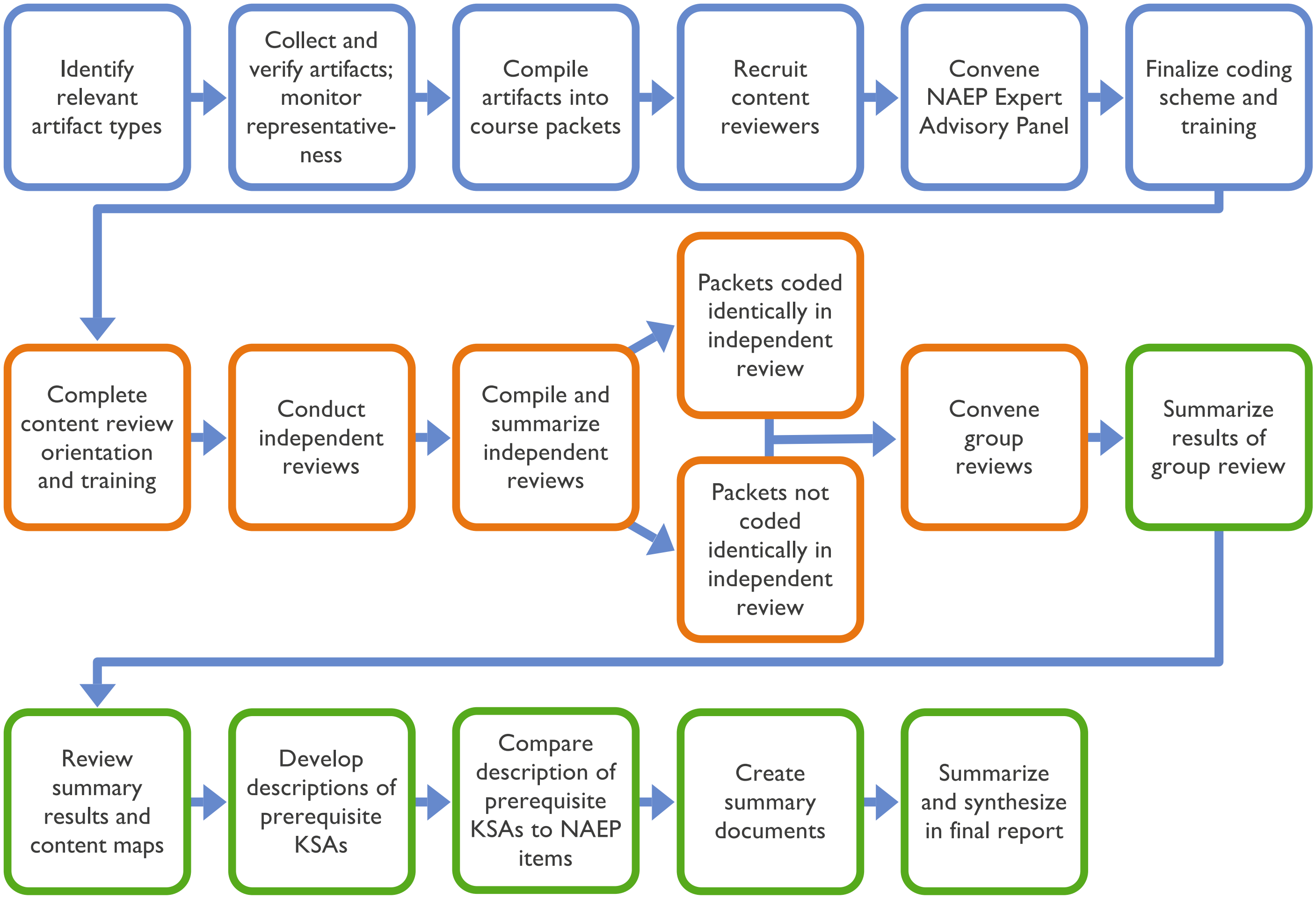

Figure 2. **Three Phases of the CCCA Study**

Note. **Artifact collection (EPIC staff); Convergent consensus (content reviewers); NAEP review (NAEP experts).**

3. Conducting NAEP expert reviews of the documentation, analyzing and synthesizing the results, and producing a final report addressing the four research questions of the CCCA study.

Through the content analysis of artifacts (syllabi, assignments, assessments, and textbook excerpts assembled into course packets), the CCCA study identified the prerequisite mathematics- or reading-related knowledge, skills, and abilities (KSAs) necessary for students to be academically prepared, without remediation, for entry-level college courses. The result was a set of detailed content maps of the KSAs. A G-study was conducted to analyze variation and determine generalizability.

The NAEP experts reviewed the content maps of prerequisite KSAs and developed narrative descriptions to summarize the prerequisite KSAs identified by the content reviewers. They then compared their narrative descriptions to the content in the items in the 2009 and 2013 12th grade NAEP item pools to analyze the correspondence between the CCCA KSAs and content assessed in the NAEP items. Next, the NAEP experts compared the narrative descriptions of the prerequisite CCCA KSAs to borderline performance descriptions and other content summaries captured in the JSS and JTPC studies.

KEY TERMS

The following section summarizes the key terms used in the CCCA study, developed in conjunction with the NAEP Glossary of Terms (U.S. Department of Education, National Center for Education Statistics, 2013). The terms are organized in alphabetical order in the glossary in Appendix A.

College Course Content Analysis (CCCA)—Acronym used throughout this study.

KSA—Knowledge, skills, and abilities.

Content Analysis—An objective and systematic technique for making replicable and valid conclusions about course content from course packets (Krippendorff, 2013).

Institution—Postsecondary college or university that met representativeness criteria from which courses were selected and course artifacts were collected to form complete course packets.

- **Institution Inclusion Criteria**—Criteria that defined the minimum requirements for an institution to become eligible to submit artifacts to be included in the CCCA study.

Artifact—A syllabus, assessment, assignment, or textbook excerpt. Artifacts were systematically collected and organized into complete course packets.

- **Artifact Inclusion Criteria**—Criteria, specific to a syllabus, assessment, assignment, or textbook excerpt, that defined the minimum requirement for the artifact to be included in a complete course packet.

  Extant Artifacts—Relevant artifacts from a repository of course materials that had been collected during previous studies by EPIC and that EPIC was given permission to use for additional studies. These artifacts from EPIC's repository were included in the CCCA study.

Course—A class offered at a postsecondary institution. The CCCA study focused on one of eight course titles with mathematics and reading content that fulfilled a set of course inclusion criteria (see the Course Packets section for the criteria). Artifacts were solicited for these courses and used to construct course packets.

- **Course Title**—A grouping of courses (e.g., U.S. history) that would be expected to have similar content regardless of the institution at which a given course is taught.
- **Course Inclusion Criteria**—Criteria that defined the minimum requirements for a course to be included in the study.
- **Course/Artifact Submitter**—A college-level instructor who submitted a minimum of three artifacts for a single course to be organized into a single course packet.
- **Online Submission Instrument**—The platform where a Course/Artifact Submitter attests that the artifacts being submitted relate to a course that meets the **Course Inclusion Criteria** for the CCCA study and submits the required artifacts for a complete **Course Packet**.

Course Packet—A set of three or more artifacts representing a single course title at one institution, including a syllabus, a textbook excerpt, and either an assignment or an assessment. There were a total of 28 course packets for each course title used for four different purposes: training reviewers to participate in the study, qualifying reviewers to participate in the study, operational use by reviewers in Phase 2 of the study, and validation of results compiled from the reviewers.

- **Code/Coding**—The category of a knowledge, skill or ability (KSA) statement, which is identified based on evidence within a course packet. The process of categorization conducted by the content reviewers is referred to as coding throughout the study. A coding scheme was developed with specific codes used by the content reviewers to facilitate analysis.

- **Coding Scheme**—A systematic and formal structure for defining, identifying, and recording prerequisite knowledge, skills, and abilities in course artifacts during review.

- **Decision Rules**—Guidance on how to identify evidence during the review process, applying the coding scheme to areas identified as potentially ambiguous.

- **Training Packet**—One of two course packets in mathematics or one of two course packets in courses with substantial reading demands that were reviewed and coded for evidence of KSAs by the content reviewers during their training and prior to conducting qualifying reviews.

- **Qualifying Packet**—One of two course packets in mathematics or one of two course packets in courses with substantial reading demands that were reviewed and coded by content reviewers after participating in training. The coding on these packets was used to assess content reviewers' understanding of the review process. If adequate understanding was not demonstrated in the qualifying packet reviews, a content reviewer was released from participating further in the study.

- **Operational Packet**—One of 80 course packets in mathematics or one of 80 course packets in courses with substantial reading demands, 20 per course title, reviewed and coded for evidence of KSAs by content reviewers.

- **Validation Packet**—One of eight course packets in mathematics or one of eight course packets in courses with substantial reading demands, two per course title, reviewed by all content reviewers during the independent and group reviews to assess reviewer consistency. Reviewers' codings on validation packets provided the data analyzed during the generalizability studies.

NAEP Framework—The blueprint that guides the development of the NAEP assessment instrument and determines the content to be assessed by NAEP. For the purposes of the CCCA, a NAEP framework is a selection of content statements used as the basis for **coding** the evidence found in course packets. The 2009 12th Grade NAEP Frameworks for Reading and Mathematics were used, and neither framework has changed since 2009.

- **Subject Area**—One of the areas assessed (or planned for assessment) by NAEP, which includes but is not limited to the arts, civics, economics, foreign language, geography, mathematics, reading, science, U.S. history, world history, and writing. CCCA examined two subject areas: mathematics and reading. The term **Course Type** has been used in CCCA-related materials and is considered synonymous with the term **Subject Area**.

- **Objective**—Level of statement within the NAEP mathematics and reading framework referred to for content review and analysis.

- **Subtopic**—A level in the hierarchy of an assessment framework; a statement that is more general than an **Objective** in the NAEP mathematics framework. For example, the NAEP mathematics framework is organized from highest level to lowest level as follows: Subject Area- 1. Content Area- 1.1 **Subtopic**- 1.1.a **Objective**. For example, Mathematics- 1. Number and Properties- 1.1 Number Sense- 1.1.a Represent, interpret, or compare expressions for real numbers, including expressions using exponents and logarithms.

- **Standard**—A level in the hierarchy of an assessment framework; a statement that is more general than an **Objective** in the NAEP reading framework. For example, the NAEP reading framework is organized from highest level to lowest level as follows: Subject Area- 1. Cognitive Domain: 1.1 **Standard:** 1.1.a **Objective**. For example, Reading- 1. Locate/Recall- 1.1 Locate or recall textually explicit information and make simple inferences within and across both literary and informational texts- 1.1.a Locate or recall specific information such as definitions, facts, and supporting details in text or graphics.

- **NAEP Item and NAEP Item Pool**—A set of basic scorable parts of the NAEP assessment or test questions **(NAEP Items)** available for administration. NAEP items are either multiple-choice or constructed-response. The CCCA study included a comparison of prerequisite KSAs with the 2009 and 2013 12th Grade NAEP item pools in mathematics and reading.

- **Holistic Review Statement**—A statement of knowledge, skills and abilities identified during the Holistic Review, which is conducted before reviewers are asked to use the NAEP Frameworks as a reference. **Holistic Review Statements** are outputs of a training exercise that familiarizes the **Content Reviewers** with all of **Course Packets** they will review in the study, while also allowing reviewers to suggest prerequisite **KSAs** in their own words, based on the evidence identified in the **Course Packets**.

- **NAEP-Specific KSA**—A statement of knowledge, skills, and abilities that is articulated in the NAEP framework. The NAEP-specific KSAs may not be evident as prerequisite in the course packets.

- **NAEP-Specific KSA Exclusion**—A selection of text from a NAEP-specific KSA that does not apply to the coding by a content reviewer or content reviewer group.

- **Non-NAEP Additional KSA**—A statement of knowledge, skills, and abilities that is not listed in the NAEP framework. These include the **Holistic Review Statements** that content reviewers within each **Subject Area** deemed appropriate to integrate into the operational **Coding** process.

Reviews—Identification and coding of evidence of knowledge, skills, and abilities within the content of course artifacts compiled into packets by experts.

- **NAEP Expert**—A highly qualified doctoral-level expert in mathematics or reading content who served as an advisor to the CCCA study. Each NAEP expert had specialized expertise on the NAEP, including a deep understanding of the NAEP and participated in the development of the NAEP framework. All had extensive experience with previous NAEP studies, including the JSS and JTPC studies.

- **Content Reviewer**—A highly qualified and trained college-level mathematics or reading content expert who reviewed course packets for evidence of KSAs for the CCCA study.

- **Holistic Review**—An initial general review of course packets conducted as a training exercise prior to content reviewer training on the NAEP frameworks and the convergent consensus review methodology.

- **Content Review**—The application of the coding scheme to a course packet, an assembly of course artifacts. Content reviews were conducted independently and in a group.

- **Content Review Group**—A group of three content reviewers who independently and collectively reviewed the same set of course packets.

- **Independent Review**—A process, preceding group review, where content reviewers reviewed a set of 28 course packets independently as part of a convergent consensus process.

- **Group Review**—A process, following independent review, where content reviewers attended a facilitated meeting to review the same 28 course packets and resolve coding disagreements as part of a convergent consensus process.

- **Content Maps**—Visual representations of the group review applicability ratings and **NAEP-Specific KSA Exclusions** related to each of the **NAEP-Specific KSAs**. Applicability ratings represent the degree to which a KSA relates to evidence in a course packet.

Generalizability Study—A statistical analysis of the reliability of using content reviewers to code course packets and the results of CCCA study under specific constraints. This should not be confused with the term "generalizability" that refers to the extension of these research findings and conclusions to the population at large.

STUDY METHODS

This study relied on a convergent consensus process to determine the mathematics and reading KSAs that are prerequisite to entry-level college courses. Dr. David Conley developed the convergent consensus model by drawing upon lessons learned from the RAND Corporation's Delphi method (Dalkey, 1969) and incorporating principles of evidence-centered design, an evidentiary reasoning approach applied in educational assessment development (Cooke, 1991). The convergent consensus process systematically solicits judgments from individuals with specific, relevant experience and expertise by developing and employing an explicit decision-making criterion that informs the judgments that experts make throughout the process. The goal at each stage is to draw upon the experts' perspectives of the subject area in question and to activate this expert knowledge within an explicit decision framework, grounding each decision in specific evidence drawn from course artifacts.

Although high levels of expert agreement often occur, they are not expected initially. The level of agreement increases as content reviewers engage in discussions of specific, contextualized differences. Consensus is the goal but not a requirement. In the final analysis, experts may not reach agreement on every item, and facilitators do not force consensus when experts have substantial or deep-seated differences on a particular code. Percentages of agreement are calculated as a finding of the study.

EPIC implemented a strong set of project management and research processes to ensure reliable and valid data collection, management, and analysis, as well as comprehensive and accurate reporting of study findings. The next sections detail the data sources, procedures, and results relative to each of the three phases of the study.

Phase I: Establishing the Foundational Study Components

The quality of the results of the CCCA study is based on the quality of its three key components:

1. Institutional representativeness
2. Course packet sufficiency
3. Selection of content reviewers and NAEP experts

First, institutional representativeness was defined for the CCCA study. Next, the criteria for a complete course packet were developed and artifacts were collected to compose course packets from institutions that would contribute to a representative sample. Finally, profiles of appropriate content experts were developed for the CCCA study and reviewers were recruited to match these profiles.

Institution Sample Selection and Recruitment

Research staff defined the population of institutions using the 2011 Integrated Postsecondary Education Data System (U.S. Department of Education, National Center for Education Statistics, 2011). IPEDS is a primary source for data on colleges, universities, and technical and vocational postsecondary institutions in the U.S.

From the 7,643 postsecondary institutions identified, the team established sampling parameters for the study. Programs shorter than two years, proprietary institutions, and those with a special focus are not

Table 1. *Institutional Criteria and Category Definitions*

Criterion	Category
Program type: Institutions are classified based on length of program. Institutions with programs that are shorter than 2 years are excluded from the CCCA and national population datasets.	**2-year:** Programs are longer than 2 but shorter than 4 years
	4-year: Programs are 4 years or longer
Enrollment size: Institution size is based on the total number of students enrolled for credit in Fall 2011.	**Small:** Enrollment of 4,999 or fewer
	Medium: Enrollment between 5,000 and 9,999
	Large: Enrollment of 10,000 or more
Geographic region: Institutions are classified by region (East or West) based on which state they are located in.	**East:** AL, AR, CT, DC, DE, FL, GA, KY, LA, MA, MD, ME, MS, NC, NH, NJ, NY, PA, RI, SC, TN, VA, VT, and WV
	West: AK, AZ, CA, CO, HI, IA, ID, IL, IN, MI, OH, WI, KS, MN, MO, MT, ND, NE, NM, NV, OK, OR, SD, TX, UT, WA, and WY
Control of institution: Institutions are identified by two classifications: public or private. Institutions that are private for-profit are excluded from the dataset.	**Public:** An educational institution in which programs and activities are operated by publicly elected or appointed school officials and that is supported primarily by public funds.
	Private: A private institution in which the individual(s) or agency in control receives no compensation other than wages, rent, or other expenses for the assumption of risk. These include independent, not-for-profit schools and those affiliated with a religious organization.

included in the sampling frame of institutions for this study due to expected differences in course content, rigor, and requirements.[2] In addition, institutions with missing values on four institutional criteria and those with values that fell outside the categories listed below (e.g., institutions not within the 50 U.S. states, such as Puerto Rico) also were excluded because they introduced unknown variance and/or cultural and language variance. After excluding these institutions, the researchers identified a population of 3,010 institutions, from which they identified a probability sample of 184 institutions that would yield 184 course packets for analysis, assuming that each institution contributed one course packet. The sample was stratified by program type, size of enrollment, geographic region, and institutional control (see Table 1 for detail).

Ultimately, 169 unique institutions submitted course artifacts. Table 2 describes the characteristics of the 169 institutions and summarizes the artifact data collection process related to representativeness. Course packets drawn from these 169 institutions were used for training and qualifying reviewers, validating coding consistency (validation packets), and content analysis (operational packets). In addition, course artifacts were collected from previous EPIC studies to augment the artifacts collected solely for the CCCA study.

Table 3 presents the number of institutions, number of packets, and distribution of the packets as required for the purpose of creating training, qualifying, operational, and validation packets.

[2] Special focus schools include doctoral research universities; master's colleges and universities; medical schools; other health professions schools; schools of engineering; other technology-related schools; schools of business and management; schools of art, music, and design; schools of law; and other special focus institutions.

Table 2. *Percentages of Institutions, by Characteristic, in the Population and in the Sample of 169 Institutions Submitting 184 Course Packets*

Institutional characteristic	Category	Population %	Mathematics sample %	Reading sample %
Program type	2-year	35	30	24
	4-year	65	70	76
Enrollment size	Small	64	51	50
	Medium	17	20	22
	Large	19	29	28
Geographic region	East	50	45	41
	West	50	55	59
Control of institution	Public	53	61	58
	Private	47	39	42

Course Packets

After the characteristics of the representative institution sample were determined, course packets were compiled using submitted artifacts. Complete course packets included at least three artifacts: a syllabus, one or more assessments or assignments, and an excerpt from a primary textbook. Syllabi were intended to provide evidence of course goals and objectives. Assignments and assessments were intended to identify what students are expected to demonstrate as evidence of what they have learned. The text excerpt was intended to identify a relevant reference available to the student. Some course packets included supplemental assignments, assessments, and other artifacts.

Course packets were solicited from colleges across the U.S. to serve as the basis of the content review for prerequisite KSAs to entry-level college courses. The research team first established a set of course-level inclusion criteria appropriate to identify prerequisites for entry-level college courses. Courses were included if they met the following criteria:

- were credit bearing
- were generally understood to be taken frequently by entry-level students
- had no college-level prerequisites[3,4]
- fulfilled general education requirements[5]
- were entry level
- were not remedial
- were not honors level
- represented actual courses taught in academic year 2009–2010 or 2010–2011
- were not identified with a specific major
- contained syllabi with sufficient information about what was taught in the course (This information would be used to identify relevant mathematics and reading KSAs.)

[3] Courses with corequisites or noncourse prerequisites were coded as having "no college-level prerequisites." Examples of noncourse prerequisites include but are not limited to sufficient scores on placement exams and minimal skills in the subject area (e.g., "minimal algebra skills").

[4] For courses collected and coded as a single course but taught over multiple terms as a sequence (e.g., 101 taught fall term, 102 taught winter term, and 103 taught spring term), only the first course in the sequence was included in the sample. The subsequent courses were excluded from the CCCA study under the assumption that completion of the first course in the sequence was required to advance to the second course.

[5] Policies indicating that credits earned in programs offering associate's degrees are transferrable to programs offering bachelor's degrees are dictated by articulation agreements between institutions and state departments of education. Representatives from the two-year institutions submitting courses for inclusion in the study verified that the submitted course fulfills general education requirements toward a four-year degree.

Table 3. *Institutions Sampled and Course Packets Required for the CCCA Study*

Process	Institutions	Course packets required
The initial assumption was that 184 institutions drawn from a stratified probability sample would contribute 1 course packet each.	184	184
The researchers reviewed the extant artifact base, found a number of courses that fit the institution sample requirements and included them in the total CCCA artifact collection. Course packets were selected from representative institutions on a rolling basis. For example, once a sufficient number of 2-year, large public institutions from the West had provided course packets, no more artifacts were collected from that type of institution. • 155 institutions submitted 1 course packet = 155 packets • 13 institutions submitted 2 course packets = 26 packets • 1 institution submitted 3 course packets = 3 packets	169	184
Four course packets were subtracted from the total and used for training content reviewers: 2 from mathematics courses and 2 from courses with substantial reading demands.	4	4
Four course packets were subtracted from the total and used for qualifying content reviewers: 2 from mathematics courses and 2 from courses with substantial reading demands.	4	4
Sixteen course packets were subtracted from the total and used for validation: 2 from each of the eight course titles.	16	16
After the training, qualifying and validation packets were subtracted, 151 institutions contributed 160 operational packets—20 packets for each of the eight course titles—providing the set of operational packets for content analysis. Seventy-seven institutions provided packets for courses with substantial reading demands, and 74 institutions provided packets for mathematics courses.	151	160
One precalculus/calculus course and one institution were removed during the NAEP mathematics expert review. The NAEP experts who convened after the group content reviewers strongly suggested removing a multivariable calculus course because it did not represent entry-level mathematics content, although it had met the inclusion criteria of being entry level at the institution that submitted it. It was not replaced due to the timing of the ineligibility determination.	150	159

Course packet recruitment began with the research team examining extant artifacts collected from previous EPIC studies to identify those that satisfied the CCCA institution sample and course inclusion criteria. An inventory of extant course artifacts from prior EPIC projects identified 52 mathematics courses and 382 courses with substantial reading demands for potential inclusion in the CCCA study. Some of these extant artifacts were composed of complete course packets and others consisted of course packets that were partially complete (i.e., missing one artifact type), given the requirements of the CCCA study. For courses with partially complete sets of artifacts, staff sent emails to the original faculty contacts requesting that they submit any missing artifacts. Those who completed their course packets were given an honorarium. Of the 184 complete course packets used in the study, 81, or 44%, were from previous EPIC studies. These 81 extant course packets include 5 mathematics and 55 reading operational course packets, all 4 training course packets, 3 of 4 qualifying packets, and 14 of 16 validation packets.

The research team conducted a gap analysis analyzing the difference between the characteristics of the institutions from which the extant course artifacts to be used as operational packets were drawn and the targeted number of institutions within the sampling frame to determine recruitment parameters for collecting the remaining 103 course packets.

The research team contacted postsecondary instructors from the targeted institutions to request courses artifacts. Instructors submitted artifacts through an online submission form. To verify that courses from selected institutions met the inclusion criteria, the research team conducted online reviews of course catalogs and department websites. An initial recruitment email sent to a selected course instructor or a department contact included an overview of the CCCA project, a request for participation via an online submission process, mention of an honorarium, the date window for artifact submission, and an opportunity to opt out of participation in the CCCA study.

Before submitting artifacts, instructors had to verify, through an online survey, that the course satisfied the course inclusion criteria. The instructor or department contact was considered unresponsive after the research team attempted one follow-up phone call and one follow-up email request. This process was followed until the necessary number of course artifacts was collected. To obtain the necessary number of artifacts to create sufficient packets, all institutions on the list were contacted. Of all the course titles, it was most challenging to find calculus courses that had no prerequisites, as most calculus courses require college algebra as a prerequisite. See the artifact solicitation email in Appendix B.

Institutions were allowed to submit artifacts for more than one course if the courses represented different course titles. For courses with substantial reading demands, six institutions provided artifacts for two courses. In mathematics, five institutions provided two courses. Three institutions provided artifacts for courses in both subject areas. It was never the case that an institution submitted artifacts for more than a single course within a course title.

The research team sent 1,570 emails and attempted 633 follow-up phone calls to instructors or departmental contacts. New course packets submitted using the online submission instrument represented 67 of 184 (36%) complete course packets required for the study. The effort to recruit new course artifacts for packets yielded 43 mathematics operational course packets and 21 operational course packets for courses with substantial reading demands. In addition, the effort yielded one of four qualifying and two of 16 validation packets. Using extant packets and newly recruited packets, the research team collected 148 of the 184 total required packets, 124 of which were operational.

To collect the remaining packets that were needed, the research team reviewed websites using general keyword Google searches. For example, the Google search "college algebra syllabus 2010 community" produced online syllabi for college algebra courses taught in community colleges during the 2010 academic year.

Mining online websites yielded the remaining 36 complete course packets required for the study. These comprised 20% of the 184 total course packets. Thirty-two mathematics operational course packets and four operational packets for courses with substantial reading demands were created from course materials mined from websites. The combined effort produced a total of 184 complete course packets, 160 of which initially were operational packets. Near the end of the study, after the content reviews were completed, one multivariable calculus packet was eliminated, leaving 159 operational packets. The NAEP experts, convened after the group content reviews, recommended removing a multivariable calculus course from the study because it did not represent entry-level mathematics content, even though it had met the inclusion criteria of being entry level at the institution that submitted it. It was not replaced due to timing of the ineligibility determination.

Table 4 summarizes the process and outcomes described in this section.

Course Title Selection

The college courses analyzed in this study represent the most frequently taken entry-level, credit-bearing mathematics courses or courses that require college-level reading, which satisfy general college graduation requirements. To identify frequently taken course titles that were potential candidates for this study, the research team referred to a report prepared by the National Center for Education Statistics (NCES) that identified the top 30 most studied postsecondary courses (U.S. Department of Education, National Center for Education Statistics, 2004). The research team also drew on previous research to narrow the list to eight course titles that were likely to meet the course inclusion criteria and contain sufficient mathematics and reading content to permit reviewers to determine the KSAs associated with minimal academic preparedness without need for remediation (Conley, 2011). The course titles selected for the CCCA study for mathematics are precalculus/calculus, college algebra, finite mathematics, and statistics. The course titles selected for courses with substantial reading demands are English literature, psychology, U.S. government, and U.S. history. Appendix C provides the names of the courses associated with each course packet analyzed in the study.

Table 4. ***Course Packet Recruitment Processes and Outcomes***

Course packet type	Extant artifact database	Online submission instrument	Internet search	Total
Mathematics total	**14**	**46**	**32**	**92**
Training	2	0	0	**2**
Qualifying	1	1	0	**2**
Validation	6	2	0	**8**
Operational	5	43	32	**80**
Reading total	**67**	**21**	**4**	**92**
Training	2	0	0	**2**
Qualifying	2	0	0	**2**
Validation	8	0	0	**8**
Operational	55	21	4	**80**
Course packet total	**81**	**67**	**36**	**184**

Note. The count of course packets from the extant courses includes complete and partially complete course packets. Table includes artifacts collected for a mathematics course packet that was disqualified from the study after the content review.

Number of courses in each course title. Because this study involved a content analysis of course documents, the criteria for determining adequate sample size of course packets were derived from the principle of redundancy. In other words, the sample would be considered to be sufficient at the point where new packets were yielding information about prerequisites that was essentially redundant with that gathered from all previous packets. Results from previous studies conducted by EPIC, including the JTPC study, and from generally accepted practices in this field of research (Krippendorff, 2013), indicate that a sample of 20 courses per course title is sufficient to achieve redundancy at a level that supports valid and generalizable inferences. The CCCA study used this sample size of 20 courses per course title to achieve sufficient redundancy.

Artifact Inclusion Criteria

Artifacts that satisfied both the institution and course inclusion criteria also had to satisfy a set of artifact inclusion criteria before being compiled into a course packet.

To be considered complete, a course packet needed three artifacts: a syllabus, an assignment or assessment, and an excerpt from a primary textbook. Course packets were not restricted to just three artifacts, so some also contained supplemental assignments, assessments, and other artifacts. The most common supplemental artifacts were study guides, grading rubrics, and assignment lists.

Inclusion criteria for each of the three required artifacts are described below.

Syllabus. Based on earlier studies (Conley, 2008), the research team expected that syllabi from some college courses would not provide sufficient information or detail for content analysis. Because the artifacts needed to provide a level of data richness that would be sufficient for reviewers to identify evidence of mathematics or reading KSAs taught in the course, each syllabus was reviewed for sufficient mathematics or reading information to conduct content analysis.

Information-lacking syllabi generally provide a brief course description, some course policies, and nothing more. Sufficient syllabi generally include detailed course descriptions, policies, schedules, objectives or goals, and brief descriptions of all course activities, assignments, and assessments. Sufficient syllabi may also describe the learning progression and allow for a more accurate identification of the prerequisite KSAs necessary for entry into the course.

Textbooks. An earlier study (WestEd & EPIC, 2013) indicated that primary textbooks provide a wealth of information about the KSAs required in a course. Past content reviewers have identified textbooks as the most helpful source of evidence for identifying prerequisite KSAs. The course text artifact was used heavily as a source of evidence for identifying KSAs across all the occupational areas reviewed in the JTPC study for both mathematics and reading.

The textbook collection process identified and obtained textbook information from instructors using three methods to obtain textbook excerpts: an online data mining process, borrowing textbooks, and purchasing/renting textbooks. The research team applied a hierarchical decision rule framework for identifying primary textbooks and selected textbook excerpts for each course packet.

The decision rule frameworks typically applied to precalculus/calculus, college algebra, statistics, finite mathematics, psychology, U.S. government, and U.S. history textbooks. For courses included under the English literature course title that use novels rather than textbooks as required texts, the first chapter(s) of the first novel to be covered in the class was included.

Textbook Selection Decision Rules

1. For courses with only one textbook, that textbook was considered the primary textbook.
2. For courses with two or more required textbooks and the syllabus did not indicate a primary textbook, the following guidelines were used:
   a. If the institution was contacted through the data collection process, the institution was asked to identify the primary textbook.
   b. If a course schedule was available, the textbook covered earliest in the course schedule was considered the primary textbook.
   c. If no course schedule was available, the following rules applied to gather the most appropriate textbook-based artifact:
      i. if one of the textbooks was used in multiple course titles, it was selected;
      ii. if topics were listed in the syllabus, the research team inferred the primary textbook from the coverage of early topics; and
      iii. if no other information was available, the textbook listed first was selected.
3. If no textbook was identified, the institution was contacted through the supplemental artifact collection process and requested to submit a primary textbook or provide a textbook-based artifact for consideration.

Textbook Excerpting Decision Rules

1. The table of contents was included when present.
2. One or two chapters were included depending on the length of the chapters. Typically, textbook artifacts did not exceed 100 pages.
   a. If the course schedule was available, the first chapter(s) covered in the course was excerpted.
   b. If no course schedule was available, the first chapter(s) in the textbook was excerpted.

See Appendix D for the complete description of artifact collection inclusion criteria and decision rules applied to this study.

Assessments and assignments. At least one assessment or assignment was required in every complete course packet. Because the goal of this study was to identify prerequisite KSAs, only assessments or assignments provided early in the course schedule were acceptable for inclusion. Midterm exams were accepted if there were no assignments or assessments available from earlier in the course. Because the artifacts needed to provide a level of data richness that would be sufficient for reviewers to identify evidence of mathematics or reading KSAs taught in the course, each assignment and assessment was reviewed for sufficient mathematics or reading information to conduct content analysis.

Many mathematics course assignments or assessments consisted of a list of problems directly from the course textbook. When available, the research team collected supplementary assessments or assignments from these courses. In cases where the only assessments or assignments were from the textbook, the problem set for the first assessment or assignment was included in the textbook excerpt.

Complete Course Packets

Table 5 displays counts of artifacts within all the course packets by type, subject area, and course title. Within course titles with substantial reading demands, U.S. history had the most artifacts with 98, and English literature had the fewest with 83. Course packets from courses with substantial reading demands relied the heaviest on assignments as a supplement to syllabi and text excerpts, with a total of 110 assignment artifacts across course packets.

Within mathematics courses, finite mathematics course packets had the fewest course artifacts with 74 artifacts, while precalculus/calculus had the most mathematics artifacts with 78. Mathematics relied more heavily on assessments as a supplement to syllabi and text excerpts, with 60 assessment artifacts across the packets.

Mathematics and courses with substantial reading demands had similar counts of "other" artifacts (i.e., study guides, grading rubrics, assignment lists, classroom handouts). All assessments for reading are either quizzes or exams produced by the instructor of the course and are not from the textbook.

Across the course packets from courses with substantial reading demands, the U.S. history course title was unique in that there were more assessments than assignments; the opposite was true in psychology, U.S. government, and English literature. English literature relied solely on assignments with one exception. Overall, each mathematics course title had approximately the same number of artifacts. College algebra relied heavily on assignments, whereas finite mathematics, precalculus/calculus, and statistics all relied more heavily on assessments.

In addition to the artifacts, each course packet contained a title page that displayed the course title (e.g., U.S. history), course name (e.g., American History Since 1877), course number (e.g., HIST 122), a list of artifacts included in the course packet, the primary textbook title and author, how the textbook excerpt was identified, and what was included from the textbook. All information that could identify the institution that submitted the course was redacted from the course packet. Appendix E contains a sample mathematics course packet and a sample packet from a course with substantial reading demands.

NAEP Grade 12 Reading and Mathematics Frameworks

This study used versions of the 2009 Grade 12 NAEP mathematics and reading frameworks modified for alignment studies (U.S. Department of Education, National Center for Education Statistics, 2009; U.S. Department of Education, 2009). Appendix F contains the 2009 Grade 12 NAEP frameworks.

Table 5. *Number and Type of Artifacts in all Course Packets by Subject Area and Course Title*

Course title	Syllabus	Assessment	Assignment	Textbook	Other	Total
Mathematics total	**92**	**60**	**44**	**92**	**16**	**304**
Precalculus/calculus	23	17	12	23	3	**78**
College algebra	23	11	16	23	4	**77**
Finite mathematics	23	13	8	23	7	**74**
Statistics	23	19	8	23	2	**75**
Reading total	**92**	**40**	**110**	**94**	**17**	**353**
English literature	23	1	32	23	4	**83**
Psychology	23	8	32	23	1	**87**
U.S. government	23	11	26	24	1	**85**
U.S. history	23	20	20	24	11	**98**
Total artifacts	**184**	**100**	**154**	**186**	**33**	**657**

Note. Table includes artifacts collected for all course packet types, including training, qualifying, validation and operational course packets. Table includes artifacts collected for a mathematics course packet that was disqualified from the study after the content review.

The 2009 NAEP Grade 12 reading framework is structured as follows:

1. **Cognitive domain**
   1.1. Standard
      1.1.a Objective

For example, as shown below, the second reading cognitive domain is "2. Integrate/Interpret: Make complex inferences within and across texts," a standard within this domain is "2.1. Integrate/ Interpret: Make complex inferences within and across both literary and informational texts," and an objective within that standard is "2.1.a. Describe problem and solution, or cause and effect." Table 6 outlines the three cognitive domains and 10 standards in the reading framework, and identifies the number of objectives, 37.

Table 6. ***2009 NAEP Grade 12 Reading Framework***

Cognitive domain: Standard (number of objectives)
Locate/recall • Locate or recall textually explicit information and make simple inferences within and across both literary and informational texts (1) • Locate or recall textually explicit information and make simple inferences within and across literary texts (5) • Locate or recall textually explicit information and make simple inferences within and across informational texts (4)
Integrate/interpret • Make complex inferences within and across both literary and informational texts (6) • Make complex inferences within and across literary texts (5) • Make complex inferences within and across informational texts (5) • Apply understanding of vocabulary to comprehension of both literary and informational texts (1)
Critique/evaluate • Consider both literary and informational texts critically (3) • Consider literary texts critically (3) • Consider informational text critically (4)

For mathematics, the framework is structured as follows:

1. **Content Area**
   1.1. Subtopic
      1.1.a. Objective

Objectives are the most specific level in the organizational structure of the NAEP frameworks. For example, as shown below, the first mathematics subject area is "1. Number properties and operations," a subtopic within that domain is "1.1. Number sense," and an objective within that subtopic is "1.1.a. Represent, interpret, or compare expressions for real numbers, including expressions using exponents and logarithms." Table 7 outlines the five content areas and 24 subtopics in the mathematics framework, and identifies the number of objectives, 130.

For the purposes of the CCCA study, the levels within the organizational structure of the NAEP frameworks were operationalized differently for coding mathematics and reading. The reading objective-level statements must be read within the context of the standard and cognitive domain levels. That is, content reviewers were required to interpret the objective in the context of its standard and domain. If any part of the "domain + standard + objective" was deemed not prerequisite but other parts were, then the parts that were not were identified as KSA exclusions. In mathematics, the hierarchy differs, and the content areas and subtopics are organizers for the objectives, rather than context for interpretation. As such, only the objective-level statements were considered for identifying KSA exclusions.

Participants

The research team recruited two separate groups of reviewers for the CCCA study: content reviewers and NAEP experts.

Table 7. ***2009 NAEP Grade 12 Mathematics Framework***

Content area: Subtopic (number of objectives)
Number properties and operations: • Number sense (4) • Estimation (3) • Number operations (5) • Ratios and proportional reasoning (2) • Properties of number and operations (4) • Mathematical reasoning using numbers (2)
Measurement: • Measuring physical attributes (6) • Systems of measurement (5) • Measurement in triangles (7)
Geometry: • Dimension and shape (4) • Transformation of shapes and preservation of properties (6) • Relationships between geometric figures (7) • Position, direction, and coordinate geometry (8) • Mathematical reasoning in geometry (5)
Data analysis, statistics, and probability: • Data representation (6) • Characteristics of data sets (7) • Experiments and samples (5) • Probability (9) • Mathematical reasoning with data (5)
Algebra: • Patterns, relations, and functions (7) • Algebraic representations (7) • Variables, expressions, and operations (7) • Equations and inequalities (6) • Mathematical reasoning in algebra (3)

Content reviewers. The research team recruited and selected content reviewers who had relevant content expertise. Mathematics reviewers were informed and knowledgeable about the mathematics requirements for placement, without remediation, into entry-level, credit-bearing courses in mathematics. Reading reviewers were informed and knowledgeable about the reading requirements for placement, without remediation, in introductory courses that require extensive reading and fulfill general education requirements.

Individuals with the following types of experience were recruited:

- Instructors of two- and four-year postsecondary, entry-level, credit-bearing mathematics or English and social science courses that fulfill general education requirements for a four-year degree program
- Instructors of remedial or developmental mathematics or courses with substantial reading requirements in postsecondary institutions
- Instructors of postsecondary mathematics or English and language arts who have participated directly in the development of entry-level placement tests for a postsecondary institution

The mathematics reviewers must have taught postsecondary courses fulfilling general education course requirements in mathematics. Reading reviewers must have specialized in reading pedagogy or have taught postsecondary courses in literature or one of the social sciences or humanities with extensive reading demands, and must be informed and knowledgeable about the reading requirements for course placement without remediation.

The pool of potential content reviewers was initially reduced through a curriculum vitae rating process that ensured only instructors that fit the criteria above were invited to participate in the study. The research team provided the Governing Board with a list of the individuals meeting the selection criteria for approval prior to recruitment. Content reviewers with extensive qualifying credentials, experience participating in the JSS or JTPC studies, or those from a pool of trained EPIC mathematics and reading content experts who had substantial experience with convergent consensus artifact review and content analysis were given priority for selection. The recruitment process resulted in a group of 32 reviewers (16 in mathematics and 16 in reading) divided into eight content review teams, each composed of three content reviewers and one alternate. Reviewers were paid for participation in the study.

NAEP experts. A panel of NAEP experts, three in mathematics and three in reading, provided guidance during each phase of the CCCA study. All the NAEP experts provided advisory support during the planning phases of the study. Four of the six NAEP experts attended the group review meetings as advisors. All the NAEP experts convened after the content review to guide the interpretation of findings related to this study's four research questions.

Individuals serving as NAEP experts possess extensive knowledge of both the NAEP framework and the mathematics or reading content domains generally. The research team successfully recruited individuals who served on NAEP expert panels during the JSS and JTPC studies. The final list of NAEP experts was presented to and approved by the Governing Board.

Phase 2. Conducting the Content Analysis

The CCCA study employs a convergent consensus approach. This method relies on multiple criterion-based expert analyses designed to reach consensus on the relationship between the elements being judged and the criteria used to judge them. Expert reviewers must agree that the elements being judged meet the judging criteria. This method is different from more common methods where individual raters work in isolation to rate an item or element and then the ratings are compared to generate a traditional reliability statistic. This more common approach works well when the elements being rated are of a small grain size, such as a test item or an individual standard statement, for example, and the criteria to rate them can be applied in a reasonably straightforward or mechanical fashion. For example, does the item cover equations or functions? Or, does the standard require analytic thinking or only procedural thinking? Reaching judgments of this type can be achieved with minimal training with little to no oversight during the rating process.

However, analyzing artifacts that are more complex and at a much higher aggregation level than a test item requires a different approach. It begins with the notion that experts by their very nature are likely to interpret complex documents somewhat differently and that rating in isolation in fact obscures the deep understanding that experts bring to the analysis and rating process. Convergent consensus begins with individual ratings but differs from more commonly employed methods by requiring reviewers to identify the evidence or data source that supports each individual judgment. In this sense, convergent consensus incorporates and is built upon an evidence-centered design approach more than a classical rater reliability model (Mislevy, 2005). Next, reviewers share their judgments with other reviewers. Areas of agreement are not discussed. For any judgment for which reviewer inconsistency is found to exist, reviewers cite the evidence to support their conclusion. The evidence must relate to the criteria used to make the judgment and may not be the reviewer's opinion or impression. In this fashion, the review process draws upon the deep expertise of the reviewers but constrains judgment by causing the reviewer to reference both evidence and decision criteria when a judgment is found to be inconsistent with other reviewers.

The CCCA study used two content reviews to address the first research question: What are the prerequisite KSAs in mathematics and reading to qualify for entry-level, credit-bearing courses that satisfy general education requirements? Table 8 summarizes the processes of these content reviews using convergent consensus.

The end result of the convergent consensus process was the creation of content maps. Content maps were created for mathematics overall and for each course title at the content area, subtopic, and objective level. Content maps were created for reading overall and for each course title at the content domain, standard, and objective level. The content maps are spreadsheets that summarize the groups' consensus ratings on the prerequisite NAEP-specific KSAs and prerequisite KSA exclusions. The spreadsheets included four percentages for each NAEP-specific KSA that captured the percent of course packets in which the NAEP-specific KSA was (1) not prerequisite, (2) prerequisite, (3) prerequisite and important, or (4) consensus was not reached during group review. The content maps and lists of non-NAEP additional KSAs were provided to the NAEP experts for the final phase of the study.

The study employed additional measures in order to examine reliability and validity of the convergent consensus process. These included process evaluations and a generalizability study. These are described later in this section.

Table 8. *Overview of Content Review Convergent Consensus Process*

	Independent review	Group review
Participants	• Reading content reviewers (12) • Alternate reading content reviewers (3) • Mathematics content reviewers (12) • Alternate Mathematics content reviewers (3)	• Reading content reviewers (12) • Mathematics content reviewers (12) • NAEP reading experts (2) • NAEP mathematics experts (2) • EPIC facilitators (5) • EPIC scribes (5) • EPIC Principal Research Scientist and Assistant Research Scientist (2) • EPIC Project Director (1)
Process	1. Holistic review training and holistic review of operational and validation course packets 2. NAEP-framework training and review of training course packet(s) 3. Qualifying process 4. Web-based submission of ratings of NAEP objectives and non-NAEP additional KSAs	1. Onsite training 2. Reading and mathematics reviewers work separately 3. Four subject area review teams work separately 4. Web-based submission of ratings 5. Individual procedural feedback
Review activities	1. Review course packet to identify and record evidence of NAEP-specific KSAs and non-NAEP additional KSAs 2. Code the NAEP-specific KSAs and identify any relevant KSA exclusions using a web-based tool 3. Code any non-NAEP additional KSAs identified in the course packet but not included in the NAEP-specific KSAs using a web-based tool	1. Discuss and adjudicate all discrepant coding of NAEP-specific KSAs, including KSA exclusions 2. Discuss all identified non-NAEP additional KSAs and code for each course packet
Content review outcome	Comprehensive list of prerequisite KSAs to address CCCA Research Question 1 (NAEP-specific KSAs and non-NAEP additional KSAs)	

Review Process

The content review phase of the CCCA study consisted of two distinct reviews: independent review and group review.

NAEP expert advisory panel. Prior to content review, the mathematics and reading NAEP experts convened to offer insights into and recommendations for the planned process, data collection, and outcomes. (See Appendix G for a meeting agenda.) A primary goal was for the research team to obtain guidance on study methods and to establish a NAEP framework-based coding scheme, which they applied to the 12 packets that would be coded by all reviewers within a subject. These included two training, two qualifying, and eight validation packets each in mathematics and reading. The NAEP experts were uniquely qualified to serve in this advisory role because they each have extensive expertise, judgment, and knowledge regarding college-level mathematics and reading demands in addition to depth of knowledge regarding the NAEP frameworks. The research team used the packets coded by the NAEP experts to assess the content reviewers' ability to code the packets using the NAEP framework during the training and qualifying periods.

The NAEP experts' recommendations were used to ensure that course artifact reviews were conducted through an evidence-based process with procedural and internal validity. The experts' review of course packets provided guidance to the research team to finalize the artifact collection decision rules related to textbooks, the coding scheme, and training for the content review. The experts' codes of the training, qualifying, and validation packets were used in both the training and content review.

Review process recommendations. NAEP experts reviewed the training materials, decision rules, and other key documents prior to the research team training the content reviewers and facilitators. Based on their review of 12 course packets, the advisory panel for each subject area, reading and mathematics respectively, provided recommendations relating to the following:

- Finalizing the coding scheme
- Finalizing the decision rules to support correct interpretation and application of NAEP objectives
- Suggesting which course packets became the training, qualifying, and validation packets
- Suggesting coding and threshold to evaluate content reviewer readiness to participate in operational packet reviews
- Suggesting appropriate use of implicit evidence to identify prerequisite KSAs
- Suggesting improvements to the global, or general, decision rules and subject area-specific decision rules
- Suggesting improvements to the training processes and materials for the content reviewers and group review facilitators
- Providing insight into the data sufficiency of a course packet, including assistance with identifying course packet textbook artifacts
- Providing insight into the best approach to the content reviewer process of course packets, including use of course packet artifacts and artifact components (such as learning objectives on a syllabus or review section in a textbook) in identifying evidence of prerequisite KSAs
- Providing insight into estimated time to complete all review tasks

Subsequent to the content reviews, the NAEP experts convened again to review study findings and support the researchers' interpretations of findings.

A list of the implemented changes from the NAEP advisory panel is contained in Appendix H.

Content Review Group Composition and Course Packet Assignment

A total of 32 content reviewers participated in the CCCA study. In preparation for the study, the content reviewers were divided into four mathematics and four reading content review groups, each composed of four content reviewers—three reviewers plus one alternate. The alternate content reviewers underwent the same training and review process as their teams during the holistic and independent review. Alternates participated in the group review process when a reviewer was unavailable to attend the group review meeting. Content reviewers were assigned to content review groups to ensure an even distribution of two- and four-year instructors and experienced reviewers.

Content Reviewer Demographics

Education	58% doctorate 42% master's
Occupation	75% university faculty 13% community college faculty 8% education consultant 4% other education-related occupation
Years Teaching in Higher Education	71% more than 10 years
Gender	54% male 46% female
Race	83% White 4% Black/African American 4% Asian or Pacific Islander 9% No response

For each course title in mathematics or courses with substantial reading demands, there were 22 course packets associated with each of the four course titles. Two of the course packets in each course title were validation packets that were coded by all content reviewers in the course subject area and which provided data for the reliability and generalizability analyses. The other 20 course packets in each course title were considered operational packets and were distributed randomly for coding among the four groups of content reviewers in the appropriate subject area. Each content reviewer coded five operational packets and two validation packets from each course title within a subject area, for a total of 28 course packets per group. Reviewers were not informed as to whether their packets were classified as validation or operational. Figure 3 summarizes the details of the operational and validation course packet assignments for mathematics; an identical process was used for the assignment of course packets for courses with substantial reading demands.

Course packets were used for different purposes, by different study participants, at different points in time. To summarize, there were 184 packets in total. The NAEP experts used the NAEP frameworks to precode 24 packets: four training, four qualifying, and sixteen validation packets. The eight training and qualifying packets were used for training and were not used for any other purpose. The sixteen validation packets were coded, using the NAEP frameworks, across the content reviewer groups so they could be used as a basis for the generalizability study to establish intra- and interrater reliability. Finally, the operational packets were coded and provided the data for developing the content maps and establishing the

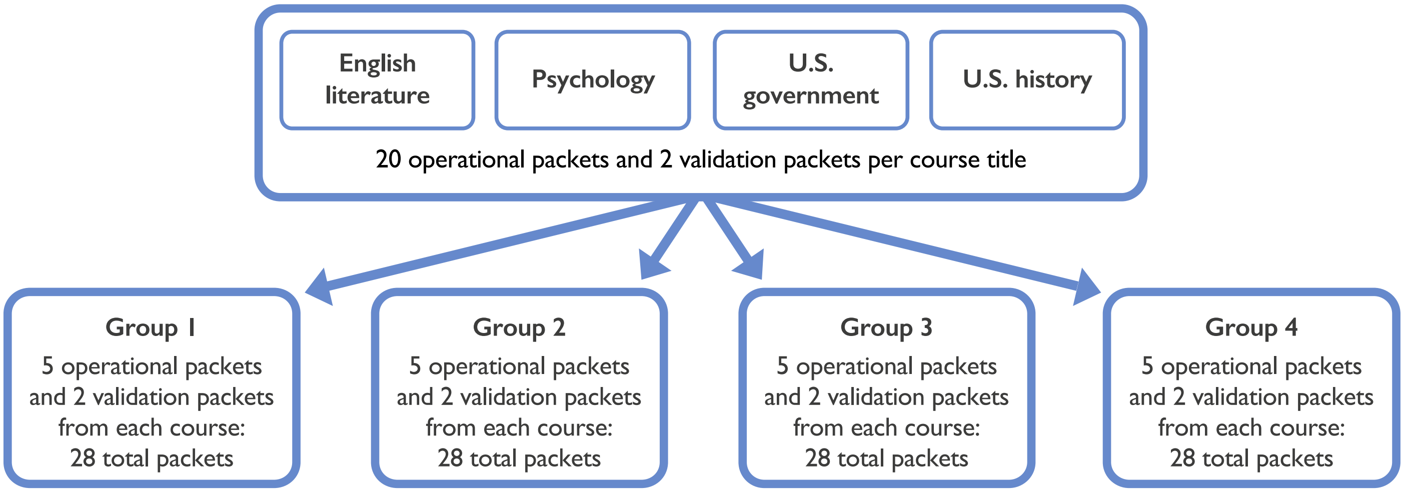

Figure 3. **Operational and Validation Course Packet Assignments**

prerequisites KSAs. Table 9 provides a summary of the review process.

Overview of Content Reviewer Training

EPIC developed a series of trainings to introduce content reviewers to the CCCA study, which incorporated the guidance of the NAEP advisory panels. Training webinars oriented the content reviewers to the main goals of the study and the concept of a prerequisite KSA, then guided the reviewers to refer to evidence in the course packets to complete content reviews. (See Appendix I for holistic review orientation and independent review training materials.) Training packets were used to determine areas for focused individualized training by the research team as deemed necessary or requested by content reviewers.

Content reviewers could comment or provide feedback on the decision rules twice during the study. The first time was during training, and the second was during independent review. During training, feedback identified needs for clarifications that were provided to everyone and documented for independent and group review. During independent review, feedback was monitored for clarifications that might be necessary to ensure consistent application of the coding scheme. No changes were made to the decision rules after training.

Definition of prerequisite knowledge, skills, and abilities. The content reviewers' main task was to identify the prerequisite KSAs based on evidence found in the course packets. This study focused on the prerequisite KSAs a student needs to be prepared to enter a credit-bearing college course. Content reviewers were trained to consider whether there was evidence of a KSA within the course packets, and then to determine whether the KSA was prerequisite. The following CCCA definition of prerequisite was provided to content reviewers.

> A KSA is prerequisite if a minimally prepared student is either expected or required to possess this knowledge, skill, or ability to be prepared for entry into the course. A prerequisite KSA may be reviewed but not taught in depth or for the first time during the course.

Holistic review. A holistic review of course packets was conducted before the independent review and prior to introducing content reviewers to the NAEP framework. The purposes of the holistic review were to develop familiarity with: the course packets, application of global decision rules, identification of sources of evidence, annotation techniques, and use of the web-based survey instrument. A product of this holistic review is a list of holistic review statements. Although they are the product of a less developed understanding of the content review, the holistic review statements are free of any bias that might be

Table 9. *Summary of Review Process*

	Advisory panel	Holistic review	Training session	Independent review	Group review
Number of packets	NAEP experts precoded the training, qualifying, and validation packets	All content reviewers, including alternates	All content reviewers, including alternates	All content reviewers passing qualification, including alternates	Content reviewers selected for group review participation
Training: 2 mathematics, 2 reading	Precoded using the NAEP frameworks by NAEP experts to establish training materials	NA	Coded using NAEP frameworks during training and coaching sessions	NA	NA
Qualifying: 2 mathematics, 2 reading	Precoded using the NAEP frameworks by NAEP experts to establish qualifying materials	NA	Coded using NAEP frameworks after training to qualify for Independent Review	NA	NA
Validation: 8 mathematics, 8 reading	Precoded using the NAEP frameworks by NAEP experts to establish reference materials	Reviewed for KSAs without reference to NAEP frameworks	NA	Coded independently using NAEP frameworks	Reviewed coding of all packets, including exclusions and Non-NAEP KSAs
Operational: 80 mathematics, 80 reading	NA	Reviewed for KSAs without reference to NAEP frameworks	NA	Coded independently using NAEP frameworks	Reviewed coding of all packets, including exclusions and Non-NAEP KSAs
Summary by subject area					
Mathematics or reading packets reviewed per group	Each team of NAEP experts coded all of the same 12 packets in their subject area	Individual reviewers reviewed 28 packets holistically: 8 validation, 20 operational	Individual reviewers coded using the NAEP frameworks up to a maximum of 4 packets: 2 training, 2 qualifying	Individual reviewers coded 28 packets in four teams: 8 validation, 20 operational	Individual reviewers reviewed the 28 coded packets: 8 validation, 20 operational
Total packets					
Total of 184: 92 mathematics, 92 reading	Total of 24: 12 mathematics, 12 reading	Total of 184: 92 mathematics, 92 reading	Total of 8: 4 mathematics, 4 reading	Total of 176: 88 mathematics, 88 reading	Total of 176: 88 mathematics, 88 reading

introduced by knowing the NAEP framework and they serve as a resource for generation of non-NAEP additional KSAs during the content review.

The holistic review orientation was conducted to introduce the content reviewers to the CCCA study, course packets, and the concepts of evidence and prerequisite KSAs. The request to each content reviewer was to review the 28 course packets, in a summary fashion, and to identify four to ten potential prerequisite KSAs per packet. There were very few restrictions on the definition of the prerequisite KSAs, and the resulting holistic review statements were at vastly different levels of specificity. Duplication of holistic review statements, from packet to packet and across reviewers, was expected. Reviewers noted sources of evidence for each holistic review statement so that the information would be available for the subsequent independent and group review cycles.

An online form was used to facilitate the collection of holistic review statements identified during the holistic review. The holistic review instrument collected course packet identifying information and four to ten holistic review statements in open-ended textboxes. The following instructions were provided to content reviewers for the holistic review of course packets.

> Review each packet in its entirety to obtain a holistic understanding of the course. Note all prerequisite knowledge, skills, and abilities, and annotate them clearly as you go. Remember that you will need to refer to your notes here when you meet with the group later on. The more clear and detailed your notes are, the more helpful they will be to you. In your own words, describe 4–10 prerequisites to this course below.

Prior to implementation of the online form, the research team completed multiple test cases to verify its ease of use and the ability to ensure data integrity. A link to the holistic review form was released to content reviewers after testing. Content reviewers completed the holistic review of the course packets in two weeks. See Appendix J for the holistic review instrument.

All annotated evidence of holistic review statements were considered for inclusion during independent review as either a non-NAEP additional KSA or a NAEP-specific KSA. Content reviewers determined whether any of the holistic review statements they generated should be proposed as either NAEP-specific KSA or non-NAEP KSA. Differences between the processes of the holistic review and the independent review resulted in holistic review statements not being carried forward into the independent review. Many of the holistic review statements were not of similar specificity as those identified during independent review, when the reviewers had the NAEP framework as a reference. Also, evidence and the process for identifying evidence became more highly defined as the reviewers were transitioned from the holistic review to the independent review phase of the study. Therefore, holistic review statements, while they may serve as resources for the independent review, were not intended to be directly comparable to the content review KSAs.

Figure 4 displays the total number of holistic review statements generated during the holistic review. These numbers include all duplications, those with very similar content, those later determined to map to the NAEP frameworks (NAEP-specific KSAs), those later identified as non-NAEP additional KSAs, and those beyond the scope of this research study, i.e., not relevant to mathematics or reading.

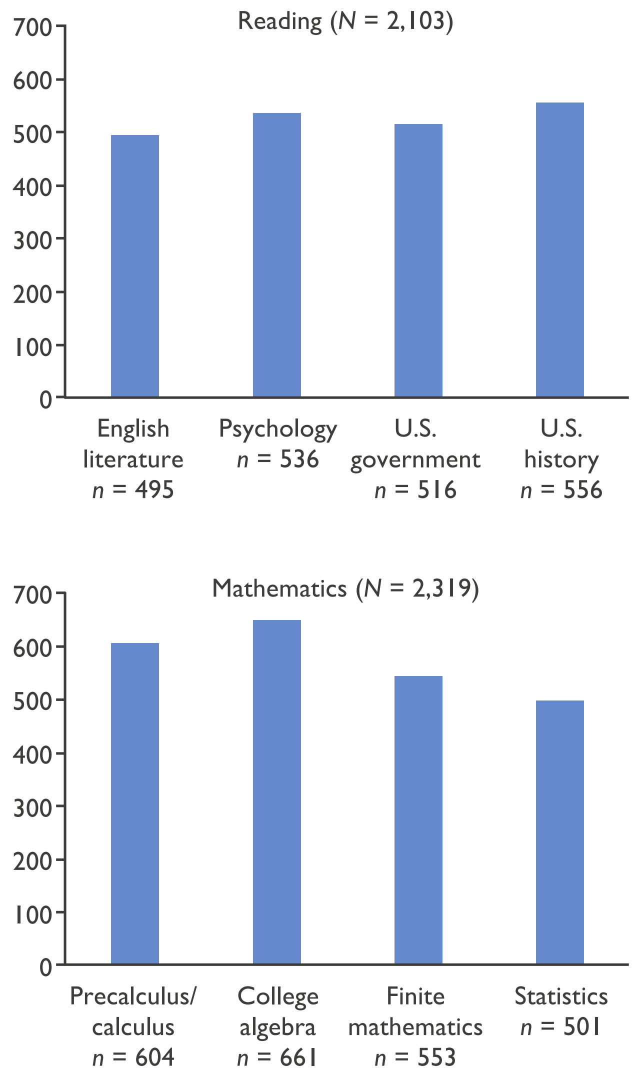

***Figure 4*. Holistic Review Statements Generated During Holistic Review**

Note. This figure represents non-NAEP additional KSAs containing duplicative or redundant content.

Independent review. The second training, the independent review training, introduced the content reviewers to the NAEP framework. The independent review training also introduced a coding scheme, decision rules, definitions of terms specific to the NAEP framework, and an expanded definition of what constituted evidence when discerning whether a statement was evidence of a KSA. See Appendix K for the independent review submission instrument.

During the independent review training, reviewers were encouraged to consider their holistic review evidence notations and the holistic review statements as they conducted the independent review of the same 28 course packets. Some of the holistic review statements identified by the reviewers mapped to a NAEP framework statement or were deemed by the reviewer to be a non-NAEP additional KSA candidate. Other holistic review statements, and related evidence, were not carried forward because they were deemed by the reviewer to be outside the scope of the study as a result of introduction of new parameters during the independent review (decision rules, definitions of evidence, etc.).

Training reviews. Content reviewers received web-based training as a content review group and then individually practiced coding course packets using the independent review instrument. The training packets were representative of those that content reviewers would encounter during the independent review. Prior to coding training packets, content reviewers attended one of four orientation webinars where they were instructed in the purposes of the study, the process and decision rules for reviewing course packets, and the coding scheme for the course packets. Three content reviewers did not attend a training webinar but reviewed the archived webinar materials.

After orientation, content reviewers received a training packet that they coded independently. They then assessed how their codes aligned to precoded responses provided by the NAEP experts during the NAEP advisory panel meetings. Content reviewers had an opportunity to complete up to two training packets and discuss any discrepancies in their coding with each other and the research team.

Qualifying reviews. After a content reviewer completed a training packet(s), he or she coded a qualifying packet. The research team compared content reviewers' coded qualifying packets with precoded responses provided by the NAEP experts. Table 10 displays the five conditions that resulted in a KSA objective match. There was no distinction made between a KSA coded as "prerequisite" and one coded as "prerequisite and important." Consistently locating prerequisite KSAs using identifiable evidence from course packets was more important for ensuring content reviewers mapped to the process than the distinction between "prerequisite" and "prerequisite and important."

Content reviewers qualified for participation in the study if they aligned 80% of their codes with the precoded responses provided by the NAEP experts during the NAEP advisory panel. If content reviewers did not meet the 80% threshold they had the opportunity to repeat training and attempt a second qualifying packet. Content reviewers were removed from the study if they did not reach the 80% threshold on their second qualifying packet based on the coding alignment noted in Table 10.

Alternate reviewers for the content review groups were identified by having lower levels of (but still acceptable) alignment on their qualifying packets as compared to the other content reviewers in their group. See Appendix L for training and qualifying results.

Table 10. ***Qualifying Review Conditions Resulting in KSA Objective Match***

Condition	Content reviewer code	Precoded response
1	KSA is NOT PREREQUISITE	KSA is NOT PREREQUISITE
2	KSA is PREREQUISITE	KSA is PREREQUISITE
3	KSA is PREREQUISITE	KSA is PREREQUISITE and IMPORTANT
4	KSA is PREREQUISITE and IMPORTANT	KSA is PREREQUISITE
5	KSA is PREREQUISITE and IMPORTANT	KSA is PREREQUISITE and IMPORTANT

Independent Review

Each content reviewer independently coded 28 course packets. The content reviewers used the independent review data collection instrument to record prerequisite NAEP-specific KSAs, KSA exclusions, and non-NAEP additional KSAs for each course packet. Content reviewers began their review by reading all material provided in the course packet and noting where they found evidence of prerequisite KSAs.

Content reviewers coded both the applicability and importance (for those KSAs that were found to be prerequisite to the course) of each NAEP-specific KSA. (The instructions provided to content reviewers are shown in the first box on the next page.)

During independent review, content reviewers manually entered prerequisite KSA exclusions when some but not all components of a NAEP-specific KSA were considered prerequisite to the course. Within the independent review instrument, a code was required for all NAEP-specific KSAs; NAEP-specific KSA exclusions were optional. (The instructions provided to content reviewers for excluding parts of non-NAEP additional KSAs are shown in the second box on the next page.)

For the purpose of analyzing the course packet sufficiency, the content reviewers were asked to provide a code for each course packet on the helpfulness of each type of artifact, including the syllabus, assignment(s), assessment(s), text excerpt, study guide/review, instructor comments, homework assignments/readings, and other artifacts (not included in the list). The following options were provided to content reviewers for coding the relative helpfulness of the different course artifacts: not applicable, not helpful, limited helpfulness, helpful, and very helpful.

For all NAEP framework objective KSAs (NAEP-specific KSAs), please indicate whether each is a prerequisite for this course or not, and if so, how important it is to preparedness for this course. **A KSA is prerequisite if a minimally prepared student is either expected or required to possess this knowledge, skill, or ability to be prepared for entry into the course**. A prerequisite KSA may be reviewed, but not taught in depth or for the first time, during the course.

1. KSA is NOT A PREREQUISITE for this course. ***There is no evidence that this is a prerequisite*** (e.g., there is no evidence of the KSAs described by this objective in the packet or this is a new skill or ability that will be taught in this course.)
2. KSA is PREREQUISITE for this course. ***Without this prerequisite, students may struggle in some areas of this course.***
3. KSA is PREREQUISITE for this course and is IMPORTANT. ***Without this prerequisite, students will not be prepared for this course and will struggle in this course.***

Many times, part(s) of a framework objective KSA is/are prerequisite to a course, while other parts are not prerequisite. For each framework objective KSA where only part of the objective is prerequisite, please list the parts that are not.

For example, an exclusion might look like this when organizing structures only need be located, but not recalled, and these structures include comparison/contrast and problem/solution, but not enumeration:

Locate ~~or recall~~ organizing structures of texts, such as comparison/contrast, problem/solution~~, enumeration~~, etc.

And would be recorded like this:

Recall, enumeration

If any part of an entire objective statement is prerequisite, while other parts are not, **list the parts that do not apply in the text box**.

Finally, for each course packet, the content reviewers entered prerequisite non-NAEP additional KSAs, if present, on the independent review instrument. Content reviewers were asked to identify non-NAEP additional KSAs if there was any evidence that appeared to be prerequisite to a course packet but not described by the NAEP frameworks.

For each prerequisite non-NAEP additional KSA provided, content reviewers annotated the evidence and provided the source of evidence (syllabus, assignment, assessment, text excerpt, etc.) they used to generate the prerequisite non-NAEP additional KSA on the independent review instrument. (The instructions provided to content reviewers for entering non-NAEP additional KSAs are shown on the next page.)

As noted earlier, content reviewers were expected to use the evidence annotated during the holistic review of the course packets as a starting point for their independent review of the same course packets and determine whether any of the holistic review statements they generated should be proposed as either a NAEP KSA or a non-NAEP additional KSA.

Since content reviewers in the same groups conducted reviews against the same set of packets, redundancy within the non-NAEP additional KSAs occurred. Since this was an interim step of the convergent consensus process, redundancies within a group were consolidated during group review. Redundancies across groups were consolidated as the non-NAEP additional KSAs were compiled for the NAEP expert review and further at the NAEP expert review. Figure 5 summarizes the number of non-NAEP additional KSAs generated during the independent review.

The following circumstances explain why some KSA statements identified during the holistic review were likely not included in the non-NAEP additional KSA list generated during independent review.

- Independent review training contributed to content reviewers' deeper understanding of prerequisite. For example, some holistic review statements were found to be taught or reviewed content in the course and, therefore, not prerequisite.
- Independent review training contributed to content reviewers' deeper understanding of evidence. Decision rules were developed for independent review, including how to identify evidence. Some annotated evidence of KSAs in the holistic review, therefore, did not meet the level of accepted evidence for the independent review.
- Independent review training helped develop a common understanding of terminology. Content reviewers held different opinions on how to define broad terms prior to independent review training. During the

Please list any additional prerequisites that you did not identify in your initial listing of prerequisites and were not contained in the NAEP objectives.

For each additional prerequisite knowledge, skill or ability evident in this course packet, please identify in which artifact the evidence was found. Please select all that apply.

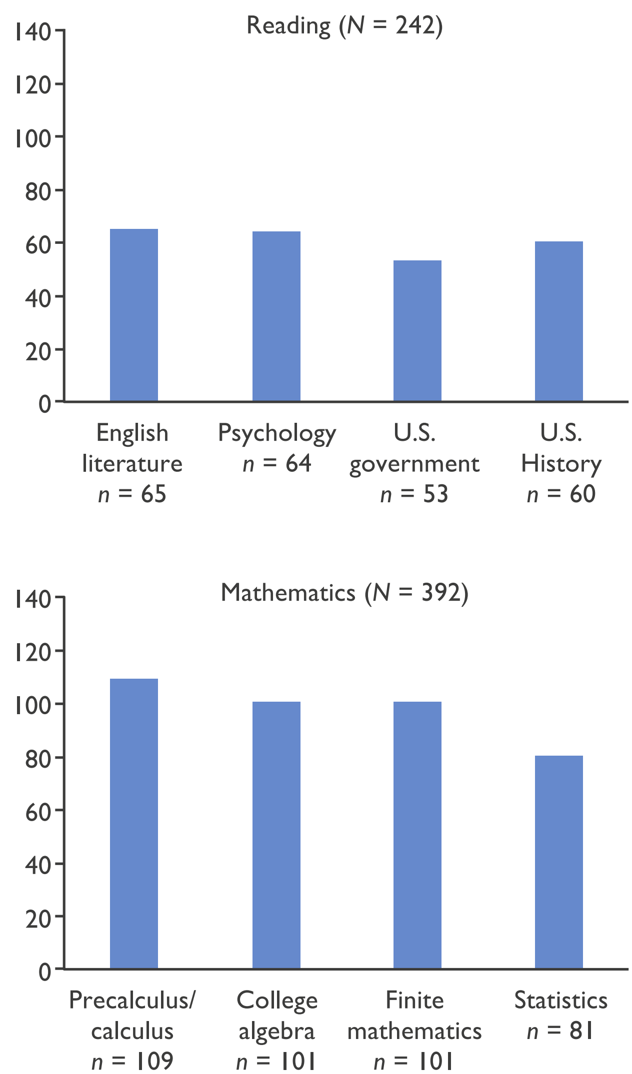

Figure 5. **Non-NAEP Additional KSAs Generated During Independent Review**

Note. This figure represents non-NAEP additional KSAs containing duplicative or redundant content.

holistic review, the term "basic algebra" might have been interpreted to mean knowing how to perform arithmetic operations by one reviewer, while another reviewer might have interpreted "basic algebra" to include solving polynomial equations. The NAEP frameworks defined many terms used in the independent review.

- Independent review training contributed to content reviewers' common understanding of the grain size of a KSA. Content reviewers did not consider a holistic review statement such as "basic algebra" to be a sufficient match for a NAEP objective statement such as "Create and translate between different representations of algebraic expressions, equations, and inequalities (e.g., linear, quadratic, exponential, or *trigonometric) using symbols, graphs, tables, diagrams, or written descriptions (NAEP objective 5.2.a)."

Appendix M contains the reference sheet for reviewers to complete coding of the content review.

Reviewer agreement. The research team constructed aggregated score reports to represent the number and type of KSA coding discrepancies within each content review group prior to the group review. Each NAEP-specific KSA had potentially two types of KSA coding discrepancies: (1) *KSA applicability discrepancies* (not prerequisite, prerequisite, or prerequisite and important), and (2) *KSA exclusion discrepancies* (when applicable). The aggregated score report served as the framework for discussion during the group review. Any packet with less than 100% agreement on KSA applicability and prerequisite KSA exclusions required group discussion. There were 2,072 possible points of discrepancy for the reading groups[6] and 7,280 for the mathematics groups.[7] The prerequisite non-NAEP additional KSAs identified by content reviewers were carried forward and discussed at the group review.

Group Review

After the independent review, teams of content reviewers participated in the group review meetings. At the beginning of the group review meetings, the research team oriented the reviewers to the process, decision rules, and expected outcomes of the study. Each content review group's task during the 4-day meeting was to come to consensus on the *KSA applicability discrepancies* and *KSA exclusion discrepancies* as identified by the aggregated score reports. Content review groups had an opportunity to revisit KSAs where consensus was reached during independent review when the interpretation of decision rules, terminology, or evidence required a coding change.

The research team eliminated duplicates prior to group review and each content reviewer group had an opportunity to combine, eliminate, and revise the list of non-NAEP additional KSAs prior to discussing coding discrepancies. The content review groups discussed each prerequisite non-NAEP additional KSA to reach consensus on an applicability code after reviewing the NAEP-specific KSA discussion points for each course packet. For some groups, the lists were pared down as they moved through their 28 packets. If there was a reason to revisit a previous packet, the same process was used as was developed for NAEP-specific KSAs. The outcome of the group review included a list of non-NAEP additional KSAs that were identified as prerequisite to the course packets reviewed by each group. The full list of prerequisite non-NAEP additional KSAs discussed at group review for both mathematics and reading is displayed in Appendix N. See Appendix O for the group meeting agendas.

[6] 28 packets per reading group x 37 reading framework statements x 2 types of possible KSA coding discrepancies.

[7] 28 packets per mathematics group x 130 mathematics framework statements x 2 types of possible KSA coding discrepancies.

Facilitators, scribes, and oversight. EPIC facilitators, experienced in group facilitation and the convergent consensus process and trained in CCCA methodology, led each review team in the discussion of KSA coding discrepancies during the group review meetings.

An EPIC-trained scribe assisted each facilitator and was responsible for recording all the decisions made by the content review groups using a group review instrument. All facilitators and scribes were trained together to ensure that they were highly knowledgeable about the purposes, goals, and design of the study, and also were instructed in protocols to ensure that decision rules were applied consistently across all content review groups. This training included mock reviews of course packets so that facilitators had direct experience with the packets, applying the same processes and decision rules that content reviewers used during the group review. During the training, scribes were acquainted with the group review instrument.[8] See Appendix P for the facilitator and scribe training overview.

Group review coding scheme. During the group review, scribes recorded content review group answers to a series of questions related to the results of the independent review. Scribes also recorded the final consensus ratings on coding discrepancies. The end result was a final content review group code for each NAEP-specific KSA. In their last task, each group attempted to reach consensus on the applicability of all prerequisite non-NAEP prerequisite KSAs recorded during independent review for each of the 28 course packets. The coding scheme for each question type is described in Table 11.

In addition to scribes and facilitators, the principal research scientist (PRS), the assistant research scientist (ARS), and the project director (PD) attended the group review meetings. The role of the PRS and the ARS was to closely monitor the group interactions, resolve issues, and ensure that the groups followed the procedures for the review meetings. The PD managed any administrative issues that arose. Two NAEP experts also attended the meetings to answer questions regarding the NAEP frameworks and to provide oversight. The participation of the NAEP experts during this phase provided additional insight and input for the next set of NAEP meetings where the content maps were reviewed and analyzed.

Phase 3: Conducting the NAEP Expert Review

A panel of mathematics and a panel of reading NAEP experts reviewed the outcomes of the group content reviews, evaluated the prerequisite KSAs, conducted a series of comparisons of the prerequisite KSAs to the NAEP framework and other preparedness research, and provided input to the research team on the interpretation of findings. See Appendix Q for the NAEP expert review meeting agendas.

The instructions below were provided to the NAEP experts at the beginning of the meetings concerning process flexibility.

Table 12 outlines the processes of NAEP expert multiple reviews.

The NAEP experts consulted the content maps of KSAs to generate narrative descriptions that summarized the KSAs necessary for students to be

> The exact process to use will be determined by what works best for your team. For example, you may complete all tasks for one course type and then move through each course type individually, or you may complete the first task for college overall and then complete the second task for college overall.

[8] Rounds of end-to-end testing that accounted for all possible question triggers and branching scenarios were completed before the group review meetings.

Table 11. *Group Review Coding Scheme*

Question	Coding scheme
Was consensus reached for this KSA during independent review?	1. Yes 2. No 3. Yes, but group revisited this KSA and changed coding
Was consensus reached for this KSA during group review?	1. Yes 2. No
What was the group's final rating for this KSA?	1. KSA is not prerequisite 2. KSA is prerequisite 3. KSA is prerequisite and important 4. Final rating not established during group review
List the portions of the KSA excluded by the group, if any.	Open-ended text
Who in the group changed his/her mind?	1. Member One 2. Member Two 3. Member Three 4. None
Why did Member One/Two/Three change his/her mind?	1. New shared understanding of the objective 2. Other group member(s) made convincing argument 3. Other group member(s) disputed evidence 4. Evidence not seen before or changed understanding of evidence 5. Changed understanding of terminology 6. Technical error with survey tool 7. Changed understanding of application of decision rule 8. Other
Does this new understanding of the application require recoding the packets?	1. Yes 2. No
Why was consensus not reached in the group review?	1. Member One was not persuaded by other two 2. Member Two was not persuaded by other two 3. Member Three was not persuaded by other two 4. All three members had different coding and were not persuaded by one another 5. Other

academically prepared, without remediation, for entry-year college-level mathematics courses and courses with substantial reading demands. The content maps are summarized in the Results section, and the objective-level content maps are shown in Appendix R.

The NAEP experts then proceeded using the following steps:

Step One: Create a narrative description of the (mathematics or reading) knowledge, skills, and abilities that are prerequisite for college courses, based on the evidence from the college course content analysis. The experts first reviewed the content maps containing the prerequisite and prerequisite and important NAEP framework objectives for each course and for mathematics and reading overall. This review also included the KSA exclusions and the non-

Table 12. *NAEP Expert Review Process*

	NAEP review process
Participants	• NAEP reading experts (3) • NAEP mathematics experts (3) • EPIC Principal Research Scientist and Assistant Research Scientist (2) • EPIC Project Director (1) • Facilitation consultant (1)
Process	• In-person, onsite, 3-day meeting • Training onsite • Procedural feedback
Review activities	• Review list of KSAs and content map for course type containing each course title • Develop narrative descriptions based on the content map for each course type • Compare the narrative descriptions of the prerequisite KSAs to the following: o Description of minimal requirements for placement into college-level coursework from the JSS research and determine the commonalities and differences in skill requirements o Grade12 NAEP 2009 and 2013 item pools to determine the content of NAEP that is or is not consistent with the prerequisite KSAs o KSAs represented by 2009 items that map to the NAEP score scale with a response probability of .67 and fall within the range of cut scores set by the two replicate panels in the JSS research for college to determine the commonalities and differences in content requirements o KSAs represented by 2009 items that map in the range of the NAEP score scale from the beginning of the Basic level to an emerging stopping point o NAEP achievement level descriptions
Review outcome	Summary document to address CCCA Research Questions 2–4

NAEP additional KSAs. The experts reviewed the content maps and then, as a panel, synthesized and interpreted them based on their expertise with the NAEP frameworks and their in-depth understanding of mathematics and reading content. Using the prerequisites extracted from the artifacts—including the KSA exclusions and non-NAEP additional KSAs—they drafted a narrative description of the mathematics and reading content that is necessary for students to be academically prepared, without remediation, for entry-year college-level mathematics and reading.

Given the differences in the structure of the NAEP frameworks between reading and mathematics, and the difference in independence[9] of course titles between the subject areas, the two NAEP expert groups had flexibility in how they determined whether a prerequisite KSA was incorporated into the narrative description. The NAEP reading experts selected a threshold of two thirds: a prerequisite KSA was required by the content review groups to be present in 67% of course packets for inclusion in the narrative description. The NAEP mathematics experts used an 80% criterion for determining whether to include the prerequisite KSA in the narrative description.

[9] The titles reviewed by the reading experts were independent of one another—any or all courses could be taken in the same school term. Some of the mathematics courses were sequential, e.g., college algebra would be taken prior to precalculus/calculus, although both are entry-level courses depending on the prior mathematics performance of the student.

Step Two: Compare the prerequisite knowledge, skills, and abilities in the narrative description to the knowledge, skills, and abilities measured by the NAEP items. After synthesizing the prerequisite NAEP-specific KSAs, KSA exclusions, and the non-NAEP additional KSAs into the narrative description, the NAEP experts reviewed the 2009 and 2013 item pools. They identified the range on the NAEP scale that corresponded to the prerequisites in mathematics and reading narratives. The NAEP experts reviewed each item to identify the KSAs assessed, and then determined if a student with the prerequisite KSAs described by the narrative would be likely to answer each item correctly. They started at the lowest difficulty item and worked through the items in order of difficulty. As soon as items assessed KSAs above those identified in the narrative, the experts noted the corresponding point or range on the NAEP scale. Items that assessed KSAs not identified as prerequisite to any course were skipped, and if this resulted in a large gap between items, the experts noted the corresponding scale range. As they engaged in this process, the NAEP experts reviewed the items' content in relation to prerequisite KSAs identified in the narrative description and the evidence (e.g., textbook samples, assignments) used to make the prerequisite determination.

The reading experts were confident in collapsing prerequisites across all courses reviewed by the reading content reviewers; the mathematics experts noted differences between courses that necessitated reporting findings by course, rather than for mathematics overall. This arose from the sequential nature inherent in the mathematics courses (e.g., college algebra would be taken prior to calculus) versus the lateral equality of the courses identified as having substantial reading demands (e.g., a first-year student could take all four course titles in the same semester).

Step Three: Compare the narrative descriptions to the Borderline Performance Descriptions (BPDs) developed for the JSS studies for college. The NAEP experts compared their narrative descriptions against the narrative BPDs created in the JSS study to determine how the results of the CCCA study compare with previous NAEP preparedness research.

Step Four: Discuss how these prerequisites inform future NAEP preparedness research. In order to address the fourth research question of the CCCA study, the NAEP experts' final task was to engage in a guided discussion on how the mathematics and reading prerequisites that were identified could inform future NAEP preparedness research. EPIC synthesized discussion points from throughout the meeting and developed questions in order to guide the NAEP experts in a discussion of their findings, how they compared with earlier NAEP preparedness research, and possible future directions for the NAEP.

The following questions for discussion were presented to the NAEP experts:

- What do each of you see as the most important implication or application of the prerequisite KSAs and their corresponding point on the NAEP scale? What are your recommendations for next steps?
- Based on the prerequisite KSAs, what can we suggest as priorities for NAEP?
- Based on the prerequisite KSAs, what can we suggest as priorities for high schools?
- JSS was done before the implementation of the Common Core State Standards (CCSS). Did the lack of the CCSS affect the development of the JSS BPD?
- What suggestions do you have that would inform future research efforts on the NAEP?

Process Evaluations

Both the content reviewers and NAEP experts completed process evaluations to address the procedural validity of the CCCA study. Procedural validity refers to evidence that the procedures employed in the study's implementation were performed as intended and were understood by all participants. Content reviewers responded to three process evaluations: one after (1) the holistic and independent review trainings, (2) the independent review, and (3) the group review. The process evaluation questions replicated, or were modifications of, evaluations used in previous research (WestEd & EPIC, 2013). The NAEP experts completed a process evaluation after the advisory panel. Appendix S contains the process evaluation questionnaires.

The first content reviewer process evaluation survey provided feedback regarding the holistic review and independent review training. Content reviewers completed this process evaluation after completing the independent review training. The evaluation questions related to the clarity and helpfulness of the training webinar and materials. Content reviewers were asked about their confidence in the training procedures to prepare them for their role and their understanding of their role in the CCCA study.

The second content reviewer process evaluation survey was completed after the content reviewers completed their independent reviews. This evaluation captured process-related feedback regarding the independent review, content reviewers' overall impressions of the process, their satisfaction with their work, what worked well, what did not work well, and how the process might be improved.

The third content reviewer process evaluation survey was completed after the group review consensus meetings. This process evaluation focused on gathering information about the convergent consensus process. An important measure of procedural validity of the convergent consensus process is the evaluation of the process by the content reviewers themselves, with high degrees of satisfaction with the training and the process boding well for the likelihood that, if the process were replicated, similar results would be found. The reviewers indicated that their opinions were heard, they were not pressured to agree, and the process overall was fair.

The NAEP experts were asked to complete a process evaluation after the advisory panels. This process evaluation gathered information about the process of the NAEP advisory panels and the NAEP experts' understanding of their role in the study. In addition to the process evaluation, NAEP experts were asked questions for discussion to which they provided narrative responses at the conclusion of the advisory panel meetings and expert review meetings about their confidence in the output and procedures of the meetings. See Appendix S for the questions for discussion.

Generalizability Study

The generalizability study was designed and conducted to investigate the reliability of the methods and operational coding processes used in this study. The validation course packets, coded during the independent and group review processes, generated the data used in the eight generalizability studies (two in both mathematics and reading for both independent review and group review). Each generalizability study provided two generalizability (G) study coefficients and two decision (D) study coefficients.

The results of the G- and D-studies contribute to the understanding of the validity of findings in different ways. The G-study provides evidence in the form of variance component estimations that measure how consistent content reviewers were in coding prerequisite KSAs. After training, content reviewers ideally did not vary much, if at all, in their ability to identify prerequisite KSAs. The findings of this study are valid and generalizable to the extent that content reviewers were consistent in coding course packets, as evidenced by the G-study coefficients.

The D-study uses the variance component estimations from the G-study to provide evidence that the operational processes used to code course packets produced reliable findings. Estimates from the D-study indicate whether the operational coding process of using 20 course packets and three content reviewers during independent review and using 20 course packets at the group-level review produced acceptably low levels of variance in identifying prerequisite KSAs. If 20 course packets produced too much variance, the D-study coefficients would be lower than .70 and more than 20 course packets would be required to produce reliable results. The same would be true of content reviewers and content reviewer groups.

The independent review generalizability study entailed an analysis of a fully crossed two-factor content reviewer (12) x course packet (8) random effects design wherein all content reviewers in both mathematics and reading coded the same eight validation course packets. The dependent outcome variable indicated whether the content reviewer coded a NAEP-specific KSA as *not a prerequisite*, *prerequisite*, or *prerequisite and important*. Absolute (ϕ) and relative (ρ) generalizability coefficients were estimated for the independent reviewer coding of the validation course packets. In addition to the analysis at the NAEP objective level of the KSAs, a separate set of generalizability coefficients were estimated at the NAEP subtopic or standard level of the KSAs by aggregating the objectives within each NAEP subtopic or standard. The NAEP subtopic or standard code was defined by the NAEP objective within the subtopic or standard that had the highest code (*prerequisite and important* was highest code, followed by *prerequisite)*.

The group review generalizability study was identical to the independent review generalizability analyses except that individual content reviewers were replaced by group consensus codes for each of the eight validation course packets. These group consensus codes were subsequently analyzed in a two-factor content reviewer group (4) x course packet (8) fully crossed random effects design to estimate absolute and relative generalizability coefficients at both the NAEP objective and subtopic or standard level.

Moreover, all generalizability analyses included a set of decision study (D-study) estimates designed to estimate the reliability of the operational coding process. Three content reviewers during the independent review and one group at the group review coded 20 operational course packets. These values were used in the D-study coefficient estimation procedure.

In summary, a total of eight generalizability analyses were conducted for this study. Each analysis provides G-study absolute (ϕ) and relative (ρ) coefficients as well as operational D-study absolute (ϕ) and relative (ρ) coefficients. The absolute g-coefficient (ϕ) is considered an "index of dependability" and is useful when one is concerned with the exact value of the score, regardless of rank ordering (Brennan, 2001; Webb & Shavelson, 2005). The relative g-coefficient (ρ) is analogous to the reliability coefficient in classical test theory and is useful when concerned with the rank ordering of elements or respondents. Thus, for the full study, 32 generalizability coefficients are provided. In general, a coefficient of .70 is an acceptable threshold to make reliable decisions based on observations from individuals. Coefficients above .70 are ideal and provide stronger evidence of reliability. The results of the analyses for independent and group reviews are presented in the Study Process Findings subsection in the Results section.

RESULTS

The results from the CCCA study provide a wealth of information regarding the knowledge, skills, and abilities that are considered prerequisite for entry into credit-bearing college courses without remediation. This section of the report consists of two major subsections. Presented first are data regarding the evidence for reliability and validity associated with the implementation of the processes articulated in the study's design. Second are the findings regarding the knowledge, skills, and abilities found to be prerequisite during the review process.

Study Process Findings

The reliability of coding, and the internal and external validity of findings based on study processes are vital elements to consider prior to an examination of the prerequisite KSAs. As described in the Methods sections, the study incorporated a number of processes to maximize the probability of obtaining reliable and valid results. The results from the measures taken to maximize and monitor reliability and validity are described below.

Institutional Representativeness for Operational Course Packets

To determine representativeness, only the 151 institutions from which operational course packets were drawn were included in the analyses. Only operational course packets were used to determine institutional representativeness because they were the packets from which data were summarized into content maps of prerequisite KSAs; operational course packet data also were the data used by the NAEP experts to construct the narrative descriptions. The 151 institutions that submitted course artifacts that were used in the operational course packets were analyzed for their representativeness in relation to the overall population of institutions by applying the four representativeness criteria used to stratify the sample. Table 13 presents the percentages by institutional

Table 13. *Expected and Observed Percentages, by Institutional Characteristic, in the Sample of 77 Institutions Providing Artifacts for the Operational Course Packets Used in Reviews of Courses With Substantial Reading Demands*

Type, region, and control			Small enrollment %		Medium enrollment %		Large enrollment %	
			Expected	Observed	Expected	Observed	Expected	Observed
2-year	East	Public	8	3	3	0	2	0
		Private	2	1	0	0	0	0
	West	Public	8	8	5	4	5	8
		Private	1	1	0	0	0	0
4-year	East	Public	4	3	3	8	4	4
		Private	20	21	2	0	1	3
	West	Public	3	5	2	3	5	13
		Private	17	12	2	5	1	0

Note. Due to rounding, percentages may not sum to 100%.

characteristic of the population and sample for those institutions providing packets used as operational packets for the courses with substantial reading demands (i.e., English literature, psychology, U.S. government, and U.S. history).

Table 14 presents similar information for the mathematics operational packet sample.

Chi-square (χ^2) analyses compared the representativeness of the CCCA sample of institutions to the U.S. population of institutions along the four representativeness criteria. The expected data come from the population of 3,010 institutions and the observed data from the operational course packet sample of 151 institutions. Eight separate χ^2 analyses (one for each of the four representativeness criteria in both mathematics and reading) compared the observed proportion of institutions in the CCCA sample to the expected proportion of institutions in the U.S. population of institutions.

Institutional representativeness for course packets from courses with substantial reading demands. The χ^2 analyses, based on an a priori alpha level of 0.05, show no significant differences by institutional characteristic in the institutions providing operational packets reviewed by the reading content experts. This analysis indicates that the reviewed artifacts, compiled into course packets, represent a sample of institutions that is representative of the population of institutions (see Table 15).

Institutional representativeness for mathematics course packets. The χ^2 analyses on the representativeness of the institutions that provided mathematics artifacts used in the operational course packets indicate that the artifacts underrepresent small institutions and private institutions and overrepresent public institutions and large institutions (see Table 16).

The relationship between the representativeness of the mathematics sample and the external validity of the findings was investigated using three sets of analyses. First, post hoc χ^2 analyses were performed on the mathematics sample, filtering by size. A second set of analyses artificially reduced the sample to one that was representative in all institutional characteristics and compared the two samples to provide insight into degree to which the sample's

Table 14. ***Expected and Observed Percentages, by Institutional Characteristic, in the Sample of 74 Institutions Providing Artifacts for the Operational Course Packets Used in Reviews of Mathematics Courses***

Type, region, and control			Small enrollment %		Medium enrollment %		Large enrollment %	
			Expected	Observed	Expected	Observed	Expected	Observed
2-year	East	Public	8	7	3	1	2	3
		Private	2	1	0	0	0	0
	West	Public	8	8	5	4	5	8
		Private	1	0	0	0	0	0
4-year	East	Public	4	3	3	5	4	11
		Private	20	8	2	5	1	0
	West	Public	3	3	2	1	5	12
		Private	17	15	2	3	1	1

Note. Due to rounding, percentages may not sum to 100%.

Table 15. *Representativeness of the 77 Institutions Submitting Artifacts Used in the Operational Course Packets for Courses With Substantial Reading Demands*

Institutional characteristic	Category	Expected number of institutions	Observed number of institutions	χ^2
Program type	2-year	27	19	3.61
	4-year	50	58	
Enrollment size	Small	49	41	4.49
	Medium	14	15	
	Large	14	21	
Geographic region	East	39	32	2.20
	West	39	45	
Control of institution	Public	40	44	0.67
	Private	37	33	

characteristics affected the NAEP experts' construction of the narrative descriptions based on prerequisite KSAs and non-NAEP additional KSAs. Finally, the researchers examined the number of average student populations of the institutions by characteristics to estimate the student-level impact of the underrepresentation of institutions with certain characteristics. All follow-up analyses and their results are presented below.

Post hoc χ^2 analyses. A series of χ^2 analyses were performed on the mathematics courses, after filtering by size, to determine the effect of the sample characteristics on generalizability of study findings. Table 17 summarizes these results. After filtering by size, the χ^2 analyses are not significant for any other characteristic, meaning that no one characteristic other than size was significantly contributing to deviation from expected values.

Table 16. *Representativeness of the 74 Institutions Submitting Artifacts Used in the Operational Course Packets for Mathematics Courses*

Institutional characteristic	Category	Expected number of institutions	Observed number of institutions	χ^2
Program type	2-year	26	24	0.21
	4-year	48	50	
Enrollment size	Small	47	33	15.18***
	Medium	13	15	
	Large	14	26	
Geographic region	East	37	33	0.87
	West	37	41	
Control of institution	Public	39	49	5.58*
	Private	36	25	

Note. *$p < .05$. ***$p < .001$.

Table 17. *Comparisons of Expected to Observed Number of Institutions Contributing Operational Course Packets for Mathematics Courses, Filtered by Institutional Control*

Institutional characteristic	Category	Expected number of institutions	Observed number of institutions	χ^2
Small schools (n = 33)				
Program type	2-year	10	12	0.57
	4-year	23	21	
Geographic region	East	17	14	1.09
	West	16	19	
Control of Institution	Public	12	15	1.18
	Private	21	18	
Medium schools (n = 15)				
Program type	2-year	8	4	2.41
	4-year	8	11	
Geographic region	East	7	9	1.07
	West	8	6	
Control of Institution	Public	12	9	3.75
	Private	3	6	
Large schools (n = 26)				
Program type	2-year	10	8	0.65
	4-year	16	18	
Geographic region	East	11	10	0.16
	West	15	16	
Control of institution	Public	23	25	1.51
	Private	3	1	

Another set of χ^2 post hoc analyses was conducted, filtering by public or private control. Table 18 summarizes these results. The χ^2 analysis indicated that public institutions were not representative of the population in terms of program type and size because two-year public and small- and medium-sized public institutions were underrepresented. The χ^2 analysis for the private institutions indicated that they were not fully representative of the population because small private institutions were underrepresented.

Comparison of findings to reduced representative sample. As a second exploration of the potential effects of the representativeness of the mathematics sample, the research team randomly deleted nine institutions from the oversampled institutional categories to create an artificial sample that would have been precisely representative of the population. Analysis determined that the revised sample, which included 17–18 packets per course title rather than 20 packets per course title, would have produced reliable findings for this study, according to the modified decision (D) study that was

Table 18. *Comparisons of Expected to Observed Number of Institutions Contributing Operational Course Packets for Mathematics Courses, Filtered by Institutional Control*

Institutional characteristic	Category	Expected number of institutions	Observed number of institutions	χ^2
Public schools (n = 49)				
Program type	2-year	30	23	4.21*
	4-year	19	26	
Enrollment size	Small	21	15	8.92*
	Medium	13	9	
	Large	15	25	
Geographic region	East	22	22	0.00
	West	27	27	
Private schools (n = 25)				
Program type	2-year	2	1	0.54
	4-year	23	24	
Enrollment size	Small	22	18	8.73*
	Medium	2	6	
	Large	1	1	
Geographic region	Small	14	11	1.46
	West	11	14	

Note. *$p < .05$.

performed.[10] The researchers examined the similarities and differences in the distribution of prerequisite KSAs between the sample of 74 institutions and the revised sample of 65 institutions. Specifically, three institutions that contributed statistics packets and two each contributing packets for finite mathematics, precalculus/calculus, and college algebra were randomly excluded from this analysis. The resulting sample of 65 institutions (71 course packets) was then representative across all four institutional characteristics.

The research team compared the content maps of prerequisite KSAs from the full sample with the content maps from the revised sample using the same 80% threshold of group agreement that the mathematics experts used to make decisions on when to include an objective within the narrative descriptions. The 80% level of agreement is defined as the four content review groups finding any given objective to be prerequisite or prerequisite and important in 80% of the course packets within a course title. Results from this analysis resulted in minimal changes in the content maps of the revised sample from the content maps of the full sample. This suggests that the NAEP experts would have received data that was very similar in distribution of prerequisite KSAs. The resulting conclusions reached by the NAEP experts would have likely been the

[10] The results of the modified D-study using 17 courses packets produced results that were consistent with the D-study using 20 course packets. The average difference between the eight coefficients generated during both D-studies was only .63%, and every coefficient was above the acceptable threshold of .70 (coefficients were between .78–.92). This suggests that using a sample size of 17 courses per course title would have only a slight negative effect on the reliability of the findings. See Generalizability Study section for more information on the method.

same or similar to those reached based on their review of the full sample.

Analysis of student populations. The third exploration of the potential effects of the representativeness of the mathematics sample used student population data from 2011 to estimate the percentage of students enrolled at the institutions in the CCCA sample. First, the representativeness profile of the sample was established by reviewing Table 16. This review identified four types of institutions in which the expected and observed percentage of institutions differed by at least three percentage points. Of these four, small private 4-year institutions in the eastern U.S. were the only type of institution with substantial underrepresentation in the CCCA sample. Whereas 20% of the sample would have been expected to be from these types of institutions, the sample contained 8%. However, small private 4-year institutions in the eastern U.S. enroll only 4% of the 24,859,900 postsecondary students in the 3,010 institutions that comprise the population for this study. In other words, the eastern small private 4-year institutions category would have been expected to represent just less than one million students but the sample in fact represents just under 400,000 students.

The representativeness of three other three types of institutions in the CCCA sample was also examined. These were large public 4-year institutions in the eastern U.S. (4% expected and 11% observed), large public 4-year institutions in the western U.S. (5% expected and 12% observed), and public 2-year institutions in the western U.S. (5% expected and 8% observed). These institutions collectively enrolled 48% of all students within the population of 3,010 institutions in 2011. Overrepresentation of these three institution types, then, reflected a collective set of institutions with larger student enrollment, which ultimately relates the CCCA study's inferences to a larger set of students.

Conclusion. The results of the follow-up analyses on the effects of sample representativeness by institution type for mathematics strongly suggest that deviations from representativeness in the four identified areas do not pose a serious threat to validity. It is important to note that the study is not intended to apply its findings to specific institution types from among the entire sample. Instead, it is designed to reach overall judgments about the presence of prerequisite KSAs among the full set of mathematics courses included in the sample. Furthermore, the results of these analyses find no reason to conclude that the substantive findings are systematically biased in one direction or another with regard to the determination of prerequisite KSAs and the NAEP mathematics experts' development of the narrative description of those KSAs a student needs to be prepared to enter a credit-bearing college course.

Artifact Sufficiency

The sufficiency of the artifacts to allow for consistent determinations of prerequisite KSAs is one of the three key elements of the method that contribute to the validity of the study: institutional representativeness, artifact quality/sufficiency, and reviewer reliability. Artifacts as they were grouped into packets were sufficient if they represented the range of materials that would be found in these entry-level courses across instructors and institutions; in other words, the range of artifacts, as compiled into course packets, were sufficient if they achieved the principal of redundancy. As shown in the content maps of prerequisite KSAs, the course packets allowed for a range of codings within course titles.

Artifacts also are sufficient for the purposes of this study if they allowed reviewers to focus on (1) what students are expected to be able to learn, via analyses of course goals and objectives; (2) what students are expected to be able to do to demonstrate they have learned, via analyses of assessments and assignments;

and (3) the kinds of content the students will reference in order to learn, via analyses of course texts. The design of the study incorporated multiple processes to ensure that each packet contained artifacts to allow for all three types of analyses by reviewers.

During the NAEP expert advisory panels preceding the training of reviewers, the NAEP experts vetted the protocols for the type, number, and quality of the artifacts. The Governing Board reviewed and approved the protocols prior to their implementation. Almost all packets consisted of three to five artifacts; the numbers were kept similar to constrain the variance attributable to number of artifacts. As materials were submitted and reviewed, the research team assessed each packet to ensure that, as a whole, the group of artifacts comprised within a packet had sufficient data richness to permit identification of prerequisite KSAs. To explore whether the number of artifacts influenced the number of KSAs that were identified, the research team divided the operational course packets into four groups by number of artifacts. See Tables 19 and 20 for findings.

Collapsing across course titles with substantial reading demands, researchers conducted an analysis of variance with number of artifacts as the independent variable and number of identified prerequisite KSAs as the dependent variable. The results were not significant, $F(3, 76) = 2.41, p > 0.05$, suggesting that the number of artifacts in a packet did not significantly influence the identification of KSAs.

A similar analysis of variance was conducted on the combined mathematics packets. The results were not significant, $F(3, 73) = 0.11, p > 0.05$.

Table 19. ***For the Courses With Substantial Reading Demands, the Average Number of NAEP-Specific KSAs Identified in Course Packets Within Each Course Title by Number of Artifacts***

Course title	3 artifacts		4 artifacts		5 artifacts		> 5 artifacts	
	Number of packets	Number of KSAs	Number of packets	Number of KSAs	Number of packets	Number of KSAs	Number of packets	Number of KSAs
English literature	12	22	4	19	2	25	2	25
Psychology	13	17	1	22	6	21	0	0
U.S. government	11	19	5	17	3	20	1	23
U.S. history	9	18	6	23	2	23	3	22

Table 20. ***For Mathematics Courses, the Average Number of NAEP-Specific KSAs Identified in Course Packets Within Each Course Title by Number of Artifacts***

Course title	3 artifacts		4 artifacts		5 artifacts		> 5 artifacts	
	Number of packets	Number of KSAs	Number of packets	Number of KSAs	Number of packets	Number of KSAs	Number of packets	Number of KSAs
Precalculus/calculus	14	28	3	25	3	23	0	0
College algebra	13	19	4	19	3	19	0	0
Finite mathematics	13	18	5	20	1	20	1	23
Statistics	12	18	7	19	1	22	0	0

Content reviewers were queried at several points about the artifacts and about their ability to make decisions about the perquisite KSAs given the study's methods. To determine the usefulness or helpfulness of each type of artifact to the review process, the content reviewers coded the helpfulness of each source of evidence provided in the course packet. In studies incorporating document analyses, effective evidence sources are expected to be helpful to reviewers in meeting study objectives.

In mathematics course packets, content reviewers found the course syllabi and textbook excerpts to be helpful sources of evidence; 86% of textbook excerpts were coded as "very helpful" or "helpful" and 52% of syllabi were coded as such. Assignments[11] were coded "not applicable" in 60% of mathematics course packets, and assessments were coded as "not applicable" in 43% of mathematics course packets. A code of "not applicable" indicates that the artifact was not present. In the mathematics course packets where assignments were applicable, 50% were coded as very helpful or helpful. In the mathematics course packets where assessments were applicable, 39% were coded as very helpful or helpful. The ratings suggest that the textbook excerpt was the most valuable artifact for mathematics reviewers to have, and that the assignments from the textbook were more helpful than assignments or assessments independent of the textbook.

In course packets from courses with substantial reading demands, content reviewers found the course syllabi and assignments to be helpful sources of evidence; 94% of syllabi were coded as "very helpful" or "helpful." Reviewers coded text excerpts as "very helpful" or "helpful" in 42% of the course packets reviewed for prerequisite KSAs related to reading. In the course packets reviewed for reading content where an assignment was applicable to the course packet, 90% were coded as "helpful" or "very helpful." In the course packets where assessments were applicable, 66% were coded as "helpful" or "very helpful." Appendix T provides more detail on ratings of artifact helpfulness.

Using the artifacts within the packets, the content reviewers identified prerequisite KSAs, including NAEP-specific KSAs and non-NAEP additional KSAs. The reviewers were asked several questions during the process evaluation. All reviewers agreed with the statement, "Overall, I am satisfied with how I coded my packets during independent review." After the group review, satisfaction with the process was very high; for instance, 92% of mathematics and 100% of reading reviewers agreed with the item, "I am confident in the outcomes of the group review process." See the Process Evaluations section for more information.

In the larger question of whether the number of artifacts that were comprised within each packet was sufficient for reviewers to validly identify prerequisite KSAs, there is no evidence to suggest that any particular characteristic of the sample of artifacts (e.g., number, type, content, specificity, etc.) would have influenced coding in a systematic way. The total variance attributable to the interaction of KSAs by packets is 15% in mathematics and 27% in reading; much of this variance would be accounted for by the to-be-expected differences among course titles (see Generalizability Study Results later in this section). Some variance might be attributable to qualities within the packet, but it is not possible given the current data to know how much would be attributable to any given packet characteristic. It is clear, however, from the analyses of variance, that the number of artifacts did not significantly affect the number of NAEP-specific KSAs that reviewers identified.

The artifacts represented a range of materials students would encounter at the beginning of a course. The

[11] For course packets where the assignment or assessment was a problem set within the textbook excerpt, helpfulness ratings were applied only to the textbook, and the assignment or assessment was coded as "not applicable."

internal logic of the methods selected for this study suppose that early materials provide the best source of evidence regarding the prerequisite KSAs because later materials are likely to be building on the KSAs students are developing as a result of being in the course. These are not prerequisite KSAs. The only title within the eight selected for this study for which this logic may hold less strongly is finite mathematics because the discrete topics selected to be taught in this course can differ in sequence and the topics can be minimally related to one another.

Levels of Reviewer Agreement

The extent to which reviewers agree with each other is key to internal reliability of study findings. Reviewer agreement is defined as the three reviewers in each group independently identifying (1) the applicability of the objective as a prerequisite KSA to the course under review, and (2) the same KSA exclusion(s) for each prerequisite KSA. If one or more reviewers differed on either decision, these counted as a disagreement.

Because this study included a multiphased design with multiple discrete outcomes at every decision point, there are several ways to present the levels of reviewer agreement. Reviewers could agree during independent review, disagree during independent review but come to consensus during group review, or disagree during independent review and not reach consensus regarding the applicability of an objective as prerequisite. The reviewers also could agree or disagree at both independent and group review on the applicability of an objective as a prerequisite KSA (applicability code) and whether an objective that was not considered a prerequisite KSA as written would become a prerequisite KSA if a part of that objective was excluded (exclusion code).

Independent review agreement. The interim independent decisions in a convergent consensus content review approach are expected to reflect each individual's expertise (see Appendix U for content reviewer characteristics). Some discrepancies in coding are expected prior to group discussion and the convergence into a single decision representing the collective expertise of individuals in the group. As such, higher or lower independent review agreement does not necessarily indicate more or less reliability in the review process or outcomes. Rather, higher or lower independent review agreement is simply the first step toward building a group decision.

Table 21 describes the similarity of individual decisions made by the 12 reading and 12 mathematics content reviewers during independent review. During independent review, overall agreement in mathematics courses reached 86%; in the 14% of decision points where there was disagreement, 12% were disagreements regarding applicability and 2% were disagreements regarding an exclusion. Overall agreement in courses with substantial reading demands reached 56%; among the 44% that were points of disagreement, 30% were disagreements regarding applicability and 14% related to exclusions. The independent review data are interim data points within the convergent consensus process.

Group review agreement. During group review, individuals convened in groups of three to discuss each decision that was not unanimous in the independent review, to share evidence, and to make decisions determining whether each NAEP objective is prerequisite and if there are any KSA exclusions for each NAEP objective in each course. Table 22 provides the rate of agreement for these decisions.

Note that the total number of group decisions (first column) is the same as the number of agreements subtracted from the total number of decisions. This provides a level of agreement percentage corresponding to interrater reliability.

Table 21. *Independent Review Agreement—Prerequisite KSAs and KSA Exclusions*

Course title	Total number of decisions	Number of agreements	Agreement %
Mathematics total (*n* = 112)	**29,120**	**24,952**	**86**
Precalculus/calculus	7,280	5,790	80
College algebra	7,280	6,070	83
Finite mathematics	7,280	6,425	88
Statistics	7,280	6,667	92
Reading total (*n* = 112)	**8,288**	**4,675**	**56**
English literature	2,072	1,024	49
Psychology	2,072	1,270	61
U.S. government	2,072	1,184	57
U.S. history	2,072	1,197	58

Note. Table includes the decisions for the precalculus/calculus course packet that was later removed from the study. The 112 course packets overall in mathematics and reading refers to the number of course packet reviews completed at group review. Each operational course packet was reviewed by one content review group (80 x 1 = 80). Each of the validation course packets was reviewed by each of the content review groups (8 x 4 = 32). Therefore, the number of mathematics course packet reviews overall is 112, and the number of reviews of packets for courses with substantial reading demands is 112.

Table 22. *Group Review Agreement—Prerequisite KSAs and KSA Exclusions*

Course title	Total number of group decisions (disagreements during independent review)	Agreement after group review %	No group decision after group review (agree to disagree) %
Mathematics total	**4,168**	**96**	**4**
Precalculus/calculus	1,490	96	4
College algebra	1,210	98	2
Finite mathematics	855	98	2
Statistics	613	95	5
Reading total	**3,613**	**97**	**3**
English literature	1,048	94	6
Psychology	802	99	1
U.S. government	888	96	4
U.S. history	875	100	0

Note. Table includes the decisions for the precalculus/calculus course packet that was later removed from the study.

The level of agreement was high across all eight course titles. In both mathematics and reading, content review groups agreed at least 94% of the time across all possible decisions. Agreement did not differ when the first 10 courses reviewed were compared to the last 10 courses reviewed, suggesting an absence of order effects.

Reasons for changes in coding decisions. When reviewers changed their independent decisions in group review, scribes recorded the reasons. See Appendix P for information on scribe training, including applicability of reasons for changes in coding decisions.

Tables 23 and 24 provide the percentages of response changes resulting from each reason.

In mathematics, the most frequent reason for selecting "other" was due to rescinding or agreeing to new KSA exclusions (e.g., "added exclusion" and "removed exclusion"). The "other" selection was also used to specify when the reviewer changed his or her mind due to importance (e.g., "new understanding of importance" and "compromised to prerequisite rather than important"). Mathematics reviewers also selected "other" when they had a "new understanding of [the] nature of [the] course" or had "previous discussion" about the nature of the course and decision rules.

In courses with substantial reading demands, the most frequent reason provided for "other" was the group member changing his or her mind regarding a KSA exclusion. For example, "No exclusion" and "Yes exclusion" were indications of whether the reviewer rescinded a KSA exclusion or agreed to a new KSA exclusion, respectively. The "other" selection was also used when reviewers wanted to specify which decision rule caused them to change their mind (e.g., the decision rule that guides reviewers on how to translate the word 'or' in the NAEP framework statements).

Consistent with the convergent consensus process, the most common reason cited for an individual changing his or her code on a KSA exclusion or prerequisite KSA during group review was due to consideration of evidence seen or described by others. This reason resolved 48% of the mathematics disagreements and 37% of the reading disagreements. Reviewers also changed their minds to reflect the shared understanding that emerged through group discussion (20% among mathematics disagreements; 17% among reading). Validity of the resulting findings is enhanced by this group review of the evidence against the decision rules (Bressen, 2007; Dalkey, 1969).

Table 23. ***Reasons Content Reviewers Indicated for Changing Independent Coding During Group Review in Course Packets From Courses With Substantial Reading Demands***

Reason	%
Evidence not seen before, changed understanding of evidence, or disputed evidence	37
New shared understanding of the objective	17
Other	16
Changed understanding of terminology	14
Other group member(s) made convincing argument	11
Changed understanding of application of decision rule	2
Technical error with survey tool	2

Note. Disputed evidence indicates a content reviewer agreed to change independent coding at group review based on other content reviewers in the group challenging the sufficiency of the evidence cited.

Table 24. ***Reasons Content Review Indicated for Changing Independent Coding During Group Review in Course Packets From Mathematics Courses***

Reason	%
Evidence not seen before, changed understanding of evidence, or disputed evidence	48
New shared understanding of the objective	20
Other group member(s) made convincing argument	12
Other	11
Changed understanding of application of decision rule	5
Technical error with survey tool	3
Changed understanding of terminology	1

Note. Disputed evidence indicates a content reviewer agreed to change independent coding at group review based on other content reviewers in the group challenging the sufficiency of the evidence cited.

A threat to the validity of the convergent consensus approach is that during group discussions, one member of the group may dominate the discussion or aggressively advance a position; conversely, a member may be extremely passive and agree with everything others suggest (Bressen, 2007). To determine the presence and impact of this potential "bully effect," the research team analyzed how many times each group member changed their independent review coding and the rationale for each change. Although it is expected that individual responses may change during the group review process, substantial differences in change rates across reviewers in a group, especially when there are very few changes for an individual group member, may suggest the presence of a "bully effect." Tables 25 and 26 provide the percentages of response changes attributable to the members within each group.

The results show that individual member's changes in coding were spread fairly equally across members, which suggests no member had more influence than another. The findings suggest that group reviews were collaborative, that debates and response changes were based on evidence and new shared understandings, and that personality and social factors had little impact on group outcomes.

Appendix V provides rationales for every response change for every reviewer.

Generalizability Study Results

A generalizability study was conducted to establish estimates regarding the interrater and intrarater reliability of the content reviewers during both the independent and group review phases. The

Table 25. ***Response Changes Attributable to Each Mathematics Group Member***

Group member	% of changes
Who in Group 1 (n = 1,930) changed their mind?	
Member One	23
Member Two	51
Member Three	24
Who in Group 2 (n = 863) changed their mind?	
Member One	26
Member Two	37
Member Three	37
Who in Group 3 (n = 1,249) changed their mind?	
Member One	32
Member Two	37
Member Three	31
Who in Group 4 (n = 1,128) changed their mind?	
Member One	35
Member Two	37
Member Three	29

Note. Due to rounding, percentages within a single group may not sum to 100%.

Table 26. ***Response Changes Attributable to Each Reading Group Member***

Group member	% of changes
Who in Group 1 (n = 1,178) changed their mind?	
Member One	26
Member Two	40
Member Three	34
Who in Group 2 (n = 1,037) changed their mind?	
Member One	35
Member Two	44
Member Three	22
Who in Group 3 (n = 909) changed their mind?	
Member One	24
Member Two	40
Member Three	37
Who in Group 4 (n = 945) changed their mind?	
Member One	19
Member Two	34
Member Three	47

Note. Due to rounding, percentages within a single group may not sum to 100%.

Table 27. *Variance Components Estimation for Mathematics Content Reviewer Judgments—Two-Facet Fully Crossed Design KSA Objective-Level Analysis*

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	φ
KSA Objective (KSA)	0.063	24.61	130	0.010	0.008	0.884	0.858
Course Packet	0.012	4.69	8				
Reviewer	0.007	2.73	12				
KSA x Course Packet	0.038	14.84					
KSA x Reviewer	0.030	11.72					
Course Packet x Reviewer	0.007	2.73					
Course Packet x Reviewer x KSA	0.099	38.67					
D-study						0.823	0.791

Note. How to understand the variance components: KSA objective variance refers to the extent to which the KSAs differ from one another in the frequency with which they are considered prerequisite; course packet variance refers to some packets having higher numbers of prerequisite KSAs than other packets; reviewer variance examines the extent to which individual reviewers differed from each other in their overall pattern of coding KSAs. The interaction terms can be understood as follows: The coding of the KSA x Course Packet interaction is a measure of the extent to which the determination of whether a KSA is considered prerequisite is a function of the course packet being reviewed; the KSA x Reviewer interaction is a measure of the extent to which the determination of whether a KSA is considered a prerequisite is a function of the reviewer; the Course Packet x Reviewer interaction considers whether reviewers provide different coding in some packets versus others; and the Course Packet x Reviewer x KSA is additional random variation not attributable to any particular characteristic that was studied.

generalizability study was designed and conducted using a set of validation course packets coded during the independent and group reviews. A decision study investigated whether the levels of reliability were maintained in the reviews of operational course packets. This section presents the findings from the generalizability and decision studies.

Independent review. For the independent review, the results indicate that the reviewers were quite consistent and reliable in coding the validation course packets. The relative g-coefficients (ρ) for the 12 reviewers coding the KSAs in the eight validation course packets were high: .853 for courses with substantial reading demands and .884 for mathematics. The absolute g-coefficients (φ) were .833 and .858 for reading and mathematics, respectively. This indicates high reliability and consistency among the reviewers. In addition, the D-study estimates for coding of operational course packets indicate that these high levels of reliability were maintained when the reviewers coded the operational course packets. The (ρ) and (φ) coefficients for mathematics were .823 and .791; for courses with substantial reading demands they were .854 and .809. Thus, the analyses indicate that the independent reviews possess high levels of reliability in both the validation course packets and in operational course packets.

Tables 27 and 28 summarize the results of the fully crossed analyses[12] of independent ratings at the level of the NAEP framework objectives.

[12] A generalizability analysis is fully crossed when all content reviewers code the same course packets using the same framework. In terms of the CCCA Independent Review Generalizability Study, all 12 content reviewers in each subject area reviewed the same eight course packets using the NAEP framework. In the CCCA Group Review Generalizability Study, all four groups in each subject area reviewed the same eight course packets using the NAEP framework.

Table 28. ***Variance Components Estimation for Reading Content Reviewer Judgments—Two-Facet Fully Crossed Design KSA Objective-Level Analysis***

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
KSA Objective (KSA)	0.144	25.17	37	0.029	0.025	0.853	0.833
Course Packet	0.014	2.45	8				
Reviewer	0.025	4.37	12				
KSA x Course Packet	0.157	27.45					
KSA x Reviewer	0.042	7.34					
Course Packet x Reviewer	0.021	3.67					
Course Packet x Reviewer x KSA	0.169	29.55					
D-study						0.854	0.809

The independent review subtopic (mathematics) or standard (reading) level coding showed comparable consistency. Tables 29 and 30 provide the g-coefficients for mathematics and reading for the subtopic/standard ratings, which are .924 and .897 for (ρ) and (ϕ) coefficients for mathematics, and .899 and .885 for (ρ) and (ϕ) coefficients for reading. The D-study coefficients likewise indicate that the independent review operational coding process of using three content reviewers to code 20 course packets was reliable at both the objective and subtopic/standard level with values of .872 (ρ) and .831 (ϕ) for mathematics and .893 (ρ) and .841 (ϕ) for reading.

Tables 29 and 30 summarize the results of the fully crossed analysis of independent ratings at the level of the NAEP framework subtopics or standards.

Table 29. ***Variance Components Estimation for Mathematics Content Reviewer Judgments—Two-Facet Fully Crossed Design Subtopic-Level Analysis***

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
Subtopic	0.161	31.94	25	0.018	0.013	0.924	0.897
Course Packet	0.025	4.96	8				
Reviewer	0.023	4.56	12				
Subtopic x Course Packet	0.056	11.11					
Subtopic x Reviewer	0.054	10.71					
Course Packet x Reviewer	0.012	2.38					
Course Packet x Reviewer x Subtopic	0.173	34.33					
D-study						0.872	0.831

Table 30. *Variance Components Estimation for Reading Content Reviewer Judgments—Two-Facet Fully Crossed Design Standard-Level Analysis*

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
Standard	0.214	34.68	10	0.028	0.024	0.899	0.885
Course Packet	0.000	0.00	8				
Reviewer	0.044	7.13	12				
Standard x Course Packet	0.148	23.99					
Standard x Reviewer	0.047	7.62					
Course Packet x Reviewer	0.015	2.43					
Course Packet x Reviewer x Standard	0.149	24.15					
D-study						0.893	0.841

Group review. Similar to the independent review results, the group reviews show consistency and reliability in the sample of validation course packets, with all coefficients estimated in excess of .80.

Reading g-coefficient estimates were consistent as well. Reliability estimates for group coding of objectives among the packets for courses with substantial reading demands were .838 (ρ) and .804 (ϕ); for group coding at the level of standards, they were .887 (ρ) and .856 (ϕ).

The mathematics g-coefficients approached or exceeded .90 for both objective and subtopic levels in group coding. Reliability estimates for group coding of objectives among the mathematics packets were .880 (ρ) and .873 (ϕ); for group coding at the level of standards, they were .926 (ρ) and .897 (ϕ).

Tables 31 and 32 provide the results of the analyses performed on the group judgments at the level of the NAEP framework objectives. Tables 33 and 34 provide the results using the NAEP framework subtopics or standards as the unit of analysis.

The D-study estimates suggest that the operational coding process of having a single group code 20 course packets yielded high reliability for objective coding [.880 (ρ) and .873 (ϕ)] and subtopic coding [.926 (ρ) and .897 (ϕ)] in mathematics. The D-study estimates for the group coding of objectives [.808 (ρ) and .720 (ϕ)] and standards [.868 (ρ) and .765 (ϕ)] were lower in reading than comparable coefficient estimates for coding in mathematics, but they nonetheless continue to demonstrate acceptable (> .70) levels of consistency and reliability of coding in operational practice.

In summary, this generalizability study provides evidence of the reliable and consistent coding of objectives and subtopics (mathematics) or standards (reading) within course packets during both independent and group review. Of all the various generalizability coefficients estimated, every one of them exceeded an acceptable threshold of .70; more

Table 31. *Variance Components Estimation for Mathematics Group Judgments—Two-Facet Fully Crossed Design KSA Objective-Level Analysis*

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
KSA Objective (KSA)	0.133	38.22	130	0.017	0.014	0.904	0.889
Course Packet	0.020	5.75	8				
Group	0.000	0.00	4				
KSA x Course Packet	0.065	18.68					
KSA x Group	0.009	2.59					
Course Packet x Group	0.002	0.57					
Course Packet x Group x KSA	0.119	34.20					
D-study						0.880	0.873

Table 32. *Variance Components Estimation for Reading Group Judgments—Two-Facet Fully Crossed Design KSA Objective-Level Analysis*

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
KSA Objective (KSA)	0.201	29.56	37	0.049	0.039	0.838	0.804
Course Packet	0.022	3.24	8				
Group	0.029	4.26	4				
KSA x Course Packet	0.209	30.74					
KSA x Group	0.028	4.12					
Course Packet x Group	0.006	0.88					
Course Packet x Group x KSA	0.185	27.21					
D-study						0.808	0.720

than 90% of the estimates exceeded a higher threshold of .80; and more than 65% exceeded .85. The majority of variation came from the NAEP objectives and subtopics or standards, which was expected because each NAEP objective measures different KSAs. The main effect for content reviewers, either individual reviewers or groups of reviewers, accounted for less than 8% of the total variance in coding in all analyses. In many cases the main effect for reviewers, either individual reviewers or groups of reviewers, accounted for less than 5% of the total variance in coding.

Likewise, course packets accounted for less than 7% of the total variance in all analyses. The Subtopic/Standard x Course Packet interaction terms demonstrate that KSAs varied in their applicability across course packets. This is expected because four different course titles were represented in the eight validity course packets analyzed in both the

Table 33. *Variance Components Estimation for Mathematics Group Judgments—Two-Facet Fully Crossed Design Subtopic-Level Analysis*

Generalizability Study Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
Subtopic	0.349	56.38	25	0.025	0.018	0.952	0.933
Course Packet	0.039	6.30	8				
Group	0.010	1.62	4				
Subtopic x Course Packet	0.273	11.79					
Subtopic x Group	0.018	2.91					
Course Packet x Group	0.006	0.97					
Course Packet x Group x Subtopic	0.124	20.03					
D-study						0.926	0.897

Table 34. *Variance Components Estimation for Reading Group Judgments—Two-Facet Fully Crossed Design Standard-Level Analysis*

Variance component(s)	Variance estimation	Variance estimation %	Number	Absolute error	Relative error	ρ	ϕ
Standard	0.294	4.129	10	0.049	0.037	0.887	0.856
Course Packet	0.006	0.84	8				
Group	0.045	6.32	4				
Standard x Course Packet	0.212	29.78					
Standard x Group	0.028	3.93					
Course Packet x Group	0.002	0.28					
Course Packet x Group x Standard	0.125	17.56					
D-study						0.868	0.765

mathematics and reading generalizability studies. Whether these judgments are being made by individual reviewers or by groups of reviewers, the data indicate the determinations are consistent, dependable, and reliable.

Process Evaluations

Process evaluation forms were administered after trainings in order to contribute information regarding the procedural validity of the study. The training process evaluation was offered to the entire pool of 16 content reviewers in each subject area, including alternate reviewers. Overall, responses to training process evaluation questions were positive. More than 90% of respondents indicated that they understood their role and felt comfortable with the training, and 91% of mathematics respondents and 83% of reading respondents reported feeling well trained and prepared to complete the independent review. There were lower levels of agreement among the reading content reviewers (58%) that the independent review training webinar made the process clear; 64% of the mathematics respondents reported that time was used efficiently during the training. Respondents commented that they would have benefited from the "opportunity to work on training packets as a group" and it would have been "helpful to receive content feedback on the training packets."

Table 35 summarizes the percent of respondents providing "Agree" or "Strongly Agree" responses to each evaluation question posed at the conclusion of the content review qualifying course packet reviews and retraining.

In the case of low levels of agreement that the independent review webinar training made the task clear to the content reviewers, the research team also provided individualized feedback to the reviewers as they mapped onto the packet review process after training packet reviews and the first qualifying packet review. This included email and phone conversations regarding any question the reviewers had after the training webinar and the training and qualifying reviews. The improved rates of alignment, as the reviewers completed the training and qualifying reviews, showed how the reviewers were able to map onto the coding process and exhibited increased understanding of the review task after the webinar. Additionally, the researchers addressed content reviewers' questions or concerns at the group review meetings.

At the conclusion of the independent review, the research team requested that the entire pool of 14 content reviewers, including alternate content reviewers, complete an independent review process evaluation. Evaluations of the independent review process were positive with one exception. Both mathematics and reading respondents indicated that independent reviews of the course packets took longer than expected. Respondents' comments showed varying opinions as to why it took longer.

Table 35. ***Percentages of Content Reviewers Agreeing or Strongly Agreeing With Each Process Evaluation Statement Regarding Holistic Review and Independent Review Training***

Process evaluation statement	Mathematics %	Reading %
The holistic review training webinar made the task clear to me.	91	75
The holistic review training webinar was well organized.	91	75
The independent review webinar training made the task clear to me.	82	58
The independent review training webinars were well organized.	82	75
The independent review training clearly identified the goals of the NAEP objective coding procedure.	91	83
The independent review training clearly identified the goals of the NAEP objective annotation procedure.	82	100
The training materials were helpful.	91	75
I am confident I understand my role.	91	92
Time was used efficiently in the trainings.	64	75
I felt comfortable participating in the training webinars.	91	92
Overall, I feel well trained and prepared to complete the independent review.	91	83

Note. All content reviewers, including alternate content reviewers, were requested but not required to complete a training process evaluation. Eleven of fifteen mathematics reviewers and twelve of fourteen reading reviewers elected to do so.

Two examples that capture the most common reasons are bulleted below:

- Finding evidence was easy—knowing how to code them (and what to infer or not infer) was difficult and more time consuming than I expected.
- The annotation process took longer than I thought it would.

The findings from the process evaluation of the independent review process suggest that the reviewers' level of comfort and confidence increased from the earlier stage of training.

Table 36 summarizes the percentages of participants responding "Agree" or "Strongly Agree" to each evaluation item presented at the conclusion of the independent review.

The group review evaluation was also positive. Almost all items had 100% agreement. In the two instances were there was not 100% agreement, 92% of reviewers agreed with the statement. Table 37 summarizes the percentage of participants providing "Agree" or "Strongly Agree" responses to each of the evaluation items presented at the conclusion of the group review.

Table 36. ***Percentages of Content Reviewers Agreeing or Strongly Agreeing With Each Process Evaluation Statement Regarding Independent Review***

Independent review process evaluation statement	Mathematics %	Reading %
The training prepared me for independent review.	93	91
The training materials were helpful.	100	100
The holistic review process helped me code my packets during independent review.	93	82
Referring to the NAEP frameworks helped me code my packets during independent review.	93	100
Referring to the decision rules helped me code my packets during independent review.	93	100
I understood how to code the NAEP objectives in my course packets during independent review.	100	91
Overall, I am satisfied with how I coded my packets during independent review.	100	100
I am satisfied with the support I received during the independent review.	100	100
Overall, the independent review survey was easy to use.	86	91
Overall, Basecamp was an effective communication tool for this project.	100	91
I found the to-dos in Basecamp useful for keeping track of packets during independent review.	100	100
I found it easy to access training materials, packets, and other files on Basecamp.	100	100
During training and qualifying, I learned how to code the NAEP objectives as I progressed, so my later training and qualifying coding may not be consistent with my earlier coding.	71	73
The amount of work required to complete independent review was about what I expected when I was recruited.	50	55

Note. All content reviewers, including alternates, were requested but not required to complete an independent review process evaluation. Fourteen of fifteen mathematics reviewers and eleven of fourteen reading reviewers elected to do so.

Table 37. *Percentages of Content Reviewers Agreeing or Strongly Agreeing With Each Process Evaluation Statement Regarding Group Review*

Group review process evaluation question	Mathematics %	Reading %
The orientation and training prepared me for group review.	100	92
My notes and annotations were useful during group review.	100	100
During group review, my group had enough time to discuss all of our packets.	100	100
Overall, I think my group's discussions were open and honest.	100	100
Overall, I believe that my opinions were considered and valued by my group.	100	100
I feel this procedure was fair.	100	100
My group followed the decision rules.	100	100
I am confident in the outcomes of the group review process.	92	100
Overall, I am satisfied with my group's final coding on our packets.	100	100
The meeting was well organized.	100	100

Note. All content reviewers who attended the group review were required to complete a group process evaluation. Twelve of twelve mathematics content reviewers and twelve of twelve reading content reviewers completed the evaluation.

Overall, evaluation results suggest that training was effective and that content reviewers understood each task, were provided the necessary supports and materials for each task, felt the process was fair and collaborative, and were confident in study outcomes. These results provide support for the procedural validity of the study.

Prerequisite Knowledge, Skills, and Abilities

The purpose of the CCCA study was to identify the prerequisite KSAs for the work required in entry-level, credit-bearing college courses. As the reviewers considered the applicability of the NAEP objectives, they were permitted to disassemble the NAEP objectives to delineate between elements that were, and were not, evident in course materials. Understanding the KSA exclusions—terms or phrases in an objective that were not evident, and thus not prerequisite—is key to understanding and interpreting the elements of the NAEP frameworks that were prerequisite.

Equally important to understanding entry-level college course prerequisites is the inclusion of non-NAEP additional KSAs that are evident in the course materials, but not in the NAEP frameworks. Thus the reviewers, based on the course artifacts, also recommended non-NAEP additional KSAs that were not captured within the NAEP objectives.

Summaries of the KSA exclusions are presented prior to the prerequisite KSA descriptions. NAEP-specific KSAs and non-NAEP additional KSAs are presented for courses with substantial reading demands followed by the presentation of prerequisite KSAs for mathematics courses.

Prerequisite NAEP-Specific KSA Exclusions

Due to the structure of the NAEP frameworks, KSA exclusions could be made at either the subtopic/standard or objective level in reading but only at the objective level in mathematics. All KSA exclusions identified in courses with substantial reading demands were made at the level of the standard: when the standard included the phrase "literary and informational text," one of the two text descriptors was excluded depending on the course. For English literature, the only KSA exclusion identified was *informational text* and the only KSA exclusion for U.S. government, U.S. history, and psychology was *literary text*. These exclusions were not universal across every packet within a course title but represent a preponderance of the packets within a course title.

The KSA exclusions in mathematics were generally one term or phrase of multipart NAEP objectives that contained prerequisites skills but also skills for which reviewers could find no evidence in course packets. The most common KSA exclusions across all course titles included logarithms, complex numbers, common irrational numbers, very large and very small numbers, and expressions and exponents. Table 38 describes the mathematics KSA exclusions by course title. The table includes objectives that had a KSA exclusion recorded in at least one course title. The KSA exclusion is the strikethrough portion of the objective. If the entire statement is listed without a strikethrough, then the objective was prerequisite to the course title without a KSA exclusion. If the objective was not prerequisite for the course title, this is noted in italics.

Table 38. *KSA Exclusions From NAEP Mathematics Objectives*

NAEP objective ID	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
1.1.d	Represent, interpret, or compare expressions for real numbers, ~~including expressions using exponents and logarithms~~	Represent, interpret, or compare expressions for real numbers, including expressions using exponents ~~and logarithms~~	Represent, interpret, or compare expressions for real numbers, ~~including expressions using exponents and logarithms~~	Represent, interpret, or compare expressions for real numbers, ~~including expressions using exponents and logarithms~~
1.1.i	Order or compare real numbers, ~~including very large and very small real numbers~~	Order or compare real numbers, ~~including very large and very small real numbers~~	Order or compare real numbers, ~~including very large and very small real numbers~~	Order or compare real numbers, ~~including very large and very small real numbers~~
1.3.b	Perform arithmetic operations with real numbers, ~~including common irrational numbers~~	Perform arithmetic operations with real numbers, ~~including common irrational numbers~~	Perform arithmetic operations with real numbers, ~~including common irrational numbers~~	Perform arithmetic operations with real numbers, ~~including common irrational numbers~~
1.3.f	Solve application problems involving numbers, including rational ~~and common irrationals~~	Solve application problems involving numbers, including rational ~~and common irrationals~~	Solve application problems involving numbers, including rational ~~and common irrationals~~	Solve application problems involving numbers, ~~including rational and common irrationals~~
1.4.c	Use proportions to solve problems (including rates of change)	Use proportions to solve problems ~~(including rates of change)~~	Use proportions to solve problems ~~(including rates of change)~~	Use proportions to solve problems ~~(including rates of change)~~
1.4.d	Solve multistep problems involving percentages, including compound percentages	Solve multistep problems involving percentages, ~~including compound percentages~~	Solve multistep problems involving percentages, including compound percentages	Solve multistep problems involving percentages, including compound percentages

Table 38. *KSA Exclusions From NAEP Mathematics Objectives*

NAEP objective ID	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
1.5.c	Solve problems using factors, multiples, ~~or prime factorization~~	Solve problems using factors, multiples, or prime factorization	Solve problems using factors, multiples, or prime factorization	Solve problems using factors, multiples, or prime factorization
1.5.d	Use divisibility or remainders in problem settings	Use divisibility or remainders ~~in problem settings~~	Use divisibility or remainders in problem settings	Objective not prerequisite for course title
1.5.f	Recognize properties of the number system (whole numbers, integers, rational numbers, real numbers, ~~and complex numbers~~) ~~and how they are related to each other~~, and identify examples of each type of number	Recognize ~~properties of the number system~~ (whole numbers, integers, rational numbers, real numbers, ~~and complex numbers~~) ~~and how they are related to each other~~, and identify examples of each type of number	Recognize ~~properties of the number system~~ (whole numbers, integers, rational numbers, real numbers, ~~and complex numbers~~) ~~and how they are related to each other~~, and identify examples of each type of number	Objective not prerequisite for course title
2.2.d	Objective not prerequisite for course title	Objective not prerequisite for course title	Understand that numerical values associated with measurements of physical quantities ~~are approximate, are subject to variation, and~~ must be assigned units of measurement	Objective not prerequisite for course title
2.3.e	*Determine the radian measure of an angle ~~and explain how radian measurement is related to a circle of radius 1~~	Objective not prerequisite for course title	Objective not prerequisite for course title	Objective not prerequisite for course title
3.2.a	Recognize or identify types of symmetries (e.g., point, line, rotational, self-congruence) of two- ~~and three-~~dimensional figures	Objective not prerequisite for course title	Objective not prerequisite for course title	Objective not prerequisite for course title
3.3.b	Apply geometric properties and relationships to solve problems in two and three dimensions	Apply geometric properties and relationships to solve problems in two ~~and three~~ dimensions	Objective not prerequisite for course title	Objective not prerequisite for course title
3.3.d	Use the Pythagorean theorem to solve problems in two- or three-dimensional situations	Use the Pythagorean theorem to solve problems in two- ~~or three-~~dimensional situations	Use the Pythagorean theorem to solve problems in two- or three-dimensional situations	Objective not prerequisite for course title

Table 38. *KSA Exclusions From NAEP Mathematics Objectives*

NAEP objective ID	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
3.3.e	Recall and interpret definitions and basic properties of ~~congruent and similar triangles~~, circles, ~~quadrilaterals, polygons,~~ parallel, perpendicular ~~and intersecting lines, and associated angle relationships~~	Recall and interpret definitions and basic properties of congruent and similar triangles, circles, ~~quadrilaterals, polygons, parallel, perpendicular and intersecting lines, and associated angle relationships~~	Objective not prerequisite for course title	Objective not prerequisite for course title
3.3.g	Analyze properties and relationships of parallel, perpendicular, or intersecting lines including the ~~angle relationships~~ that arise in these cases	Objective not prerequisite for course title	Analyze properties and relationships of parallel, perpendicular, or intersecting lines including the angle relationships that arise in these cases	Objective not prerequisite for course title
3.4.g	*Graph ellipses ~~and hyperbolas~~ whose axes are parallel to the coordinate axes and demonstrate understanding of the relationship between their standard algebraic form and their graphical characteristics	Objective not prerequisite for course title	Objective not prerequisite for course title	Objective not prerequisite for course title
4.1.b	For a given set of data, complete a graph and solve a problem using the data in the graph (~~histograms,~~ scatterplots, and line graphs)	Objective not prerequisite for course title	For a given set of data, complete a graph and solve a problem using the data in the graph (histograms, scatterplots, and line graphs)	For a given set of data, complete a graph and solve a problem using the data in the graph (histograms, ~~scatterplots, and line graphs~~)
5.1.b	Express linear and exponential functions in ~~recursive~~ and explicit form given a table, verbal description, or some terms of a sequence	Objective not prerequisite for course title	Express linear and exponential functions in recursive and explicit form given a table, verbal description, or some terms of a sequence	Objective not prerequisite for course title
5.1.i	Determine the domain ~~and range~~ of functions given in various forms and contexts	Determine the domain ~~and range~~ of functions given in various forms and contexts	Determine the domain and range of functions given in various forms and contexts	Objective not prerequisite for course title
5.1.j	*Given a function, determine its inverse if it exists ~~and explain the contextual meaning of the inverse for a given situation~~	Objective not prerequisite for course title	Objective not prerequisite for course title	Objective not prerequisite for course title

Table 38. *KSA Exclusions From NAEP Mathematics Objectives*

NAEP objective ID	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
5.2.a	~~Create and~~ translate between different representations of algebraic expressions, equations, and inequalities (e.g., linear, quadratic, exponential, or *trigonometric) using symbols, graphs, tables, diagrams, or written descriptions	~~Create and~~ translate between different representations of algebraic expressions, equations, and inequalities (e.g., linear, quadratic, exponential, or *trigonometric) using symbols, graphs, tables, diagrams, or written descriptions	~~Create and~~ translate between different representations of algebraic expressions, equations, and inequalities (e.g., linear, quadratic, exponential, or *trigonometric) using symbols, graphs, tables, diagrams, or written descriptions	Objective not prerequisite for course title
5.2.b	Analyze or interpret relationships expressed in symbols, graphs, tables, diagrams (including Venn diagrams), or written descriptions ~~and evaluate the relative advantages or disadvantages of different representations to answer specific questions~~	Analyze or interpret relationships expressed in symbols, graphs, tables, diagrams (including Venn diagrams), or written descriptions and evaluate the relative advantages or disadvantages of different representations to answer specific questions	Analyze or interpret relationships expressed in symbols, graphs, tables, diagrams (including Venn diagrams), or written descriptions ~~and evaluate the relative advantages or disadvantages of different representations to answer specific questions~~	Objective not prerequisite for course title
5.2.d	Perform or interpret transformations on the graphs of linear, quadratic, exponential, and *trigonometric functions	Perform or interpret transformations on the graphs of linear, quadratic, ~~exponential, and *trigonometric~~ functions	Objective not prerequisite for course title	Objective not prerequisite for course title
5.3.b	Write algebraic expressions, equations, or inequalities to represent a situation	Write algebraic expressions, equations, or inequalities to represent a situation	Write algebraic expressions, equations, or inequalities to represent a situation	Objective not prerequisite for course title
5.3.c	Perform basic operations, using appropriate tools, on algebraic expressions including polynomial ~~and rational~~ expressions	Perform basic operations, using appropriate tools, on algebraic expressions including polynomial ~~and rational~~ expressions	Perform basic operations, using appropriate tools, on algebraic expressions ~~including polynomial and rational expressions~~	Perform basic operations, using appropriate tools, on algebraic expressions including polynomial and rational expressions
5.3.d	Write equivalent forms of algebraic expressions, equations, or inequalities to represent ~~and explain~~ mathematical relationships	Write equivalent forms of algebraic expressions, equations, or inequalities to represent and explain mathematical relationships	Write equivalent forms of algebraic expressions, equations, or inequalities to represent and explain mathematical relationships	Objective not prerequisite for course title
5.3.e	Evaluate algebraic expressions including polynomials and rational expressions	Evaluate algebraic expressions including polynomials ~~and rational~~ expressions	Evaluate algebraic expressions ~~including polynomials and rational expressions~~	Evaluate algebraic expressions including polynomials and rational expressions

Table 38. *KSA Exclusions From NAEP Mathematics Objectives*

NAEP objective ID	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
5.3.f	Use function notation to evaluate a function at a specified point in its domain and combine functions by addition, subtraction, multiplication, division, ~~and composition~~	Use function notation to evaluate a function at a specified point in its domain and combine functions by addition, subtraction, multiplication, division, and composition	Use function notation to evaluate a function at a specified point in its domain and combine functions by addition, subtraction, ~~multiplication, division, and composition~~	Use function notation to evaluate a function at a specified point in its domain ~~and combine functions by addition, subtraction, multiplication, division, and composition~~
5.3.h	Use basic properties of exponents ~~and *logarithms~~ to solve problems	Use basic properties of exponents ~~and *logarithms~~ to solve problems	Objective not prerequisite for course title	Objective not prerequisite for course title
5.4.a	Solve linear, rational, or quadratic equations or inequalities, ~~including those involving absolute value~~	Solve linear, rational, or quadratic equations or inequalities, ~~including those involving absolute value~~	Solve linear, rational, or quadratic equations or inequalities, ~~including those involving absolute value~~	Solve linear, rational, or quadratic equations or inequalities, ~~including those involving absolute value~~

Note. The exclusions in this table represent varying frequencies across packets. For more information, see the mathematics content maps in Appendix R. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments.

Non-NAEP Additional KSAs

One goal of the CCCA study was to identify prerequisite KSAs not found in the current NAEP mathematics and reading frameworks. The narrative below describes the final list of non-NAEP additional KSAs identified for consideration by the NAEP experts.

For group reviews, the research team compiled by course packet the list of non-NAEP additional KSAs generated during independent review. Included in the list were all the non-NAEP additional KSAs for that packet identified by each reviewer. EPIC cleaned each list to remove duplicates noted by the following:

- Non-NAEP additional KSAs with identical phrasing were collapsed into a single KSA.
- Almost-identical duplication of phrasing such as "Discern credibility of source" vs. "Discern credibility of a source" was combined into a single KSA.

The researchers were conservative in the elimination of duplicates; if there was any doubt regarding whether two statements were duplicates, the two statements were left in the list for the groups to review. Eighty-two non-NAEP additional KSAs were generated during independent review for review by the mathematics content reviewer groups. Seventy-six non-NAEP additional KSAs were generated during independent review for review by the reading content reviewer groups.

Each non-NAEP additional KSA was reviewed within the context of each of the 28 packets. The following are explanations for how non-NAEP additional KSAs were eliminated during group review.

- Non-NAEP additional KSAs were not directly related to mathematics or reading KSAs.
- Groups determined the KSA could be found within the NAEP framework.

- In the group reviews, content reviewers discussed and shared their expertise and annotated evidence. In this process, content reviewers could change their mind on a non-NAEP additional KSA (see the Reasons for Changes in Coding Decisions section).
- Groups had the opportunity to edit the non-NAEP additional KSA to better reflect the intended meaning. Facilitators recorded the edits. All were discussed thoroughly in the group reviews and all 28 packets were coded using any new non-NAEP additional KSA. Below are examples of the edited non-NAEP additional KSAs recommended in both reading and mathematics.
    - One mathematics group indicated that "Use the Cartesian coordinate system" and "Basic properties of the coordinate plane including graphing sets of points" were the same skill and could be combined.
    - One reading group edited "Distinguish between primary and secondary sources" to "Locate and distinguish between primary and secondary sources."

The group review culminated in a list of 16 non-NAEP additional KSAs across the courses with substantial reading demands and 15 non-NAEP additional KSAs across the mathematics courses. These lists were brought forward to the NAEP expert reviews for consideration. These non-NAEP additional KSAs are presented in the following sections after the KSAs that are related to NAEP objectives.

Prerequisite KSAs for Courses With Substantial Reading Demands

Table 39 summarizes, by KSA, the percentages of course packets for which the KSA was considered to be a prerequisite, within and across the four courses with substantial reading requirements. A KSA was considered to be a prerequisite if, for at least one course packet, it was identified as prerequisite during independent review and agreed upon as a prerequisite at the group review. Highly qualified and trained content reviewers identified the prerequisite KSAs.

Prerequisite KSAs from the NAEP reading framework. The KSAs that appear to be most ubiquitous in their applicability as prerequisite to college course entry include the following five, which are considered to be foundational for reading comprehension at the college level:

1. Locate and recall specific information such as definitions, facts, and supporting details (1.1.a.)
2. Describe a problem and solution or cause and effect (2.1.a.)
3. Determine word meaning (2.4.a.)
4. Take different perspectives in relation to a text (3.1.c.)
5. Compare or connect ideas, perspectives, problems, or situations (2.1.b.)

The KSAs found to be prerequisite generally differed between course titles that relied heavily on literary texts (English literature) and course titles that relied heavily on informational texts (psychology, U.S. history, U.S. government). The KSAs relating to locating or recalling textually explicit information and making simple inferences within and across literary texts (standard 1.2) were considered prerequisite in most English literature course packets but rarely in course packets within other course titles. Also prerequisite to almost all of the English literature course packets (and very few packets from other courses) was the ability to integrate ideas to determine theme (2.2.b.). This is expected, given the group reviewers' determination that literary texts, and therefore KSAs related to literary texts, were more relevant to English literature than to the other course titles.

Table 39. *Percentages of Course Packets in Which the Reading Objective Was Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	English literature %	Psychology %	U.S. government %	U.S. history %
1. Locate/recall: Locate or recall textually explicit information within and across texts, which may involve making simple inferences as needed for literal comprehension					
1.1. Locate or recall textually explicit information and make simple inferences within and across both literary and informational texts					
1.1.a. Locate or recall specific information such as definitions, facts, and supporting details in text or graphics	100	100	100	100	100
1.2. Locate or recall textually explicit information and make simple inferences within and across literary texts					
1.2.a. Locate or recall character traits	24	85	0	0	10
1.2.b. Locate or recall sequence of events or actions	26	90	0	0	15
1.2.c. Locate or recall setting	25	85	0	0	15
1.2.d. Locate or recall figurative language	20	80	0	0	0
1.2.e. Locate or recall organizing structures of literary texts, such as verse or stanza in poetry or description, chronology, comparison, etcetera in literary nonfiction	21	80	0	0	5
1.3. Locate or recall textually explicit information and make simple inferences within and across informational texts					
1.3.a. Locate or recall the topic sentence or main idea	88	55	100	95	100
1.3.b. Locate or recall the author's purpose	69	35	80	85	75
1.3.c. Locate or recall causal relations	86	47	100	100	95
1.3.d. Locate or recall organizing structures of texts, such as comparison/contrast, problem/solution, enumeration, etc.	76	30	95	85	95
2. Integrate/interpret: Make complex inferences within and across texts					
2.1. Make complex inferences within and across both literary and informational texts					
2.1.a. Describe problem and solution or cause and effect	91	85	95	95	90
2.1.b. Compare or connect ideas, perspectives, problems, or situations	99	100	100	95	100
2.1.c. Determine unstated assumptions in an argument	69	55	65	75	80
2.1.d. Describe or analyze how an author uses literary devices or text features to convey meaning	64	80	70	55	50

Table 39. *Percentages of Course Packets in Which the Reading Objective Was Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	English literature %	Psychology %	U.S. government %	U.S. history %
2.1.e. Describe or analyze how an author uses organizing structures to convey meaning	59	85	40	50	60
2.1.f. Describe or analyze author's purpose	78	90	80	65	75
2.2. Make complex inferences within and across literary texts					
2.2.a. Interpret mood, tone, or voice	19	70	0	0	5
2.2.b. Integrate ideas to determine theme	26	95	0	0	10
2.2.c. Interpret a character's conflicts, motivations, and decisions	16	55	0	0	10
2.2.d. Examine relations between or among theme, setting, plot, or characters	19	65	0	0	10
2.2.e. Explain how rhythm, rhyme, sound, or form in poetry contribute to meaning	14	55	0	0	0
2.3. Make complex inferences within and across informational texts					
2.3.a. Summarize major ideas	84	45	100	90	100
2.3.b. Draw conclusions and provide supporting information	76	35	95	85	90
2.3.c. Find evidence in support of an argument	78	35	100	85	95
2.3.d. Distinguish facts from opinions	68	15	80	85	90
2.3.e. Determine the importance of information within and across texts	81	35	100	95	95
2.4. Apply understanding of vocabulary to comprehension of both literary and informational texts					
2.4.a. Determine word meaning as used in context	88	80	100	75	95
3. Critique/evaluate: Consider text(s) critically					
3.1. Consider both literary and informational texts critically					
3.1.a. Judge the author's craft and technique	33	65	15	15	35
3.1.b. Analyze, critique, or evaluate the author's perspective or point of view	68	60	60	75	75
3.1.c. Take different perspectives in relation to a text	84	75	80	90	90

Table 39. *Percentages of Course Packets in Which the Reading Objective Was Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	English literature %	Psychology %	U.S. government %	U.S. history %
3.2. Consider literary texts critically					
3.2.a. Evaluate the role of literary devices in conveying meaning	16	65	0	0	0
3.2.b. Determine the degree to which literary devices enhance a literary work	10	40	0	0	0
3.2.c. Evaluate a character's conflict, motivations, and decisions	15	50	0	0	10
3.3. Consider informational texts critically					
3.3.a. Evaluate the way the author selects language to influence readers	23	15	10	40	25
3.3.b. Evaluate the strength and quality of evidence used by the author to support his or her position	58	15	70	75	70
3.3.c. Determine the quality of counterarguments within and across texts	63	20	65	85	80
3.3.d. Judge the coherence or logic of an argument	65	20	80	85	75

The sampled course titles that rely heavily on informational texts (i.e., psychology, U.S. government, U.S. history) had similar prerequisite KSAs, with U.S. history demonstrating slight differences in KSAs related to literary texts across the standards. The ability to locate or recall textually explicit information, including topic sentence, author's purpose, causal relations, and organizing structures, and make simple inferences within and across informational texts (1.3.a. – 1.3.d.) were considered prerequisite in a majority of course packets from courses that rely heavily on informational texts. Specific abilities (2.3.a – 2.3.e) related to making complex inferences within and across informational texts were coded as prerequisite in almost all of these course packets. The ability to judge the coherence or logic of an argument (3.3.d.) was also commonly considered a prerequisite for the course titles that rely heavily on informational texts.

KSAs related to the ability to critique or evaluate literary and informational texts (standard 3.1) were considered prerequisite within the course packets across course titles. The ability to consider literary texts literally (standard 3.2) was not considered to be prerequisite for psychology or U.S. government; it was considered prerequisite in a minority of U.S. history course packets. Other KSAs that were considered prerequisite in some English literature course packets but not others (and rarely considered prerequisite in psychology, U.S. government, or U.S. history packets) included most KSAs relating to making complex inferences within and across literary texts (standard 2.2), and considering literary texts critically (standard 3.2). Taking different perspectives in relation to literature (3.1.c.) was found to be a frequent prerequisite for English literature course packets and across all other course titles.

Overall, fewer course packets across the English literature, U.S. history, U.S. government, and psychology course titles were found to contain prerequisite KSAs from within the following standards:

- Locate or recall textually explicit information and make simple inferences within and across literary texts (standard 1.2)
- Make complex inferences within and across literary texts (standard 2.2)
- Consider literary texts critically (standard 3.2)

Table 39 is color-coded to show KSAs considered to be prerequisite in 25% or fewer of the course packets (shown in orange), KSAs considered prerequisite in 26% to 74% of packets (shown in blue), and KSAs considered prerequisite in 75% or more of the packets (shown in green).

The group review generated 16 prerequisite KSAs that were not included in the NAEP framework. These non-NAEP additional KSAs are presented in Table 40 in terms of the frequency with which content reviewers, during group review, identified them in course packets overall and by course. The most commonly identified KSAs that were not represented within the NAEP framework related to a student's ability to interact with text and resources in an online environment, apply course material to world events and contexts, critique the significance of the context and time period in which an author wrote, discern source credibility and process research materials, and analyze both factual and theoretical information in informational text. All commonly identified non-NAEP additional KSAs were found in course packets across course titles.

Prerequisite KSAs for Mathematics Courses

Given the number of mathematics objectives in the NAEP framework, the presentation of prerequisite KSAs for mathematics courses is organized into separate data tables by subject area, followed by a presentation of the non-NAEP additional KSAs that are not represented in the NAEP framework.

Across all mathematics course titles, the *Number Properties and Operations* subject area of the NAEP framework was the area from which the most prerequisites were identified. The ability to represent, interpret, or compare expressions for real numbers, including exponents, was the most ubiquitous prerequisite KSA for college-level coursework. The ability to perform arithmetic operations with real numbers, including common irrational numbers (1.3.b.), and apply basic properties of operations, including conventions about the order of operations (1.5.e.), were considered prerequisite KSAs for significant proportions of course packets within all sampled course titles except statistics. KSAs related to ratios and proportional reasoning were considered prerequisite only for some (26%) precalculus/calculus courses. KSAs relating to estimation or mathematical reasoning subtopics in the NAEP framework were considered prerequisite in only a small proportion of course packets.

Many NAEP objectives in the subject area of *Number Properties and Operations* were considered prerequisite in some courses and not in others. Whether the following KSAs were considered prerequisite varied by course packet: ability to order or compare real numbers; describe the effect of multiplying and dividing by numbers (including by 0, less than 0, between 0 and 1, and greater than 1); solve application problems involving numbers (including rational and common irrationals); solve problems using factors, multiples, or prime factorization; apply basic properties of operations; and recognize properties of the number system and how they relate to each other. These KSAs were, however, considered prerequisite in more precalculus/calculus and college algebra course packets than in finite mathematics or statistics course packets.

Table 40. *Non-NAEP Additional KSAs for Courses With Substantial Reading Demands*

Non-NAEP additional prerequisite KSA	Number of course packets	English literature	Psychology	U.S. government	U.S. history
Apply course material to think about the world	19	5	4	5	5
Critique/evaluate the significance of the historical or cultural context of a text or author	18	5	4	4	5
Locate or recall textually explicit information through a course website or other websites	14	2	4	4	4
Have some knowledge of interacting with reading/text in an online environment	14	3	4	4	3
Discern credibility of source	12	1	5	4	2
Read and process research materials	12	2	2	4	4
Analyze both factual and theoretical information in informational text	11	2	5	4	0
Utilize text features (e.g., glossaries, key terms, key ideas, or issues that are highlighted) or online links (e.g., online study center, charts, or technology sections) as an aid to reading	11	0	5	3	3
Integrate text with personal experience	7	1	4	2	0
Locate and distinguish between primary and secondary sources	7	1	3	1	2
Understand various theoretical models of domain-specific content (e.g., historical, feminist response, or ecocriticism)	6	0	5	1	0
Distinguish between primary text sources and secondary text sources	4	0	0	0	4
Analyze complex literary or informational text	3	0	0	0	3
Recognize complexities of the underlying traditions in a literary text (e.g., Romanticism, Modernism, or Transcendentalism)	2	2	0	0	0
Able to read English well	2	0	1	1	0
Able to read texts aloud in class to engage in the class discussion and interpretation	1	1	0	0	0

The following tables, representing each mathematics content area, are color-coded to show KSAs that were considered to be prerequisite in 25% or less of the course packets (shown in orange), KSAs that were considered prerequisite in 26% to 74% of packets (shown in blue), and KSAs that were considered prerequisite in 75% or more of the packets (shown in green). See Table 41.

Table 41. *Percentages of Course Packets in Which the Mathematics Objectives Under Number Properties and Operations Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
1. Number properties and operations					
1.1. Number sense					
1.1.d. Represent, interpret, or compare expressions for real numbers, including expressions using exponents and logarithms	92	100	90	95	85
1.1.f. Represent or interpret expressions involving very large or very small numbers in scientific notation	20	0	65	10	5
1.1.g. Represent, interpret, or compare expressions or problem situations involving absolute values	34	63	75	0	0
1.1.i. Order or compare real numbers, including very large and very small real numbers	73	79	95	60	60
1.2. Estimation					
1.2.b. Identify situations where estimation is appropriate, determine the needed degree of accuracy, and analyze* the effect of the estimation method on the accuracy of results	1	0	0	5	0
1.2.c. Verify solutions or determine the reasonableness of results in a variety of situations	10	21	15	5	0
1.2.d. Estimate square or cube roots of numbers less than 1,000 between two whole numbers	0	0	0	0	0
1.3. Number operations					
1.3.a. Find integral or simple fractional powers of real numbers	62	95	90	40	0
1.3.b. Perform arithmetic operations with real numbers, including common irrational numbers	97	100	100	90	0
1.3.c. Perform arithmetic operations with expressions involving absolute value	34	63	75	0	0
1.3.d. Describe the effect of multiplying and dividing by numbers including the effect of multiplying or dividing a real number by 0, or a number less than 0, or a number between 0 and 1, 1, or a number greater than 1	19	26	37	10	0

Table 41. *Percentages of Course Packets in Which the Mathematics Objectives Under Number Properties and Operations Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
1.3.f. Solve application problems involving numbers, including rational and common irrationals	63	89	85	40	30
1.4. Ratios and proportional reasoning					
1.4.c. Use proportions to solve problems (including rates of change)	24	26	20	20	25
1.4.d. Solve multistep problems involving percentages, including compound percentages	19	26	25	15	0
1.5. Properties of number and operations					
1.5.c. Solve problems using factors, multiples, or prime factorization	47	89	85	10	0
1.5.d. Use divisibility or remainders in problem settings	8	16	10	5	0
1.5.e. Apply basic properties of operations, including conventions about the order of operations	89	95	95	85	0
1.5.f. Recognize properties of the number system (whole numbers, integers, rational numbers, real numbers, and complex numbers) and how they are related to each other and identify examples of each type of number	28	42	50	20	0
1.6. Mathematical reasoning using number					
1.6.a. *Give a mathematical argument to establish the validity of a simple numerical property or relationship	3	11	0	0	0
1.6.b. *Analyze or interpret a proof by mathematical induction of a simple numerical relationship	0	0	0	0	0

Note. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments.

All of the KSAs considered prerequisite under the *Measurement* subject area of the NAEP Mathematics framework were found in precalculus/calculus, college algebra, and finite mathematics course packets. There were six KSAs represented by objectives that were considered to be prerequisite in between a fourth and a third of the precalculus/calculus course packets (2.1.f, 2.1.h, 2.3.c, 2.3.d, 2.3.f.). The majority of these related to trigonometry. A few other *Measurement* KSAs were found in a small minority of precalculus/calculus course packets; for instance, solve problems involving rates such as speed, density, population density, or flow rates (2.1.i.), was found to be an applicable prerequisite in 21% of precalculus/calculus packets. Some *Measurement* prerequisites were found in college algebra and finite mathematics course packets, although less frequently than were found in the precalculus/calculus course packets. The most commonly determined prerequisites for college algebra involved solving problems involving perimeter or area of plane figures (2.1.f.); solving problems by determining, estimating, or comparing volumes or surface areas of three-dimensional figures (2.1.h.); and solving problems involving indirect measurement (2.3.a.). Three KSAs were determined to be prerequisite in one finite mathematics packet each (2.1.h, 2.2.b, 2.2.d). There were no *Measurement* KSAs considered prerequisite in the sampled statistics course packets. See Table 42.

Table 42. *Percentages of Course Packets in Which the Mathematics Objectives Under Measurement Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
2. Measurement					
2.1. Measuring physical attributes					
2.1.b. Determine the effect of proportions and scaling on length, area, and volume	0	0	0	0	0
2.1.c. Estimate or compare perimeters or areas of two-dimensional geometric figures	1	0	5	0	0
2.1.d. Solve problems of angle measure, including those involving triangles or other polygons or parallel lines cut by a transversal	1	5	0	0	0
2.1.f. Solve problems involving perimeter or area of plane figures such as polygons, circles, or composite figures	16	32	35	0	0
2.1.h. Solve problems by determining, estimating, or comparing volumes or surface areas of three-dimensional figures	14	26	25	5	0
2.1.i. Solve problems involving rates such as speed, density, population density, or flow rates	10	21	20	0	0
2.2. Systems of measurement					
2.2.a. Recognize that geometric measurements (length, area, perimeter, and volume) depend on the choice of a unit and apply such units in expressions, equations, and problem solutions	0	0	0	0	0

Table 42. *Percentages of Course Packets in Which the Mathematics Objectives Under Measurement Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
2.2.b. Solve problems involving conversions within or between measurement systems, given the relationship between the units	1	0	0	5	0
2.2.d. Understand that numerical values associated with measurements of physical quantities are approximate, are subject to variation, and must be assigned units of measurement	1	0	0	5	0
2.2.e. Determine appropriate accuracy of measurement in problem situations (e.g., the accuracy of measurement of the dimensions to obtain a specified accuracy of area) and find the measure to that degree of accuracy	0	0	0	0	0
2.2.f. Construct or solve problems involving scale drawings	0	0	0	0	0
2.3. Measurement in triangles					
2.3.a. Solve problems involving indirect measurement	9	11	25	0	0
2.3.b. Solve problems using the fact that trigonometric ratios (sine, cosine, and tangent) stay constant in similar triangles	4	16	0	0	0
2.3.c. Use the definitions of sine, cosine, and tangent as ratios of sides in a right triangle to solve problems about length of sides and measure of angles	8	32	0	0	0
2.3.d. Interpret and use the identity $\sin^2 q + \cos^2 q = 1$ for angles q between 0° and 90°; recognize this identity as a special representation of the Pythagorean theorem	6	26	0	0	0
2.3.e. *Determine the radian measure of an angle and explain how radian measurement is related to a circle of radius 1	6	26	0	0	0
2.3.f. *Use trigonometric formulas such as addition and double angle formulas	9	37	0	0	0
2.3.g. *Use the law of cosines and the law of sines to find unknown sides and angles of a triangle	5	21	0	0	0

Note. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments.

KSAs in the *Geometry* subject area of the NAEP Mathematics framework were infrequently found to be prerequisite. Two KSAs (3.3.c. and 3.3.d.) were determined to be prerequisite in roughly a third of college algebra course packets, and one KSA (3.4.a.) was found to be prerequisite in slightly less than half of the precalculus/calculus course packets. Five KSAs (3.3.c, 3.3.d, 3.3.g, 3.4.a, 3.4.f) were determined to be prerequisite within at least one finite mathematics course packet. None of the *Geometry* KSAs were considered to be prerequisite for statistics based on the course packets in the CCCA sample. See Table 43.

The subject area of *Data Analysis, Statistics, and Probability* did not include many objectives that were considered through this content analysis process to be prerequisites for many of the sampled course packets; 27 of the 32 KSAs were determined to be not prerequisite in any course packet sampled. The ability to read or interpret graphical or tabular representation of data (4.1.a.) was considered a prerequisite KSA within almost half of the course packets, although slightly less commonly found in college algebra packets. Completing a graph or solving a problem using data in the graph (4.1.b.) was a KSA found to be prerequisite within a few course packets in the precalculus/calculus, finite mathematics, and statistics course titles. One KSA (4.1.d) was considered prerequisite in one college algebra course packet, and one KSA (4.1.f) was considered prerequisite in one statistics course packet. One KSA (4.2.e) was determined to be prerequisite in one precalculus/calculus course packet and one finite mathematics course packet. See Table 44.

Table 43. ***Percentages of Course Packets in Which the Mathematics Objectives Under Geometry Were Considered a Prerequisite Across all Courses and by Course Title***

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
3. Geometry					
3.1. Dimension and shape					
3.1.c. Give precise mathematical descriptions or definitions of geometric shapes in the plane and in three-dimensional space	0	0	0	0	0
3.1.d. Draw or sketch from a written description plane figures and planar images of three-dimensional figures	3	0	10	0	0
3.1.e. Use two-dimensional representations of three-dimensional objects to visualize and solve problems	9	16	20	0	0
3.1.f. Analyze properties of three-dimensional figures, including spheres and hemispheres	0	0	0	0	0
3.2. Transformation of shapes and preservation of properties					
3.2.a. Recognize or identify types of symmetries (e.g., point, line, rotational, or self-congruence) of two- and three-dimensional figures	1	5	0	0	0

Table 43. *Percentages of Course Packets in Which the Mathematics Objectives Under Geometry Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
3.2.b. Give or recognize the precise mathematical relationship (e.g., congruence, similarity, or orientation) between a figure and its image under a transformation	0	0	0	0	0
3.2.c. Perform or describe the effect of a single transformation on two- and three-dimensional geometric shapes (reflections across lines of symmetry, rotations, translations, and dilations)	1	0	5	0	0
3.2.d. Identify transformations, combinations, or subdivisions of shapes that preserve the area of two-dimensional figures or the volume of three-dimensional figures	1	0	5	0	0
3.2.e. Justify relationships of congruence and similarity and apply these relationships using scaling and proportional reasoning	0	0	0	0	0
3.2.g. Perform or describe the effects of successive transformations	1	5	0	0	0
3.3. Relationships between geometric figures					
3.3.b Apply geometric properties and relationships to solve problems in two and three dimensions	8	5	20	0	0
3.3.c. Represent problem situations with geometric models to solve mathematical or real-world problems	14	0	30	5	0
3.3.d. Use the Pythagorean theorem to solve problems in two- or three-dimensional situations	19	0	40	10	0
3.3.e. Recall and interpret definitions and basic properties of congruent and similar triangles, circles, quadrilaterals, polygons, parallel, perpendicular and intersecting lines, and associated angle relationships	3	0	5	0	0
3.3.f. Analyze properties or relationships of triangles, quadrilaterals, and other polygonal plane figures	0	0	0	0	0
3.3.g. Analyze properties and relationships of parallel, perpendicular, or intersecting lines including the angle relationships that arise in these cases	3	5	0	5	0

Table 43. *Percentages of Course Packets in Which the Mathematics Objectives Under Geometry Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
3.3.h. Analyze properties of circles and the intersections of lines and circles (inscribed angles, central angles, tangents, secants, and chords)	0	5	0	0	0
3.4. Position, direction, and coordinate geometry					
3.4.a Solve problems involving the coordinate plane such as the distance between two points, the midpoint of a segment, or slopes of perpendicular or parallel lines	16	42	15	10	0
3.4.b Describe the intersections of lines in the plane and in space, of a line and a plane, or of two planes in space	1	0	5	0	0
3.4.c Describe or identify conic sections and other cross sections of solids	5	21	0	0	0
3.4.d Represent two-dimensional figures algebraically using coordinates and/or equations	8	21	10	0	0
3.4.e *Use vectors to represent velocity and direction; multiply a vector by a scalar and add vectors both algebraically and graphically	0	0	0	0	0
3.4.f Find an equation of a circle given its center and radius and, given an equation of a circle, find its center and radius	8	21	5	5	0
3.4.g *Graph ellipses and hyperbolas whose axes are parallel to the coordinate axes and demonstrate understanding of the relationship between their standard algebraic form and their graphical characteristics	3	11	0	0	0
3.4.h *Represent situations and solve problems involving polar coordinates	0	0	0	0	0
3.5. Mathematical reasoning in geometry					
3.5.a Make, test, and validate geometric conjectures using a variety of methods including deductive reasoning and counterexamples	0	0	0	0	0
3.5.b Determine the role of hypotheses, logical implications, and conclusion in proofs of geometric theorems	0	0	0	0	0

Table 43. *Percentages of Course Packets in Which the Mathematics Objectives Under Geometry Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
3.5.c Analyze or explain a geometric argument by contradiction	0	0	0	0	0
3.5.d Analyze or explain a geometric proof of the Pythagorean theorem	0	0	0	0	0
3.5.e Prove basic theorems about congruent and similar triangles and circles	0	0	0	0	0

Note. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments.

Table 44. *Percentages of Course Packets in Which the Mathematics Objectives Under Data Analysis, Statistics, and Probability Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
4. Data analysis, statistics, and probability					
4.1. Data representation					
4.1.a. Read or interpret graphical or tabular representations of data	49	58	35	55	50
4.1.b. For a given set of data, complete a graph and solve a problem using the data in the graph (histograms, scatterplots, and line graphs)	8	21	0	5	5
4.1.c. Solve problems involving univariate or bivariate data	0	0	0	0	0
4.1.d. Given a graphical or tabular representation of a set of data, determine whether information is represented effectively and appropriately	1	0	5	0	0
4.1.e. Compare and contrast different graphical representations of univariate and bivariate data	0	0	0	0	0
4.1.f. Organize and display data in a spreadsheet in order to recognize patterns and solve problems	1	0	0	0	5

Table 44. *Percentages of Course Packets in Which the Mathematics Objectives Under Data Analysis, Statistics, and Probability Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
4.2. Characteristics of data sets					
4.2.a. Calculate, interpret, or use summary statistics for distributions of data including measures of typical value (mean and median), position (quartiles and percentiles), and spread (range, interquartile range, variance, and standard deviation)	0	0	0	0	0
4.2.b. Recognize how linear transformations of one-variable data affect mean, median, mode, range, interquartile range, and standard deviation	0	0	0	0	0
4.2.c. Determine the effect of outliers on mean, median, mode, range, interquartile range, or standard deviation	0	0	0	0	0
4.2.d. Compare data sets using summary statistics (mean, median, mode, range, interquartile range, or standard deviation) describing the same characteristic for two different populations or subsets of the same population	0	0	0	0	0
4.2.e. Approximate a trend line if a linear pattern is apparent in a scatterplot or use a graphing calculator to determine a least-squares regression line and use the line or equation to make predictions	3	5	0	5	0
4.2.f. Recognize that the correlation coefficient is a number from -1 to +1 that measures the strength of the linear relationship between two variables; visually estimate the correlation coefficient (e.g., positive or negative, closer to 0, .5, or 1.0) of a scatterplot	0	0	0	0	0
4.2.g. Know and interpret the key characteristics of a normal distribution such as shape, center (mean), and spread (standard deviation)	0	0	0	0	0
4.3. Experiments and samples					
4.3.a. Identify possible sources of bias in sample surveys and describe how such bias can be controlled and reduced	0	0	0	0	0

Table 44. *Percentages of Course Packets in Which the Mathematics Objectives Under Data Analysis, Statistics, and Probability Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
4.3.b. Recognize and describe a method to select a simple random sample	0	0	0	0	0
4.3.c. *Draw inferences from samples, such as estimates of proportions in a population, estimates of population means, or decisions about differences in means for two "treatments"	0	0	0	0	0
4.3.d. Identify or evaluate the characteristics of a good survey or of a well-designed experiment	0	0	0	0	0
4.3.e. *Recognize the differences in design and in conclusions between randomized experiments and observational studies	0	0	0	0	0
4.4. Probability					
4.4.a. Recognize whether two events are independent or dependent	0	0	0	0	0
4.4.b. Determine the theoretical probability of simple and compound events in familiar or unfamiliar contexts	0	0	0	0	0
4.4.c. Given the results of an experiment or simulation, estimate the probability of simple or compound events in familiar or unfamiliar contexts	0	0	0	0	0
4.4.d. Use theoretical probability to evaluate or predict experimental outcomes	0	0	0	0	0
4.4.e. Determine the number of ways an event can occur using tree diagrams, formulas for combinations and permutations, or other counting techniques	0	0	0	0	0
4.4.h. Determine the probability of independent and dependent events	0	0	0	0	0
4.4.i. Determine conditional probability using two-way tables	0	0	0	0	0
4.4.j. Interpret and apply probability concepts to practical situations	0	0	0	0	0
4.4.k. *Use the binomial theorem to solve problems	0	0	0	0	0

Table 44. *Percentages of Course Packets in Which the Mathematics Objectives Under Data Analysis, Statistics, and Probability Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
4.5. Mathematical reasoning with data					
4.5.a. Identify misleading uses of data in real-world settings and critique different ways of presenting and using information	0	0	0	0	0
4.5.b. Distinguish relevant from irrelevant information, identify missing information, and either find what is needed or make appropriate approximations	0	0	0	0	0
4.5.c. *Recognize, use, and distinguish between the processes of mathematical (deterministic) and statistical modeling	0	0	0	0	0
4.5.d. Recognize when arguments based on data confuse correlation with causation	0	0	0	0	0
4.5.e. *Recognize and explain the potential errors caused by extrapolating from data	0	0	0	0	0

Note. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments.

Few of the KSAs represented by objectives in the *Algebra* subject area of the NAEP Mathematics framework were considered to be prerequisite consistently within or across course titles. Four of the 30 KSAs (5.3.c, 5.3.e, 5.3.f, 5.4.a) were determined to be prerequisite in at least one packet from all course titles. Eleven KSAs (5.1.e, 5.1.g, 5.1.h, 5.h.i, 5.2.a, 5.2.e, 5.3.b, 5.3.d, 5.4.c, 5.4.e, 5.4.f) were determined to be prerequisite in at least one packet from three course titles. However, across course titles, the percentages of course packets where the KSA was deemed prerequisite were not consistent. For example, the ability to evaluate algebraic expressions including polynomials and rational expressions (5.3.e) was found to be prerequisite in as many as 90% of course packets within one course title (college algebra) and as little as 10% of course packets within another course title (statistics). This was also the KSA that was most frequently identified as prerequisite across course titles.

Similarly to the *Number Properties and Operations* subject area, there were generally more KSAs considered prerequisite in precalculus/calculus and college algebra than in finite mathematics or statistics. For any given KSA under the *Algebra* subject area, the KSA was considered prerequisite in fewer than 50% of the finite mathematics or statistics course packets. Only three *Algebra* KSAs (5.3.g, 5.4.g, 5.5.b) were determined not to be prerequisite in any course packet across all course titles in the CCCA sample. See Table 45.

Table 45. *Percentages of Course Packets in Which the Mathematics Objectives Under Algebra Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
5. Algebra					
5.1. Patterns, relations, and functions					
5.1.a. Recognize, describe, or extend numerical patterns, including arithmetic and geometric progressions	5	16	0	5	0
5.1.b. Express linear and exponential functions in recursive and explicit form given a table, verbal description, or some terms of a sequence	5	16	0	5	0
5.1.e. Identify or analyze distinguishing properties of linear, quadratic, rational, exponential, or *trigonometric functions from tables, graphs, or equations	27	68	30	10	0
5.1.g. Determine whether a relation, given in verbal, symbolic, tabular, or graphical form, is a function	16	42	20	5	0
5.1.h. Recognize and analyze the general forms of linear, quadratic, rational, exponential, or trigonometric functions	20	53	20	10	0
5.1.i. *Determine the domain and range of functions given in various forms and contexts	25	68	30	5	0
5.1.j. Given a function, determine its inverse if it exists and explain the contextual meaning of the inverse for a given situation	8	32	0	0	0
5.2. Algebraic representations					
5.2.a. Create and translate between different representations of algebraic expressions, equations, and inequalities (e.g., linear, quadratic, exponential, or *trigonometric) using symbols, graphs, tables, diagrams, or written descriptions	44	89	70	20	0
5.2.b. Analyze or interpret relationships expressed in symbols, graphs, tables, diagrams (including Venn diagrams), or written descriptions and evaluate the relative advantages or disadvantages of different representations to answer specific questions	8	21	0	10	0

Table 45. *Percentages of Course Packets in Which the Mathematics Objectives Under Algebra Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
5.2.d. Perform or interpret transformations on the graphs of linear, quadratic, exponential, and *trigonometric functions	10	37	5	0	0
5.2.e. Make inferences or predictions using an algebraic model of a situation	19	32	25	20	0
5.2.f. Given a real-world situation, determine if a linear, quadratic, rational, exponential, logarithmic, or *trigonometric function fits the situation	8	21	10	0	0
5.2.g. Solve problems involving exponential growth and decay	6	26	0	0	0
5.2.h. *Analyze properties of exponential, logarithmic, and rational functions	5	21	0	0	0
5.3. Variables, expressions, and operations					
5.3.b. Write algebraic expressions, equations, or inequalities to represent a situation	46	68	75	40	0
5.3.c. Perform basic operations, using appropriate tools, on algebraic expressions including polynomial and rational expressions	53	89	90	30	5
5.3.d. Write equivalent forms of algebraic expressions, equations, or inequalities to represent and explain mathematical relationships	29	63	30	25	0
5.3.e. Evaluate algebraic expressions including polynomials and rational expressions	58	89	90	45	10
5.3.f. Use function notation to evaluate a function at a specified point in its domain and combine functions by addition, subtraction, multiplication, division, and composition	23	68	5	15	5
5.3.g. *Determine the sum of finite and infinite arithmetic and geometric series	0	0	0	0	0
5.3.h. Use basic properties of exponents and *logarithms to solve problems	28	42	70	0	0

Table 45. *Percentages of Course Packets in Which the Mathematics Objectives Under Algebra Were Considered a Prerequisite Across all Courses and by Course Title*

Objective	Overall %	Precalculus/ calculus %	College algebra %	Finite mathematics %	Statistics %
5.4. Equations and inequalities					
5.4.a. Solve linear, rational, or quadratic equations or inequalities, including those involving absolute value	48	89	75	25	5
5.4.c. Analyze situations, develop mathematical models, or solve problems using linear, quadratic, exponential, or logarithmic equations or inequalities symbolically or graphically	35	89	50	5	0
5.4.d. Solve (symbolically or graphically) a system of equations or inequalities and recognize the relationship between the analytical solution and graphical solution	1	0	0	5	0
5.4.e. Solve problems involving special formulas such as: $A = P(I + r)^t$, $A = Pe^{rt}$	10	26	10	5	0
5.4.f. Solve an equation or formula involving several variables for one variable in terms of the others	15	26	25	10	0
5.4.g. Solve quadratic equations with complex roots	0	0	0	0	0
5.5. Mathematical reasoning in algebra					
5.5.a. Use algebraic properties to develop a valid mathematical argument	3	5	0	5	0
5.5.b. Determine the role of hypotheses, logical implications, and conclusions in algebraic argument	0	0	0	0	0
5.5.c. Explain the use of relational conjunctions (and, or) in algebraic arguments	1	0	0	5	0

Note. An asterisk (*) denotes objectives that describe mathematics content beyond that typically taught in a standard 3-year course of study (the equivalent of 1 year of geometry and 2 years of algebra). Therefore, these objectives will be selected less often than the others for inclusion on the NAEP assessments

An examination of the 15 prerequisite KSAs identified by the content reviewers that are not represented by objectives in the NAEP framework reveals that few of the non-NAEP additional KSAs were considered to be common prerequisites across course packets. Eight non-NAEP prerequisite KSAs were identified in nine or more packets. Three of these relate to the use of calculators, two more broadly to the use of technology and computers, one involves using interval notation and another set notation, and one incorporates reading skill into the ability to convert sentences into mathematical expressions. The remaining non-NAEP prerequisite KSAs were found in six or fewer course packets. Notably, despite condensing the prerequisite KSAs when redundancy was clearly evident, the 15 non-NAEP additional KSAs do not represent 15 unique and unrelated abilities. KSAs related to the use of technology, including web-based content, computers, and calculators, comprise one third of the total non-NAEP additional KSAs. The ability to read and communicate mathematical information comprised four of the non-NAEP additional KSAs. Two relate to the Cartesian coordinate system and determining the equation of a line. See Table 46.

Prerequisite KSA Narrative Descriptions

The primary objective of the NAEP expert review of the group review results was to develop a more integrative narrative description of the knowledge, skills, and abilities a student would need to possess on entry into credit-bearing college courses. The narrative descriptions contain the key prerequisite content and skills from the knowledge, skills, and abilities contained in the NAEP-specific content maps, KSA exclusions, and non-NAEP additional KSAs identified by the content review groups.

Table 46. ***Non-NAEP Additional KSAs Determined to Be Prerequisite for Mathematics Courses***

Non-NAEP additional prerequisite KSAs	Number of course packets	Precalculus/ calculus	College algebra	Finite mathematics	Statistics
Reading comprehension sufficient to convert sentences to mathematical expressions	20	5	5	5	5
Use of technology	19	4	5	5	5
Basic calculator skills	15	2	4	5	4
Use of scientific calculator	14	2	3	5	4
Understanding and using interval notation	12	6	6	0	0
Facility with/use of graphing calculators	9	2	2	2	3
Facility in use of computers, including loading software, submitting homework, taking quizzes online, and manipulating charts	9	0	3	0	6
Understanding and using basic set notation, including symbols for element of, not an element of, subset of, and not a subset of	9	2	4	2	1
Writing ability sufficient to prepare a brief report and a reflection paper	6	2	0	1	3
Communicating mathematics in written form	5	0	0	0	5
Ability to: given points, determine the equation of a line; given a point and slope, determine the equation of a line; given an equation and a point, determine the equation of a line parallel and perpendicular to the given equation	5	4	0	1	0
Ability to work in groups	5	1	0	2	2
Knowledge of the Cartesian coordinate system	1	1	0	0	0
Problem-solving skills	1	1	0	0	0

The NAEP reading experts generated a single description of prerequisite KSAs, integrating findings across all courses in the study with substantial reading demands. The NAEP mathematics experts determined that mathematics courses differed from each other enough to make a single overall description of mathematics prerequisite KSAs problematic. The mathematics team addressed this issue by identifying a set of overall prerequisite KSAs plus course-specific descriptions of prerequisite knowledge, skills, and abilities.

Following are the summaries describing the prerequisite KSAs that were evident in the analyzed courses. Because these descriptions account for the KSA exclusions and include the non-NAEP additional KSAs, they are not a listing of NAEP objectives, nor are they NAEP-specific or only interpretable in the context of NAEP. Underlined statements indicate non-NAEP additional prerequisite KSAs not contained in the content maps.

Prerequisite KSAs Compared to Content Addressed in NAEP 2009 and 2013 Item Pools

The NAEP experts used the narrative descriptions of prerequisites KSAs as reference points for reviewing item pools from the 2009 and 2013 NAEP administrations. In general, most of the reading items seemed to align with the CCCA prerequisite KSAs found for entry-level courses requiring substantial reading. After reviewing the item pools against the narrative descriptions, the NAEP experts concluded that the prerequisite KSAs identified in the CCCA study assume students have prior knowledge of the content (e.g., a student in a U.S. government course has some prior knowledge of government to comprehend a passage) whereas the NAEP reading selections and associated items appeared to be selected for wide accessibility, i.e., not geared towards students with prior knowledge.

For mathematics, the narrative description of prerequisite KSAs focused more heavily on

NAEP Reading Expert Narrative Description of Prerequisite KSAs

To be minimally prepared for college reading of printed texts <u>and online resources</u>, students need to be able to locate and recall specific information such as definitions, facts, events, and other supporting details and to determine word meanings as used in context. <u>Students should be able to distinguish between primary and secondary materials</u> and fact and opinion.

Students need to be able to identify and describe causal relationships and organizational structure of texts, such as comparison/contrast, problem/solution, and enumeration. Within and across texts they need to be able to make simple and complex inferences, summarize major themes and ideas, draw conclusions, and provide supporting information. <u>Students need to be able to describe and analyze how an author uses text features such as graphics, tables, and charts to convey meaning.</u>

Students need to be able to take different perspectives in relation to a text and analyze, critique, and evaluate author's purpose, point of view, and bias. Students need to be able to find evidence in support of an argument and evaluate the strength and quality of the evidence, determine the quality of counter arguments, and judge the coherence and logic of an argument. <u>Students need to be able to critique and evaluate the significance of the historical and cultural context of texts. Finally, students need to be able to apply information from readings to contemporary issues and real-world problems.</u>

In addition to these knowledge, skills, and abilities, to be minimally prepared for literature courses students need to be able to describe and analyze relations among settings, characters, and themes in a variety of literary texts. Students need to be able to interpret the text critically, evaluating the role of figurative language and literary devices and describing, analyzing, and evaluating characters' conflicts, motivations, and decisions.

Note: Technology literacy was identified in some artifacts as being prerequisite. "Digital" text is included here, but not addressed.

NAEP Mathematics Expert Narrative Description of Prerequisite KSAs

Number Properties and Operations: *For all four courses, students should be able to represent, interpret, and solve problems with real numbers. They can compare and order numbers as well as use conventions about the order of numerical operations. Integral or simple fractional powers of real numbers are especially needed for college algebra and precalculus/calculus. For none of the courses do students need to know about logarithms, but knowledge of exponents is needed for college algebra and precalculus/calculus. Students entering college algebra or precalculus/calculus courses need to be able to solve application problems involving factors and multiples. They also need to be able to represent, interpret, compare, or perform operations with expressions involving absolute values.*

Measurement and Geometry: *Overall, none of the objectives [NAEP-specific KSAs] in measurement or geometry was deemed a prerequisite other than some emphasis on coordinate geometry for the study of precalculus/calculus, and some attention to area, perimeter, and the Pythagorean Theorem for college algebra.*

Statistics: *For all four courses, students should be able to read or interpret graphs or tables. Otherwise, none of the statistics objectives was deemed a prerequisite.*

Algebra: *For statistics, none of the algebra objectives is a prerequisite. For finite mathematics, a minimal knowledge of algebra is needed, such as writing and evaluating expressions. College algebra and precalculus/calculus have as a prerequisite the ability to write and translate between different representations using algebraic expressions, equations, and inequalities. They also require that students be able to evaluate and perform basic operations on expressions. In addition, students entering those courses should be able to analyze, or solve problems with, linear, rational, or quadratic equations or inequalities. For precalculus/calculus, students should be able to write equivalent forms of algebraic expressions, equations, or inequalities to represent situations. Precalculus/calculus students should also have knowledge of functions, including domain and range. They should be able to evaluate functions and analyze function properties.*

Non-NAEP Additional KSAs. *Overall, students should be familiar with sets and their properties and notation. For their courses, they should have facility in the use of computers and calculators.*

application of mathematics than is evident in the NAEP item pools. The items are skill-based and procedural in nature rather than applied. The CCCA content contained more instances of application problems. This finding is consistent with the NAEP framework, but the NAEP items do not reflect this to the same degree. Another significant difference between NAEP mathematics and the narrative description of prerequisite KSAs is the absence of measurement and geometry in the majority of courses and the presence of measurement and geometry content in the NAEP item pools.

College-Course Prerequisites Compared to Other Study Findings

The narrative descriptions from this study were compared to the borderline performance descriptions (BPDs) for college preparedness (version 4.0) from the JSS study. The BPDs and the narrative descriptions from this study were compared for breadth of KSAs included and the level of cognitive demand (Bloom, 1956) represented within those KSAs. Appendix W contains the BPDs from the JSS study.

Comparison of reading JSS BPD and CCCA narrative description. A comparison of the JSS BPD and the CCCA narrative description for reading suggests that the level of cognitive demand and breadth of prerequisite KSAs are greater in the CCCA study than in the JSS study. Almost all KSAs described in the JSS BPD are included in the CCCA narrative description; one exception is that the JSS BPD includes students' ability to explain, when locating relevant information in texts, why specific information is included. This ability to explain why an author includes certain information is implied within the CCCA narrative description under the ability to analyze, evaluate, and critique author's purpose, and to locate and recall supporting details.

The JSS BPD includes few verbs, such as critique or evaluate, that relate to higher-order thinking skills. More common in the JSS BPD are verbs such as locate, identify, understand, interpret, and explain. The CCCA narrative description includes more KSAs that represent demands for higher-order skills. As an example of the distinction, the JSS BPD includes the KSA, "They should be able to identify or explain the author's point or central theme and supporting textual evidence." The statement in the CCCA narrative description that references similar KSAs relating to author's purpose is more complex: "Students need to be able to take different perspectives in relation to a text and analyze, critique, and evaluate author's purpose, point of view, and bias."

The CCCA narrative description includes several KSAs that are not evident in the JSS BPD. The JSS BPD makes no reference to KSAs related to evaluating the strength and quality of evidence in support of an argument, the quality of counterarguments, and the overall coherence and logic of an argument. The CCCA narrative description also draws in the need for students to be able to understand the cultural and historical contexts of texts, and to be able to apply information from texts to contemporary issues and real-world problems. Also in the CCCA narrative description but not the JSS BPD is the specification that the prerequisite KSAs apply to the reading of both printed and online resources. A final distinction between the CCCA narrative description and the JSS BPD is the inclusion in the CCCA narrative description of a reference to students' ability to distinguish between primary and secondary materials and fact and opinion.

Comparison of mathematics JSS BPD and CCCA narrative description. The JSS BPD and CCCA mathematics description are more challenging to compare than the JSS reading BPD to the narrative description for the courses with substantial reading demands. The JSS BPD and CCCA narrative description include many similar prerequisite KSAs; however, there are some prerequisite KSAs unique to either the JSS BPD or CCCA narrative description. The JSS BPD places more emphasis than the CCCA narrative description on surface area, volume, and other units of measurement in the *Measurement* and *Geometry* subject areas. Likewise, the CCCA narrative description states that students need only read or interpret graphs and tables in the *Data Analysis, Probability and Statistics* subject area, whereas the JSS BPD emphasizes computing mean, median, mode, and other basic concepts of probability. There is reasonable overlap in the *Number Properties and Operations* and *Algebra* subject areas between the JSS BPD and the CCCA narrative description. Lastly, the CCCA narrative description states that students should be familiar with sets and their properties and notation and should have facility in the use of computers and calculators. The JSS BPD includes neither of these prerequisite KSAs. However, the JSS BPD was drawn entirely from the NAEP framework objectives, so the exclusion of any KSA that was not based on a NAEP objective is to be expected.

CONCLUSIONS

The College Course Content Analysis study, using a convergent consensus process involving expert judgment, systematic review processes, and standardized sets of course artifacts, complements other types of studies that have been sponsored by the National Assessment Governing Board in its 12th Grade Preparedness Research Program. The CCCA study was designed to elicit, through an evidence-based content analysis design, the knowledge, skills, and abilities that students need to bring with them into entry-level, credit-bearing college courses. The four research questions that formed the focus of this study are addressed in detail below.

Research Question 1

What are the prerequisite knowledge, skills, and abilities (hereafter referred to as prerequisite KSAs) in mathematics and reading to qualify for entry-level, credit-bearing courses that satisfy general education requirements? The findings from the study suggest that there is a set of reading KSAs that are prerequisite to entering entry-level, credit-bearing college courses that have substantive informational text reading demands, and a set of prerequisite KSAs for courses that demand engagement with literary texts. The findings for mathematics were specific to a course title, without a single set of prerequisite KSAs that covered all entry-level, credit-bearing courses. Most of the prerequisite KSAs for the sample of both mathematics course titles and course titles that require extensive college-level reading are reflected in the NAEP frameworks. However, there were non-NAEP additional KSAs that are considered prerequisite for these courses that are not included in the NAEP frameworks.

Reading Prerequisite KSAs

The KSAs that were prerequisite to entry-level, credit-bearing college courses that have substantial reading demands included those requiring various levels of cognitive demand. The KSAs that appear to be ubiquitous in their relevance as prerequisite to college course entry were represented within the NAEP framework cognitive domain *Locate/Recall: Locate or recall textually explicit information within and across texts, which may involve making simple inferences as needed for literal comprehension.* Slightly less uniform but still very commonly found in the packets were KSAs that are reflected in the NAEP framework's cognitive domain *Integrate/Interpret: Make complex inferences within and across texts* (e.g., compare or connect ideas, perspectives, problems, or situations). This is consistent with the information provided in the course syllabi, texts, assignments, and assessments. KSAs that relate to locating or recalling information or integrating and interpreting information are foundational to being able to succeed at work that demands deeper levels of cognitive complexity, which are likely taught in college-level courses.

There are few differences in prerequisites among the courses that incorporate primarily informational texts, suggesting that the list in the Results section may well represent the prerequisite KSAs for such entry-level courses. English literature was the sole course title that relies primarily on literary texts. Within the KSAs represented in the NAEP framework, there were few differences in prerequisites if one allows for expected differences based on whether standards refer to informational or literary texts. A slight difference, however, is in KSAs related to a student's ability to critique or evaluate texts; related KSAs are more commonly considered to be prerequisite in the literary text-dependent course than in the informational text-dependent courses.

Referencing the course artifacts, it was evident to the content reviewers that students are asked to engage with texts in sophisticated ways. This comes through in the KSAs that were determined to be prerequisite but were not a part of the NAEP framework. These non-NAEP additional KSAs included the ability to critique/evaluate the significance of the historical or cultural context of a text or author, analyze both factual and theoretical information in informational text, and discern credibility of a source. Within the NAEP framework, the objective "take different perspectives in relation to a text" also illustrates this conclusion, and was considered a prerequisite KSA across all course titles.

Facility with technology and accessing online resources also arose as a prerequisite KSA for courses with substantial reading demands.

Mathematics Prerequisite KSAs

The majority of the KSAs that were determined to be prerequisite to all the entry-level college mathematics courses included in this study related to objectives in the NAEP framework under the subject area *Number and Operations*. The majority of mathematics course prerequisites, across all courses, were represented within the NAEP framework's *Number and Operations* subject area, specifically the *Number sense*, *Properties of number and operations*, and *Number operation* subtopics. Prerequisite KSAs for precalculus/calculus and college algebra were notably different from the prerequisite KSAs for finite mathematics and statistics. Prerequisite KSAs for precalculus/calculus and college algebra were represented by the objectives within the *Variables, Expressions, and Operations* and *Equations and Inequalities* subtopics of the *Algebra* subject area, whereas there were fewer prerequisite KSAs from these subject areas for statistics and finite mathematics. KSAs related to most of the objectives in the NAEP framework subject areas of *Measurement; Data Analysis, Statistics, and Probability;* and *Geometry* were not commonly determined to be prerequisite to the course titles sampled. However, many KSAs were found in a minority of course packets, which suggests that, although these KSAs may not be consistently prerequisite to entry into these courses, there is a range of prerequisites across course titles and within course titles as they are taught at different institutions.

Several non-NAEP additional KSAs that were not found within the NAEP framework were identified as prerequisites for mathematics courses. The most commonly noted non-NAEP additional KSAs that were found within the artifacts related to use of technology (e.g., calculators, online resources) and the ability to read and communicate in various modes about mathematics.

Research Question 2

How do these prerequisite KSAs compare with the 2009 and 2013 NAEP mathematics and reading frameworks and item pools? The NAEP reading items pools measure content that corresponds fairly well with the prerequisite KSAs developed in this study. The text excerpts in the 2009 and 2013 NAEP reading item pools did not cover the full range of texts necessary to assess all of the KSAs. This limits the ability of the 12th grade reading assessment to capture fully the degree of student preparedness for college courses that require significant amounts of informational text. The NAEP items focus more on the density and complexity of expository, discipline-based text. One explanation of this distinction is that NAEP reading passages are selected based on the criterion that students do not need to have significant prior content knowledge in order to be able to comprehend the passage and answer the questions associated with it.

The NAEP reading framework aligned well with the prerequisite KSAs identified in this study, especially in the cognitive domains of *Locate/Recall* and *Integrate/Interpret*. The prerequisite KSAs reflected less evidence of the need to be able to critique or evaluate when entering the course. This may reflect the fact that these skills are taught and developed more intensively within the college course and, therefore, are not viewed as a prerequisite. The non-NAEP additional KSAs that went beyond the NAEP framework did, however, address the ability to critique and evaluate. The prerequisite KSAs also included the application of knowledge to the real world and the interpretation of information through historical and cultural lenses with close attention to evaluating an author's purpose and potential biases in text.

One challenge that emerged from comparing entry-level college course content to the 12th grade NAEP mathematics framework is that many college courses require or imply mastery of mathematical knowledge and skills that are found in the 8th grade objectives and, occasionally, the 4th grade objectives. Some additional prerequisite KSAs were implied within the NAEP frameworks, and others were explicitly stated in the frameworks for earlier grade levels, but these earlier grade frameworks were not referenced by NAEP experts as they considered the results of this study.

Because the 12th grade framework focuses on the mathematics that is prerequisite mainly to college algebra or calculus courses, it does not identify content needed to be prepared for some other introductory college mathematics courses, including some examined in this study. The framework currently identifies the mathematics that all 12th grade students need to know to pursue a wide variety of potential options after high school. The fact that many of the courses in this study include KSAs that are addressed in the frameworks at lower grades suggests the importance of ensuring that students have thoroughly mastered foundational mathematics content and concepts taught in earlier grades. Whereas the 4th and 8th grade objectives may identify the content and NAEP may test basic understanding, by the time students enter college they need to have mastered this content and these skills at an automatic level. They need strong fluency with the foundational mathematics because the courses examined in this study do not teach this content as new material, nor in many cases do they spend much time, if any, on review. Instead, instructors may assume incoming students are fully capable of employing mathematics they first learned in earlier grades. Student success often hedges on this assumption being true, given that college instructors do not reteach this material.

Course materials suggest that mathematics in entry-level courses appears applied in nature, with an emphasis on real-world problems and mathematical modeling. The entry-level courses analyzed in this study reflect a wider range of uses of mathematics. They are in many cases designed to lead to subsequent courses that begin to develop student ability to apply the mathematics in specific contexts dictated by the nature of the discipline. High school courses, by contrast, are designed to prepare students for a wide range of potential college mathematics courses or are simply not well aligned with college mathematics courses. It may be that NAEP frameworks and items are more general and less applied as a reflection of the more general nature of high school mathematics and the problems students encounter in those classes.

The NAEP framework sets the parameters for what will be included on an assessment; it is not a curriculum framework. For this reason, the NAEP framework will be less likely than a curriculum framework to include the full range of KSAs that are prerequisites to at least some entry-level college courses (e.g., use of calculators, facility in an online environment, ability to solve certain types of problems that require applications to real-world contexts specific to a disciplinary area). This distinction is not unique to the NAEP, but it is important to recognize in the area of mathematics because of the range of courses offered and their connection to the specific academic disciplines in which students will apply the mathematics they take in an entry-level math course.

Research Question 3

How do these prerequisite KSAs compare with previous NAEP preparedness research; i.e., the descriptions of minimal academic preparedness requirements produced in the JSS research? Compared to the JSS college preparedness borderline performance descriptions (BPDs) of KSAs necessary for minimal preparedness in entry-level college courses, prerequisites identified in the current study tend to describe more challenging performance in reading. Mathematics prerequisites appear to be more nuanced in the current study than is evident in the JSS BPD, with prerequisite KSAs differing greatly by mathematics course title.

Reading Prerequisite KSA Comparison With Previous NAEP Preparedness Research

The CCCA prerequisite KSAs describe a depth of understanding and a level of cognitive demand that are beyond those described by the JSS minimum preparedness requirements. The NAEP experts described the relationship between the two descriptions as concentric circles, with the JSS circle completely inside the CCCA circle. They concluded that the CCCA study, with the inclusion of the courses that relied heavily on informational texts as well as those relying primarily on literary texts, resulted in a narrative description that was broader and deeper than the JSS BPD.

The reading prerequisites identified in the current study are more numerous and constitute more higher-order thinking skills than those described by the JSS description of minimal preparedness. The specific NAEP objectives necessary for minimal preparedness from JSS were all subsumed by the prerequisites evident in CCCA course artifacts. For example, the JSS description included *offer evidence in support of*, but not judging, evaluating, and critiquing, which subsumes offering evidence to support a claim.

Mathematics Prerequisite KSA Comparison With Previous NAEP Preparedness Research

The prerequisites identified for precalculus/calculus and college algebra are similar to the JSS description of the KSAs necessary for minimal preparedness for entry-level college mathematics courses. The prerequisites for finite mathematics and statistics, however, require fewer and less cognitively complex KSAs than are described by the JSS description.

The NAEP mathematics experts described the CCCA prerequisites as a subset of the JSS borderline performance description (BPD). They concluded that the JSS BPD was broader than the CCCA prerequisite description for precalculus/calculus. Some of the differences between the JSS and CCCA studies are likely to contribute to the observed differences. For example:

- In the JSS research, the NAEP experts were heavily involved in helping the JSS panelists understand and interpret the NAEP frameworks. In the current study, the NAEP experts were available to answer questions about the NAEP framework but were intentionally less involved because the design called for content experts to classify specific instances of evidence.
- Proportional reasoning and estimation are two big ideas that may not have been apparent to CCCA reviewers. Proportional reasoning is a big idea that undergirds all four mathematics courses. Instructors reflecting on a course

they have taught can see this, but for reviewers looking at course artifacts from a sample of courses taught by others, proportional reasoning may be harder to find.
- Some prerequisites may not appear until weeks into the class, and thus would not be observable in the artifacts selected for analysis in the CCCA study. This may be especially relevant to finite mathematics courses, in which the topics of study are not sequential and where the first chapter of a text may or may not be the best representation of course prerequisites.

Given the differences in evidence, process, and unit of analysis, dissimilarities between studies were expected. This study identified prerequisite KSAs from the evidence contained in college course packets of artifacts. The JSS study identified what minimally prepared college students need to know and be able to do to succeed in entry-level college mathematics courses and courses with substantial reading demands.

Research Question 4

How can these prerequisites inform future NAEP preparedness research? This research question addresses the next steps that arise from the prerequisite KSAs found in this study. The NAEP program of preparedness research includes five major types of studies. The CCCA study relates to Judgmental Standard Setting studies. The type of content analysis conducted for CCCA does not constitute a major strand of research within the preparedness research agenda. However, identifying the KSAs that are necessary for college or career preparation coursework—the coursework students might encounter the year following their performance on the 12th grade NAEP—broadens understanding of the relevance of the 12th grade NAEP with respect to academic preparedness for college. Including a suite of content analyses as a separate category of studies, or expanding the scope of studies currently categorized as Judgmental Standard Setting would be one way to expand the preparedness research agenda to be more inclusive of the questions that should be addressed by the research program overall.

Prerequisites for English literature courses differed from those for the other included courses because English literature included primarily literary texts, while the other courses included only informational texts. A separate study focusing specifically on the prerequisites from a broader set of entry-level college courses might be useful at identifying differences in prerequisites for courses that use a variety of texts and text types. Courses of interest might include mathematics- and graphics-based social science courses, such as economics, and courses that include both fiction and nonfiction, such as humanities, philosophy, or library and information science courses. Focusing on what students need to know to be prepared for all entry-level college courses that require reading and comprehending various forms and types of texts will differentiate the knowledge, skills, and abilities necessary for each. This is a goal consistent with the Governing Board's perspective that reading skills are utilized and necessary in all academic contexts and day-to-day real-world activities, not just required for high grades in English language arts courses. It may also help the NAEP team to determine whether changes in parameters regarding reading passage selections need to be made to capture a wider range of reading skills necessary for entry-level college course success.

An interesting question to consider might be, given the discipline-specific knowledge required in most courses, should a generic reading framework like the current NAEP framework be used for determining the necessary prerequisite KSAs or should frameworks and accompanying assessments be developed that include some measure of subject matter knowledge? An analysis of the various NAEP assessments and an exploration of prerequisite KSAs needed to perform well on those assessments could be an interesting study.

There are course characteristics that may be important to future content analysis studies, including, but not limited to, the following:

- The types of items used for quizzes and exams early in the course. The level of skills required of a multiple choice vs. short answer or constructed-response item would reflect the level of cognitive complexity and expectations for entering students.
- The department providing a course may have a moderate to profound influence on the prerequisite KSAs students will need when they enter the course (e.g., statistics offered by the mathematics department versus the psychology department or calculus offered in business versus mathematics departments).
- The quantitative reasoning skills expected in a full range of entry-level college courses and the alignment of those quantitative reasoning skills to the 4th, 8th, and 12th grade NAEP mathematics frameworks.

Future content analysis studies should present the 12th grade objectives beside the subsumed 8th and 4th grade objectives. Any indication of a 12th grade objective as prerequisite would also identify the corresponding 4th and 8th grade objectives as prerequisite. The mathematics experts suggested that the NAEP framework taken as a whole across grades would provide a better match to the prerequisite KSAs than looking solely at the 12th grade framework. Future research could include a content analysis study using the NAEP frameworks for all grades. Although proficient- or advanced-level performance on the 4th or 8th grade NAEP assessments does not necessarily indicate readiness for postsecondary work, a study of the full NAEP frameworks may result in the development of a preparedness framework that is more inclusive of all prerequisite KSAs.

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