SUGGESTIONS FOR CALIFORNIA COMMUNITY COLLEGE INSTITUTIONAL RESEARCHERS CONDUCTING PREREQUISITE RESEARCH

RESEARCH AND PLANNING GROUP FOR CALIFORNIA COMMUNITY COLLEGES

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theRPgroup
The Research & Planning Group
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The RP Group strives to build a community college culture that views planning, evidence-based decision-making, and institutional effectiveness as integral strategies for student success.

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Introduction

Prerequisites, corequisites and advisories are an integral part of the community college curriculum. They help ensure that students have adequate preparation and the skills needed to succeed in a course. Prerequisites, corequisites and advisories are meant to help boost student retention and success rates, thus maximizing the use of available resources.

Title 5 regulations require that a relationship be demonstrated between a course and its respective prerequisite before implementing a mandatory prerequisite requirement. (Source: Matriculation Evaluation: Phase III Local Research Options (Design 23, Validating Course Prerequisites, p23.1)

Title 5 regulations state:

> 5 CCR § 55003 (d) (2) the prerequisite will assure, consistent with section 55002, that a student has the skills, concepts, and/or information that is presupposed in terms of the course or program for which it is being established, such that a student who has not met the prerequisite is highly unlikely to receive a satisfactory grade in the course (or at least one course within the program) for which the prerequisite is being established;

In 2011, the Board of Governors amended Title 5 regulations to allow California Community College districts to adopt a policy on prerequisite courses allowing the initial imposition of a prerequisite requirement after an analysis using a qualitative research method (content review) rather than a quantitative statistical analysis. The new regulations give districts the discretion of using only content review or using a combination of quantitative and qualitative research methodologies to implement a prerequisite. Quantitative statistical analysis is still required post-implementation to validate the impact of a prerequisite that has been adopted.

Given the changes in Title 5 regulations for prerequisites, this guide organizes and updates materials that researchers can use as a model for their work. The Matriculation Advisory Committee compiled a significant amount of materials outlining various approaches to prerequisite research in the early 1990s. While this work is still largely applicable, this guide seeks to update the materials available in regard to prerequisite research.

This document will use the language for prerequisites knowing that similar approaches apply to corequisites and advisories.

The following section will first provide a research framework for examining prerequisites research. It will then introduce several prerequisite research questions that can be used to guide a discussion on campus. With the research questions as a foundation, background information on the questions and example approaches will be provided. The example approaches point to a series of appendices that provide examples or methodologies that have been used by researchers around the state. Campus researchers can select the methodology that best addresses campus concerns.

Suggested Use for Guide

This guide was written mainly for researchers in their work assisting faculty and others on campus in analyzing the impact of proposed and implemented prerequisites (See Appendix A: Tips for Communicating with Faculty about Prerequisites). It includes a number of appendices that provide examples of how researchers at several different California Community Colleges have supported the prerequisite process. While content review is in the faculty purview of expertise, it is a type of research methodology that institutional researchers may be called upon to provide support for and thus it is important that researchers are familiar with the approach. This guide includes sections on what institutional researchers might consider when assisting faculty with content review research as well when conducting quantitative analyses.

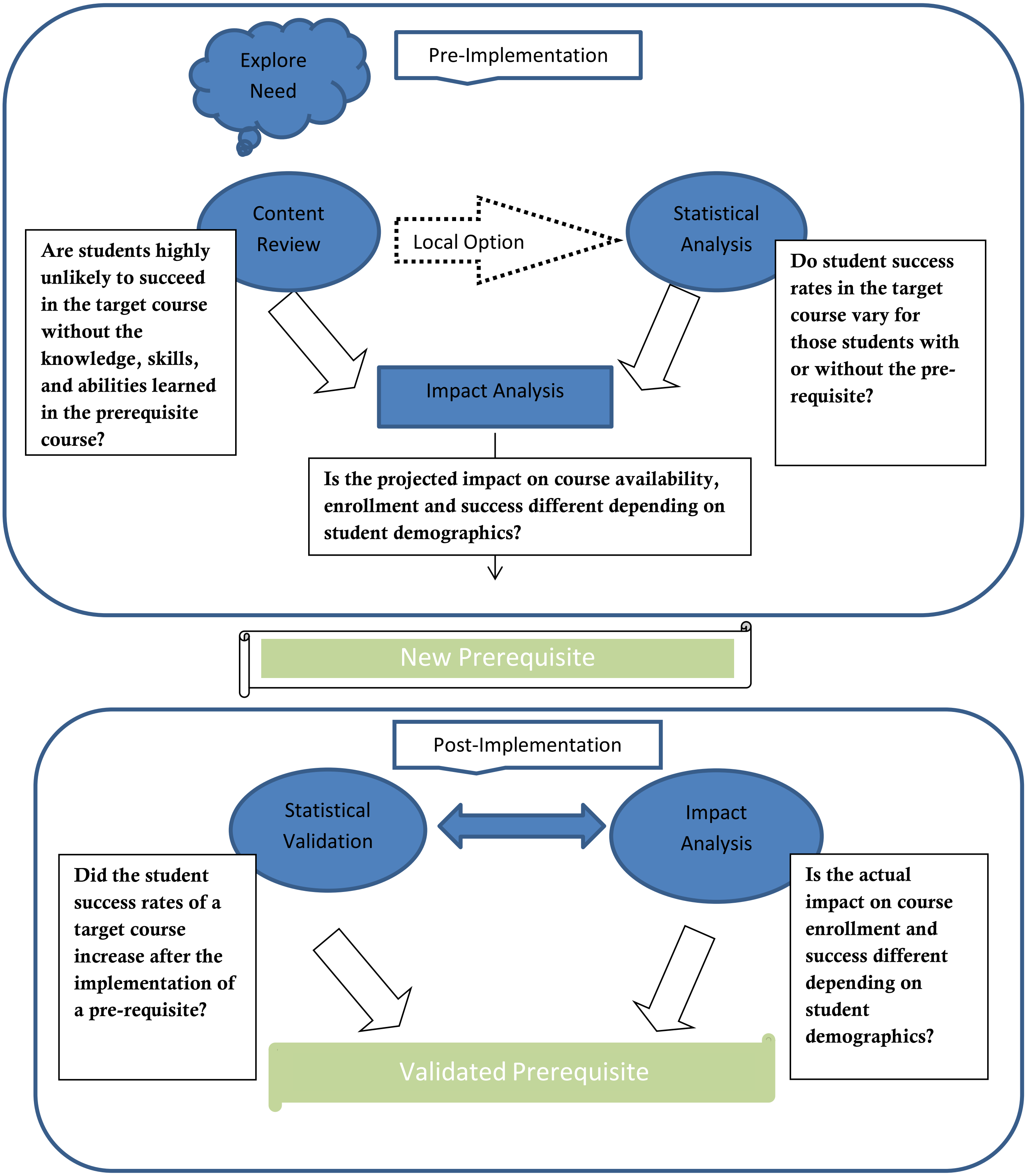
The Prerequisite Research Framework

Figure 1 is a depiction of the research involved in prerequisite selection and validation. The figure includes research questions that might be considered over a six-year period from selection of a prerequisite to the validation of an existing prerequisite. The framework starts with the use of information to explore whether student success might increase if a prerequisite was implemented on selected courses. Once a decision is made to undertake and document an analysis for a particular course, the research shifts to looking at the knowledge needed prior to entering a course. The analysis is driven by local policy and the type of course involved, for example, whether it is a basic skills or vocational course. Prior to implementing a prerequisite, the college should examine evidence of the potential impact of the prerequisite on course availability and the success of students.

After a prerequisite has been in place for a period of time, research shifts to a comparison of success before and after implementation. In this case, the analysis is looking at what has taken place in the past rather than what might happen in the future. The impact on students from different backgrounds and preparations can be compared against baseline data prior to implementation of a prerequisite. The research post-implementation assesses whether the prerequisite has had the intended impact on student success.

The following sections will discuss background and example approaches for each of the research questions in the framework. As a reminder, the first task of any researcher when working with faculty to implement or validate prerequisites is to consult the district/college policies and regulations regarding local college requirements.

Figure 1. The Prerequisite Research Framework *



* Local policy should guide district/campus research practices

Explore Need Prior to Prerequisite Implementation

There are several approaches that can be used to explore the need for prerequisites across the college curriculum. As noted by the Academic Senate, data and other forms of evidence will be useful to discipline faculty as they prioritize which courses to consider for the establishment of new prerequisites. Exploring available information may help to establish trends or patterns of success that may be affected by student preparation for a course (See Implementing Content Review for Communication and Computation Prerequisites, p.8). This information can be used to explore which courses might be targeted for further research.

Prerequisite review involves three primary research questions:

1. **Are students highly unlikely to succeed in the target course without the knowledge, skills, and abilities learned in the prerequisite course?**
2. **Do student success rates in the target course vary for those students with or without the prerequisite?**
3. **Is the projected impact on course availability, enrollment and success different depending on student demographics?**

The first research question is perhaps best answered using a qualitative research methodology such as content review, while the second and third research questions might best be answered using quantitative statistical techniques. Please note that qualitative research methodologies may also include some quantitative or numerical analysis of the information.

Pre-Implementation: Content/Review/Statistical Review/Projected Impact

Content Review Prior to Prerequisite Implementation

Background

Outlined below and in Appendix B is information that might be helpful to answering the research question:

Are students highly unlikely to succeed in the target course without the knowledge, skills, and abilities learned in the prerequisite course?

Content review might be used as a methodology to answer this question. Content review is defined in Title 5 as:

55000 (f) “Content review” means a rigorous, systematic process developed in accordance with sections 53200 to 53204, approved by the Chancellor as part of the district matriculation plan required under section 55510, and that is conducted by faculty to identify the necessary and appropriate body of knowledge or skills students need to possess prior to enrolling in a course, or which students need to acquire through simultaneous enrollment in a corequisite course.

A course prerequisite represents a professional judgment by the institution's faculty that a student's ability to succeed in a particular course is dependent upon possessing certain abilities, skills, and/or knowledge prior to undertaking the course (Danenberg, 2007). In determining course objectives, various assumptions are made about the entering students' abilities, skills, and knowledge. The classification of these assumptions and the validation of a prerequisite require that a systematic process of assessment be undertaken.

Each institution needs to develop a systematic approach that will be manageable for its faculty and staff to conduct a content review. Researchers are often involved in a similar activity when conducting the content validation for placement tests. The need for researchers to assist in the content review process for establishing prerequisites will vary depending on the institution. For instance, the researcher could assist the faculty with the set-up of a scannable form to evaluate the relevance of the course objectives in the proposed prerequisite to the skills necessary to be successful in the target course, summarize the results from the analysis, and/or facilitate a discussion of the meaning of the results.

Example Approaches

Examples for Conducting a Content Analysis can be found in Appendix B: An Illustration of the Steps in Content Review Research which was adapted from Assessment Validation Project: Local Research Options, Design 14, Evaluating Content Validity, February 1991. Appendix B also has some suggestions of research tools that might help, especially, in the comparative analysis needed for matching the knowledge and skills between courses.

Institutional Researchers should also be familiar with "Implementing Content Review for Communication and Computation Prerequisites" (Academic Senate for California Community Colleges, Spring 2011).

Appendix D: Content Review for Computational Prerequisite for Geology Lab provides a good example of the content review process.

Statistical Review Prior to Prerequisite Implementation

Background

Quantitative statistical analysis might be used as a methodology to answer this question:

Do the student success rates in the target course vary for those students with or without the prerequisite?

Prior to implementation, this analysis might be viewed as a projection or estimate of the likely impact of a prerequisite, given that student behavior may change after implementation. The statistical approach gives clear indications of differences in success rates that go beyond casual observation. Outlined below in the limitations section are factors that should be considered when interpreting the results from these analyses.

Example Approaches

Appendix C: An Illustration of the Steps in Conducting Statistical Validity Analysis Prior to Prerequisite Implementation, as well as Appendix F: Examination of Math-101 as a Prerequisite to Geol-1 and Appendix G: Chi Square and T-Test Examples, include examples for conducting statistical analyses. Included are references and links to additional research examples within the appendices. Appendix G provides an overview of two common statistical techniques – Chi Square and the T-Test. These two techniques can be used for both pre- and post-implementation analysis.

Estimating the Enrollment Impact Prior to Prerequisite Implementation

Background

Prior to implementation of a prerequisite, an assessment of the impact on section availability and students should be done. The research question might be:

What is the projected/actual impact on course enrollment disaggregated by student demographic?

Enrollment management considerations are at the forefront of many college planning systems today. It is important to be able to estimate and plan for any reductions that might occur in courses that have prerequisites, while simultaneously anticipating increased demand for prerequisite courses. Students excluded from a course for not having completed the prerequisite will need to enroll in the prerequisite course. Although enrollment may decline in one discipline, there may be higher demand in another as a result. Thus, variation across discipline enrollment levels may not result in an overall change in college enrollment levels (Dannenberg, 2011).

Registration and waiting-list data can be examined to estimate the effect of placing a prerequisite on a course. However, in many colleges, these data may not be readily accessible to researchers and may need to be requested from admissions and records, information technology or instruction. Some colleges do not maintain formal waiting lists, so it will be more difficult for them to accurately estimate "true" demand and enrollment impact. Although students not meeting a prerequisite will be excluded from the course and reduce enrollment, if enrollments and waiting lists are full, it is possible that the enrollment impact may be minimal even if prerequisite courses are also full (Dannenberg, 2011).

Example Approaches

Examples for estimating the enrollment impact of a prerequisite can be found in Appendix E. This appendix shows an example that uses assessment results, enrollment data, and wait list information to estimate how many students might be excluded from instituting an English prerequisite. Appendix E also includes an example that uses wait lists, enrollments, and whether or not the section closed to enrollments in order to estimate the impact of the prerequisite on future enrollments in the target course.

Post-implementation: Statistical Validation / Assessment of Impact

After a prerequisite has been implemented and in place for a period of time, the focus of the research changes from developing an estimate of the impact of a proposed change to enrollment, to a comparison of the results pre and post implementation. The research questions might be:

1. **Did the student success rates of a target course increase after the implementation of a prerequisite?**
2. **Is the actual impact on course enrollment and success different depending on student demographics?**

Statistical Validation to Assess the Impact of a Prerequisite

Background

Outlined below is information that might be helpful to answering the research question: **Did the success rates of a target course increase after the implementation of a prerequisite?**

After the prerequisite has been implemented, it is important to measure the relationship between meeting the prerequisite and student success in the target course. Statistical analysis after prerequisite implementation is required under Title 5.

In addition to examining the relationship between the prerequisite and student success in the target course, disproportionate impact must also be examined. The process for assessing the relationship between meeting the prerequisite and student success in the target course is the same for colleges that implemented the prerequisite based on content analysis and/or statistical validation.

It is recommended that data from at least two primary terms are available when analyzing the impact of the prerequisite on student success in the target course. In courses with low enrollments, it is possible that three or four primary terms of data need to be collected to achieve statistical confidence in the results. The number of primary terms to include in the analysis should be based on the number of students enrolled in the target course and should not be less than 30 students.

Example Approaches

Examples for conducting statistical validity analysis to assess the impact of the prerequisite can be found in Appendix D. This appendix walks the reader through a series of techniques that can be used to validate an existing prerequisite.

Assessment of the Impact of a Prerequisite

Background

The answer to the question:

> **Is the actual impact on course enrollment and success different depending on student demographics?**

Answering this question will provide guidance to the college regarding the impact on enrollment as well as whether any group will be or has been disproportionately impacted. Title 5 defines disproportionate impact as:

> 55502 (d) "Disproportionate impact" occurs when the percentage of persons from a particular racial, ethnic, gender, age or disability group who are directed to a particular service or placement based on an assessment instrument, method, or procedure is significantly different from the representation of that group in the population of persons being assessed, and that discrepancy is not justified by empirical evidence demonstrating that the assessment instrument, method or procedure is a valid and reliable predictor of performance in the relevant educational setting.
>
> 55003 (g) (2) the district establishing the prerequisite or corequisite conducts an evaluation to determine whether the prerequisite or corequisite has a disproportionate impact on particular groups of students described in terms of race, ethnicity, gender, age or disability, as defined by the Chancellor. When there is a disproportionate impact on any such group of students, the district shall, in consultation with the Chancellor, develop and implement a plan setting forth the steps the district will take to correct the disproportionate impact.

Example Approaches

Appendix D from City College of San Francisco provides a post-implementation example. Other examples can be found at Chaffey College and Crafton Hills College.

Other methodologies for conducting disproportionate impact analyses will be available soon from the California Community Colleges Chancellor's Office Student Success & Support Program (formerly Matriculation).

Limitations in Prerequisite Review

Four general problem areas may be encountered by institutions attempting to demonstrate the appropriateness of a prerequisite:

1. The prerequisite course outcome may not be reliable;
2. The content mastery expectation by different instructors in an outcome course may vary so greatly that a relationship cannot be demonstrated with the prerequisite;
3. The difficulty in identifying who has met the prerequisite and the various ways it can be met; and
4. The grading standards among faculty of the outcome course may be inconsistent regardless of content consistency

(Design 23, Validating Course Prerequisites, Matriculation Evaluation: Phase III, Local Research Options, June 1992).

In addition, variations in the degree to which methods of assessment emphasize different skills can influence grades. For example, there may be variability amongst faculty with regards to the percentage of students' grades that are based on writing assignments.

Basic Skills-Related Limitations

As most prerequisites involve English and math, institutions may also face two additional limitations:

1. accuracy and consistency with which basic skills courses are taught and graded, and
2. whether the outcome course required the demonstration of written and computational skills as cited in Title 5.

Different instructors, content, standards and grading practices are part of the educational process which can significantly influence student outcomes. Each of these considerations needs to be reviewed as part of the study (Design 23, Validating Course Prerequisites, Matriculation Evaluation: Phase III, Local Research Options, June 1992).

Other Limitations

Other limitations to consider are:

1. Students are not randomly assigned to classes, they self-select. The assumption of independence is inherent in most statistical approaches. However, with a large enough population (or sample) studied, the random assignment should not matter, especially with very large discrepancies between groups.
2. The pre-implementation analysis assumes that the historical pattern of course taking will continue into the future. However, if a prerequisite is imposed, student behavior may change. Researchers should attempt to look at the changes that have occurred when other prerequisites have been implemented to inform the analysis.

Background Resources

The California Community College Chancellor's Office has issued a new resource to help explain the Title 5 changes, which includes FAQs:

> Guidelines for Title 5 regulations section 55003 policies for prerequisites, corequisites and advisories on recommended preparation. February 2012.
> http://extranet.cccco.edu/Portals/1/AA/Prerequisites/Prerequisites_Guidelines_55003%20Final.pdf

Institutional Researchers should also be familiar with the approach used to validate placement tests. Resources available through the Matriculation division at the California Community College Chancellor's Office include:

- Studies Establishing or Validating Cut-Scores
- Studies Addressing Content-Related Validity
- Studies Monitoring Disproportionate Impact

The Model District Policy on Prerequisites, Corequisites, and Advisories on Recommended Preparation (Model District Policy, Board of Governors, 1993), also outlines considerations for the research analyses involved when establishing or monitoring prerequisites (see II.A.1.g.). http://asccc.org/sites/default/files/MODDIST.pdf

Summary

Sound research starts with the research question and selects the methodology most appropriate for answering that question. Figure 1 described a prerequisite research framework that colleges might consider when examining new or existing prerequisites. As described above and in the appendices, the analytical approach and statistical techniques deployed will depend upon the question being asked. Often there is more than one technique that can be used. Sometimes the results are not clear cut and more research is needed to inform the decision. The best research involves dialogue with those impacted by the results and a willingness to consider multiple information sources and methodologies.

Appendix A: Tips for Communicating with Faculty about Prerequisites

As a reminder, the first task of any researcher when working with faculty to implement or validate prerequisites is to consult the district/college policies and regulations regarding local college requirements or plans for evaluating the need for and implementing prerequisites.

General Tips

1. Ensure that you are cognizant of the local policies and procedures that have been developed by the board, senate and curriculum committee.
2. Focus on the function and role of the steps that have been outlined by your college's policies and practices.
3. Affirm your common interest in supporting and enhancing student success.
4. Affirm that you are there to support and assist faculty.
5. Affirm that the research is not meant to substitute for faculty's professional judgment and that the final decision about whether to implement a prerequisite is up to each department's faculty, the College's curriculum committee, and administration.

If faculty are considering implementing a prerequisite

1. Discuss the general issues regarding prerequisites, which include:
   a. Demonstrating that the prerequisite is reasonably likely to improve student success
   b. Identifying whether any group might be particularly disadvantaged by the implementation of the proposed prerequisite
   c. Identifying any enrollment/access issues that might arise from implementing the prerequisite
   d. Being cognizant of the impact of prerequisite implementation on other programs, which might impose restrictions on the number of units the affected program can require

2. Discuss whether to conduct an initial descriptive study that investigates:
   a. Whether the proposed prerequisite is likely to make a difference in student success
   b. Whether some groups will be impacted more by the proposed prerequisite
   c. Possible impacts on enrollment and access
   d. How this study would be used in the decision-making process

Appendix B: An Illustration of the Steps in Content Review Research

(Adapted from Design 14, Evaluating Content Validity)
http://extranet.cccco.edu/Portals/1/SSSP/Matriculation/Resources/AssessmentValidationProjectLocalResearchOptionsFeb1991.pdf

Step 1: Define entrance expectations in the outcome course.

Assemble a panel of four or more faculty who teach the outcome (or target) course of interest. This group of faculty needs to specify the prerequisite skills necessary for success in the outcome course. It is valuable to reflect on the content of the outcome course and to focus on the skills students will need to possess upon entrance to the outcome course in order to successfully acquire the skills that will be taught. This list should be as comprehensive and specific as possible. The group of faculty needs to be in agreement on the list of skills required.

Step 2: Review variable approaches that might impact the outcomes.

Faculty teaching the outcome course should meet to verify adherence to the course syllabus and to identify their expectations for entrance abilities, skills, and knowledge of students. If faculty teaching the outcome course does not have experience teaching the prerequisite course, faculty teaching the prerequisite course should be involved. Factors to consider during this process include:

1. For each expectation, faculty should be able to identify how it is related to the content of the outcome course.
2. If the prerequisite course is from a discipline outside the outcome course, it is important to involve faculty from the outcome course in the content review to ensure that adequate coverage of the entrance abilities, skills and knowledge are covered in the prerequisite course.
3. If the expectation involves a basic skill, these could be manifested in the reading level of the material, requirements for oral and written presentations, the ability to do basic mathematical operations, term papers, etc.
4. If specific knowledge is a prerequisite, it should be clearly related to the content covered in the course. For example, the ability to fill a syringe, knowledge of the major events in American colonial history, knowledge of chemical reactions when heated or the ability to operate a lathe are needed to be successful in the outcome course.

Step 3: List common expectations.
The faculty teaching the outcome course will need to agree upon a common list of expectations for entering students. For assistance in this activity, Design 14, Evaluating Content Validity, was adapted from the following: *Assessment Validation Project: Local Research Options.* (1991) An example of how content review can be organized using prerequisite math skills needed for a Land Surveying course is illustrated below.

Faculty in the Land Surveying program wanted to establish Intermediate Algebra as a prerequisite course for the Introductory Land Surveying course. For each of the following entering skills, knowledge or abilities needed for the beginning land surveying course (SURV-101) faculty would rate their level of agreement with the statements in Table 1. In assigning their rating they would assess whether there is adequate coverage of the required entrance skills for SURV-101 in the assignments, exams and reading materials within the proposed prerequisite course.

Table 1. Example Rating Template

There is adequate coverage of the following abilities in the course content, exams, assignments, reading materials, etc. (entering skills)	Strongly Disagree	Disagree	Neither Disagree or Agree	Agree	Strongly Agree
Skill 1: Ability to solve radical, quadratic equations.					
Skill 2: Ability to solve logarithmic equations.					
Skill 3: Ability to solve exponential equations.					
Skill 4: Ability to solve a variety of problems by applying the definitions, postulates and theorems of plane geometry.					
Skill 5: Ability to graph linear, quadratic, simple polynomial, exponential logarithmic functions and conic sections.					

Step 4: Establish how the results will be utilized.
Analysis of the data should involve establishing how the results will be utilized. Specifically, faculty need to:

1. Determine what mean rating among those involved in the content review is required to determine that there is adequate coverage and evidence that the skills, knowledge

and abilities are present in the prerequisite or co-requisite course. For example, a mean rating of 4 or higher (Agree or Strongly Agree) might be established as the criterion for determining if the prerequisite or co-requisite course has adequate coverage of the desired entrance skills for the outcome course.

2. Calculate the percent of the desired abilities, knowledge or skills required for successful completion of the course. Determine what percent of the skills must be deemed to be adequately covered for the course to be deemed a valid prerequisite or co-requisite course. For example, the faculty might decide that there be adequate coverage of at least 80 percent of the desired abilities, knowledge or skills in the prerequisite or co-requisite course.

Table 2. Example Data Table

[This example uses fabricated data to illustrate the recommend reporting format.]

Skill	**Rater**					**Mean Rating**
	#1	**#2**	**#3**	**#4**	**#5**	
Skill 1: Ability to solve radical, quadratic equations.	4	3	4	4	4	3.8
Skill 2: Ability to solve logarithmic equations.	4	4	5	4	5	4.4
Skill 3: Ability to solve exponential equations.	3	4	4	5	4	4.0
Skill 4: Ability to solve a variety of problems by applying the definitions, postulates and theorems of plane geometry.	5	4	4	3	5	4.2
Skill 5: Ability to graph linear, quadratic, simple polynomial, exponential logarithmic functions and conic sections.	5	4	5	4	4	4.4

Number of skills with a mean rating of ≥ 4.0: 4
Percent of skills with a mean rating of ≥ 4.0: 80%

Step 5: Discuss the results.

At the conclusion of the process, it is worthwhile for the faculty to discuss their ratings and revise them if appropriate (norming).

Step 6: Document and communicate the results.

Document the results and distribute to the appropriate departments on campus (e.g., curriculum committee, senate, assessment).

Appendix C: An Illustration of the Steps in Conducting Statistical Validity Analysis Prior to Prerequisite Implementation

(Adapted from Design 23, Validating Course Prerequisites)

Matriculation Evaluation: Phase III, Local Research Options, June 1992

Step 1: Identify the subjects to study.

The study should maximize the number of students attempting the outcome course (first attempt) with and without the proposed prerequisite(s). It is very difficult to achieve statistical confidence when you have fewer than 30 students in any of the comparison groups. In the case of small enrollments, an effort should be undertaken to compile data over several primary terms. As long as there have not been changes in the objectives of the prerequisite and/or target courses, the data can be aggregated to provide a sufficient sample size. Students who have met the proposed entrance criteria by other means should be identified as such. In addition, institutions may consider excluding students who have previously completed a college degree.

Step 2: Define student success.

Faculty senates, curriculum committees, and other groups may want to be involved in determining the levels of student success they are attempting to obtain in the outcome course by implementing a prerequisite, recognizing that it may vary across disciplines and at different levels within the college curriculum. Additionally, everyone should agree on what constitutes an acceptable proportion of students who could succeed in the outcome course without the prerequisite course. Each institution needs a working definition of "highly unlikely to obtain a satisfactory grade" and "necessary for success" before beginning the validation process.

Although the collection of empirical data may indicate differences between students with and without prerequisites as significant statistically, it may not be significant on a practical level. One should examine the differences between the groups for educational and practical significance. One guide for using empirical data to advise prerequisite implementation is the "2-to-1 guideline:" at least twice the proportion of students who entered with the prerequisite skill succeed compare to those who did not have this skill. For example, a prerequisite would not be implemented unless success rates for those with the prerequisite were twice as high as those without the prerequisite (e.g., 30% versus 15%). However, colleges may also take into account practical considerations. If resources are limited to support the outcome course, the college might consider instituting a prerequisite if 30% of those with the prerequisite and 20% of those without the prerequisite would succeed. Therefore, each institution needs to develop a definition for "highly unlikely to obtain a satisfactory grade" before starting the validation process. In this example, while 30% of the students with the prerequisite would succeed, 20% without the prerequisite would also succeed. If there are limitations on the resources to offer the outcome course, this might well be sufficient to institute the prerequisite. On the other hand, using the 2-to-1 guideline, the prerequisite would not be required unless the proportion of the excluded group who could succeed was 15% or less. This is an example of why each institution needs to develop a guideline as to their interpretation of "highly unlikely to obtain a satisfactory grade" before starting the validation process.

Step 3: Identify the outcome measure.
The students' grades in the outcome course traditionally have been chosen as the measure of student success. There are other options to measure student success such as midterm grades and instructor ratings of students' readiness for the course. Use of these alternative measures can minimize other factors that contribute toward final grades (e.g., attendance) and also will maintain larger sample sizes by including in the study those students who may withdraw from the course because they did not have the necessary prerequisite skills.

Step 4: Collect the necessary data.
All students attempting the outcome course should be identified. The data gathered might include: outcome measures, relevant prior course completions and/or assessment measures, and additional variables such as gender, ethnicity, age, and disability status, which need to be used in monitoring for disproportionate impact.

Step 5: Analyze the Results.
The data can be analyzed in several ways, including a 2x2 matrix of successful and non-successful comparisons, an experience table comparison, and correlational analysis. There are other statistical techniques that can be used as well that are described in some of the examples in this document.
It is also important to consider practical significance as well as statistical significance when interpreting the results of a prerequisite validation study. Determining the threshold for practical significance is a discussion that needs to occur with the faculty involved.

Step 6: Examine Disproportionate Impact.
Disproportionate impact examines whether the prerequisite differentially impacts students based on race, ethnicity, gender, age, or disability status. Equally important to disproportionate impact is how the prerequisite affects the course success rates of students in the disproportionately impacted groups. The process for examining disproportionate impact and what to do when it exists is described in different ways in forthcoming examples such as the classification and regression tree (CART) modeling used by Chaffey College and differential prediction used by Crafton Hills College.

Step 7: Discuss the Findings with Faculty.

An important aspect of the entire prerequisite validation process is to discuss each component of the process with faculty. Namely, after the findings have been generated from the statistical review, a discussion with faculty needs to occur centering on the meaning of the results and reviewing the options for establishing a prerequisite. For example, perhaps two or more proposed courses are related to success in the target course. The benefits and limitations of implementing a prerequisite should be discussed with faculty (and the administration) to help facilitate the process of choosing an appropriate prerequisite course.

Another Example for Conducting Statistical Validity Analysis Prior to Prerequisite Implementation

The example in the link below examines the use of reading as a prerequisite to an Emergency Medical Technician course. The study includes a description of how the participants were identified for the study, a definition of success and the outcome measure, a description of the data collection process, effect size measurements as indicators of practically significant findings, a description of the process of using the restricted bivariate correlation coefficient to measure course success, and guidelines for interpreting results (Wurtz & Riggs, 2010).

http://www.craftonhills.edu/~/media/Files/SBCCD/CHC/About%20CHC/Research%20and%20Planning/Research%20Reports/0910_EMS_Read_PrerequisiteStudy.ashx

Appendix D: Example for Analyzing the Impact of Prerequisite Post-Implementation

(Adapted from Spurling, 2010, City College of San Francisco)
This analysis was guided by the following research questions:

Post-implementation

1. Once the prerequisite is implemented, is the course success rate higher?
2. What is the racial/age/gender/disability makeup of the course post-implementation compared to pre-implementation?
3. Does the increased success of students in each protected category support the implementation if indeed the distribution of students in each group has changed?
4. What effect did the implementation have on overall course enrollment patterns?
5. Are there sufficient class offerings of the prerequisite course to allow redirected students to it to take it?

Physics 4A is the course at City College of San Francisco defined in the catalog as "Physics for Scientists and Engineers." In Fall 2010, a mandatory prerequisite of completion of first semester calculus was established and enforced in the main computer registration system. Table 1 presents the number of students above and below the prerequisite level both before and after implementation of the prerequisite. A three-semester window excluding summers was used to extract and present sufficient data.

Before the implementation of the prerequisite, 107 (25%) of the 427 total students enrolled in Physics 4A were below the prerequisite level. Post-implementation, no students were below that level. The question of the validity of the prerequisite pre-implementation and its effect post-implementation will be addressed next.

Table 1. Physics 4A: Number of Students At or Above versus Below the Prerequisite Level Pre and Post-Implementation of the Prerequisite in Fall 2010 (Three Semester Window Before and After).

	Implementation		
Prerequisite Level	**Pre**	**Post**	**Total N**
At or Above	320	365	685
Below	107		107
Total N	427	365	792

Validation

One of the main concerns in setting a prerequisite class for another 'target class' is whether students who take it will improve their likelihood of success in the target class. This kind of relationship can be determined using historical data on course success by simply cross-tabulating success versus failure in the target class with prior prerequisite fulfillment by the students in that class. In so doing, one would create a table similar to the one below.

Tables 2. Physics 4A: Pre-Implementation Success in Physics 4A by Fulfillment of the Mathematics Prerequisite (Completion of First Semester Calculus) – Number.

Prerequisite Level	Pass	Fail	Total
At or Above	187	133	320
Below	49	58	107
Total	236	191	427

Tables 3. Physics 4A: Pre-Implementation Success in Physics 4A by Fulfillment of the Mathematics Prerequisite (Completion of First Semester Calculus) – Percentage.

Prerequisite Level	Pass	Fail	Total
At or Above	58%	42%	320
Below	46%	54%	107
Total	55%	45%	427

It should be obvious from Tables 2 and 3 that those students who completed the prerequisite of Calculus-I have a decided advantage in Physics 4A compared to students who had not completed this level; 58% of students at or above the prerequisite passed Physics 4A versus 46% below that level. Two questions arise from this: How strong is the effect of the prerequisite and is the difference statistically significant? In order to answer these questions, let's examine the odds of success in Physics 4A by prerequisite level.

The odds of success of passing Physics 4A for those students at or above the prerequisite level is the percentage passing the course divided by the percentage failing it: 58% divided by 42% = 1.41. For those students below the prerequisite level, the odds of success are 46%

divided by 54% = .84. One can construct an 'Odds Ratio' to see how much more likely it is that students at or above the prerequisite are to succeed compared to those below. That ratio is 1.41/.84 = 1.66. Interestingly, the odds of success is also a cross product[1] that gives the ratio of correct identifications to incorrect ones. That ratio is the product of the percentage of students at or above the prerequisite level who pass the target course multiplied by the percentage of students below the prerequisite level who fail divided by the product of the percentage of students at or above the prerequisite level who fail the target course multiplied by the percentage of students below the prerequisite level who pass. In this example, the equation is (.58)(.54) divided by (.42)(.46) = 1.66. This result of 1.66 shows that using the Calculus I prerequisite improved admission or placement into Physics 4A by 66 percent.

Note that when prerequisite level is independent of success in the target class, the odds ratio is 1.0. This ratio would signify that the odds of success at or above the prerequisite level is the same as the odds of success below it. As the odds ratio increases above one or decreases below one, both the strength of association and the likelihood of its statistical significance increase.

The remaining issue involves calculating the statistical significance of the odds ratio. An acceptable way to do this is outlined by Agresti (1992). This author recommends, first, calculating the natural log of the odds ratio: log(1.66) = .51. Next, determine the asymptotic standard error of the log odds ratio using the following formula:

Asymptotic standard error (log(odds ratio)) = ((1/ N (Below Prereq Fail)) + (1/ N (At or Above Prereq Fail) + (1/ N (Below Prereq Pass) + (1/ N (At or Above Prereq Pass)) $^{(1/2)}$

$$(\log(1.66)) = (1/58 + 1/133 + 1/49 + 1/187)^{(1/2)}$$

$$= .22$$

The researcher can then calculate the 95% confidence interval using the formula log odds +/- standard error (significant z-distribution), which equates to .51 +/- .22(1.96), or .07 - .95) in this example. Since these values are logarithms, they need to be transformed back into the original estimates to be meaningful. This can be accomplished by expressing them as exponents of the base e, $e^{.07}$,$e^{.95}$ = 1.07 - 2.58). Since this interval does not include 1, which is the value of the odds ratio when passing and failing Physics 4A is independent of prerequisite level, we can conclude that the association between prerequisite fulfillment and success is statistically significant (Agresti, 1996, p.24).

The Effect on Success Post-Implementation

The same statistical approach can be used to examine the effect of the prerequisite from pre- to post-implementation. Table 3 has the number and percent of students who passed and failed Physics 4A pre- and post-implementation of the prerequisite in fall 2010.

[1] Agresti, Alan. 1996. An Introduction to Categorical Data Analysis. John Wiley and Sons, New York.

Table 4. The Overall Passing Rate in Physics 4A Pre- and Post-Implementation of the Calculus I Prerequisite - Number

Implementation	Pass	Fail	Total
Post	237	128	365
Pre	236	191	427
Total	473	319	792

Table 5. The Overall Passing Rate in Physics 4A Pre- and Post-Implementation of the Calculus I Prerequisite - Percent

Implementation	Pass	Fail	Total
Post	65%	35%	365
Pre	55%	45%	427
Total	60%	40%	792

Once again, it is apparent from the tables that success in Physics 4A is higher post-implementation of the prerequisite than pre-implementation. Post-implementation, the passing rate is 65% versus 55% pre-implementation. To address the question of magnitude of the effect and statistical significance, we will follow the same process as before.

The odds of success post-implementation were 65% divided by 35% = 1.85 versus 55% divided by 45% = 1.24 pre-implementation. The odds ratio is 1.85/1.24 = 1.50.
The asymptotic standard error is…

$$= (1/237+ 1/236 + 1/128 + 1/191)^{(1/2)}$$
$$= .147$$

…and the 95% confidence interval is the natural log(1.5) +/- 1.96(.147) = (.12,.69).
Converting these logs back into the original odds ratio gives $(e^{.12}, e^{.69})$ = (1.12,2.00). As with the prior example, because the interval does not include 1.0, we can conclude that implementation of the prerequisite had a positive impact on course success.

The Highly Unlikely to Succeed Criteria
Enshrined in the Title 5 mandate is the qualification that "a student who has not met the requirement is highly unlikely to receive a satisfactory grade in the course." In the above Physics 4A example, the question is whether those students who were restricted from entrance into the course post-implementation were highly unlikely to succeed. While those below the prerequisite had a passing rate of 46%, the question arises if this rate satisfies the highly unlikely to succeed requirement.

This issue has been raised by other researchers. Spicer[2] suggests a two-to-one ratio guideline for prerequisite implementation. He further recommends that at least two-thirds of the students at or above the prerequisite level should pass the target course versus one-third or fewer below the prerequisite level. As an odds ratio this would equal:

<u>.66/.33</u> = 2.0 .33/.66

Borden[3] takes a different approach but recognizes that "what we really need is an agreed upon yardstick (or rule) for determining what constitutes 'highly unlikely' to succeed" (p.9). He suggests using the Equal Employment Opportunity Commission's (EEOC) 80% rule. This compares the access rate of historically underrepresented groups to those of the following reference groups: males, White students, students' ages 18 to 24 years, and students without disabilities. Evidence of disproportionate impact exists for any group with a ratio of less than 80 percent. In the Physics 4A example, the ratio of success for those with and without the prerequisite is 46% divided by 58% = 78%.

Comparing the two criteria leads to different conclusions. Given that Spicer recommends an odds ratio of 2.0, the calculated odds ratio of 1.66 would be too low to recommend prerequisite implementation. Given Borden's 80% criteria, the calculated ratio of successful students at or above the prerequisite to successful students below the prerequisite versus below of 78% would be sufficient to recommend prerequisite implementation. These authors suggest, first, a minimum passing rate for those students below the prerequisite level under 50% and a minimum passing rate of students at or above the prerequisite above 50%. Second, the passing rate of students at or above the prerequisite should be statistically significantly higher than that of students below the prerequisite. This recommendation is more lax than either Spicer's or Borden's and should be regarded as the absolute minimum criteria for prerequisite implementation.

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[2] Spicer, Scott. 1989. "Monograph on Design 6. History Course Success Based on English Eligibility." In Matriculation location Research Options Project: California Community Colleges, Sacramento (editors, Marty Dunlap et al).

[3] Borden, Richard. 2002. "Validation of English 1A as a Prerequisite for Psychology 1A." Planning and Research Office, Cabrillo College.

Disproportionate Impact

Title 5 regulations require that colleges "conduct an evaluation to determine the impact on student success including whether the prerequisite or co-requisite has a disproportionate impact on particular groups of students described in terms of race, ethnicity, gender, age or disability." (Title 5 §55003). The first part of this requirement was addressed earlier in the Physics 4A example, where it was found that overall student success increased in Physics 4A after implementation of the prerequisite. In this section, we will examine disproportionate impact by student groups.

Disproportionate impact involves two pieces, as it is defined by the state Chancellor's Office. First, the makeup of students (ethnicity, race, age, gender, disability) who are admitted to a course must be substantially different from the makeup of students seeking entrance to that course for disproportionate impact to be considered an issue. Second, observed differences in the makeup of students enrolled and seeking entry must not be justifiable by empirical evidence that the assessment instrument, method, or procedure is a valid and reliable predictor of performance in the relevant educational setting. We will examine disproportionate impact on racial/ethnic groups in Physics 4A by observing the association of target course success by prerequisite level for each racial/ethnic category. We then calculate an odds ratio (success/fail) for each category and compare. If we find that the odds ratios are similar for each category we can assume an absence of disproportionate impact.

Table 6 provides an example of a disproportionate impact analysis using the Physics 4A example at City College of San Francisco.

Table 6. The number of students with .5 added to each cell[4] in Physics 4A by Success and Prerequisite level for Each Race/Ethnicity Category.

Race/Ethnicity	Prerequisite	Pass	Fail	Odds Ratio
African American/Non Hispanic	Above	2.5	1.5	5.00
	Below	0.5	1.5	
Asian	Above	101.5	69.5	1.61
	Below	29.5	32.5	
Filipino	Above	6.5	13.5	1.06
	Below	2.5	5.5	
Hispanic/Latino	Above	11.5	18.5	11.81
	Below	0.5	9.5	
Other Non White	Above	5.5	4.5	0.41
	Below	1.5	0.5	
South East Asian	Above	15.5	5.5	0.56
	Below	2.5	0.5	
Unknown/No Response	Above	17.5	11.5	2.74
	Below	2.5	4.5	
White Non Hispanic	Above	30.5	12.5	1.36
	Below	13.5	7.5	

Interestingly, by examining the odds ratios it would appear that the relationship between prerequisite level and success in Physics 4A is strongest for African-American and Latino/a students and weakest for Other Non-White and Southeast Asian students. That is, prerequisite level best identifies African-American and Latino/a students who will be successful. However, the despite the apparent differences, we need to statistically test the hypothesis that the odds ratios are homogeneous across ethnicity/race categories. The calculation is complex and is best done using specialized software. The relevant statistic is the Breslow-Day statistic and can be calculated using Proc Freq in SAS. This statistic is appropriately used when 80% or more of cells have n's of 5 or more. That is not the case here. Nonetheless, for purposes of illustration the Breslow-Day statistic = 6.92, with df equal to 7 and $p = .43$. As $p > .05$, we can reject the null hypothesis that odds ratios differ by racial/ethnic category (Agresti, pg 63), hence, we can conclude that the data do not point to disproportionate impact.

There is nonetheless the question of whether the race/ethnicity makeup of students in Physics 4A changed as a result of the implementation of the prerequisite. That question is addressed in Table 7.

[4] Agresti, page 60.

Table 7. The Makeup of the Student Population in Physics 4A pre and post-implementation.

Race/Ethnicity	Pre	Post	% Change in N
African American/Non Hispanic	4	7	175%
American Indian/Alaskan Native	0	1	
Asian	231	173	-75%
Filipino	26	16	-62%
Hispanic/Latino	38	44	116%
Other Non White	10	3	-30%
South East Asian	22	13	-59%
Unknown/No Response	34	28	-82%
White Non Hispanic	62	80	129%
Total N	427	365	-85%

From the table, it is evident that there have been sizeable changes in the makeup of the population not the least of which is a 15% decrease in total enrollment. The largest increases in population from pre- to post-implementation are evident among African-American, White and Latino/a students. The largest decreases in population from pre- to post-implementation are evident among Other Non-White, Southeast Asian, Filipino and Asian students.

One last question regarding disproportionate impact is whether changes in the odds of success from pre- to post-implementation justify these observed racial/ethnic changes. Table 8 presents data that address this question. Odds ratios were again calculated, this time by racial/ethnic category to compare target course success of students' pre- and post-prerequisite implementation. When reading the table, if the odds of success pre- to post-implementation vary significantly by racial/ethnic category, we can conclude that there has been disproportionate impact. To test whether the odds ratios are different between racial/ethnic categories, we will once again calculate the Breslow-Day statistic. The Breslow-Day Statistic in this case is 5.8 with 6 degrees of freedom. The significance level is .44, which is not significant, thus, we can conclude that changes in success rates in the target course pre- to post-prerequisite implementation are not significantly different by racial/ethnic group.

Table 8. Changes in the Odds of Success Pre- to Post-Implementation of the Prerequisite by Race/Ethnicity.[5]

Race/Ethnicity	Implementation	Pass	Fail	Odds Ratio
African American/Non Hispanic	Post	7	3	3.50
	Pre	2	3	
Asian	Post	121	55	1.73
	Pre	132	104	
Filipino	Post	5	14	0.68
	Pre	10	19	
Hispanic/Latino	Post	24	23	2.35
	Pre	12	27	
Southeast Asian	Post	10	3	0.98
	Pre	17	5	
Unknown/No Response	Post	21	10	1.66
	Pre	19	15	
White Non Hispanic	Post	52	30	0.94
	Pre	48	26	

Another Example for Analyzing the Impact of Prerequisite Post-Implementation

This example is from Chaffey College and examines the impact of reading as a prerequisite to World History: Pre-Civilization to 1500, World History: 1500 to Present, and History of the Middle East (Fillpot, 2011). The example describes the process for setting up the database, measures the relationship between successful completion of the prerequisite and target course success using bivariate correlation coefficients correcting for restricted range, utilizes an effect size metric to determine the practical significance of the relationship between successful completion of the prerequisite and target course success, and employs segmentation modeling to analyze disproportionate impact.

http://www.chaffey.edu/research/IR_PDF_Files/Research_Reports/Academic_Success/1011-History%201,%202,%20and%207%20Reading%20Prerequisite%20Validation.pdf

5 Race/Ethnicity categories with very small cell counts have been removed.

Appendix E: Two Examples of How to Estimate the Enrollment Impact of a Prerequisite

(Adapted from Methodological and Data Considerations for a Communication or Computation Prerequisite Implementation Study (2011), Anne Danenberg, M.A., Sacramento City College)

Example #1

Scenarios can be simulated using known data to estimate unknown impact. A recent example from a CCC campus with approximately 25,000 unduplicated headcount is provided below. Assume that the research question is:

> How many students would be excluded from enrolling in the target course if a prerequisite were instituted?

The majority of students for whom we have preparation level data have transfer-level English preparation level. Table 1 reviews the distribution of preparation levels and forms the basis for scenarios in this section.

Table 1. Student Preparation Levels

PREPARATION LEVELS	Number	Percent
Students with Transfer level English	661	57.5
Students with 1 level below Transfer English	304	26.5
Students with 2 levels below Transfer English	129	11.2
Students with 3 levels below Transfer English	45	3.9
Students with 4 levels below Transfer English	10	0.9
TOTAL Students with prior preparation data	1,149	100.0

Table 2 lists the numbers and percentages of students who would be excluded if the prerequisite were implemented at each of the four English writing course levels, including only students with known preparation levels. The number excluded is obtained by summing the numbers across the levels below a hypothetical prerequisite.

Table 2. Excluded Students under Prerequisite Implementation (2009 *known* data)

If the Prerequisite Were:	Number Excluded (known prep)	Percentage of Total Sample Excluded (n=1149)
Transfer Level English	488	42.5
1 level below Transfer English	184	16.0
2 levels below Transfer English	55	4.8
3 levels below Transfer English	10	0.9

Note: table excludes data for the 620 students for whom preparation data are missing.

We could simply stop after examining the numbers of students for whom we have preparation level data and subtracting those who would be excluded under a prerequisite rule. However, that will understate the numbers substantially because there are 620 students with missing preparation levels. We can proceed by assuming that the students with missing data have a distribution of preparation level similar to students for whom we have data. However, the number of students with missing preparation data presents a problem in this analysis, because 620 students is a substantial proportion of the total sample—over 35 percent—and an assumption that the distribution of preparation levels for students without data is similar to those with data may be flawed. Students with missing data may have adequate but *undemonstrated or unmeasured* preparation levels, either because they took English writing elsewhere or because they are taking the target course before they assess for or take English writing at the current institution.

By applying the *known distribution* of preparation level to the *unknown* data in the next table, we attempt to approximate the extent of an exclusionary effect more closely. Note that although the numbers of expected exclusions increase from those in the table above, the percentages do not, because we apply the same distribution of preparation levels to the unknown data as to the known data.

Table 3. Excluded Students under Prerequisite Implementation (2009 *known* and imputed unknown data)

If the Prerequisite Were:	Number Excluded (known prep)	Number Excluded (missing prep assumption)	Expected Number Excluded (combined)	Expected Percentage of Total Sample Excluded (n=1769)
Transfer Level English	488	263	751	42.5
1 level below Transfer English	184	99	283	16.0
2 levels below Transfer English	55	30	85	4.8
3 levels below Transfer English	10	6	16	0.9

Clearly, based on 2009 data, establishing a prerequisite of transfer-level English writing would have excluded over 40% of students who enrolled—more students than is easily defensible for an open-access institution. Another scenario would be to apply the assumptions above to Fall 2011 data and the current scarce supply-high demand situation, taking into account both enrollments ***and*** wait-listed registrations.

An analysis looked at the Fall 2011 combined target course registrations and wait-lists as of early July 2011. Overall enrollment was at maximum capacity—approximately 1,400—down from around 1,800 in 2009. Combined wait-lists were at their 650 capacity (no 2009 comparison data available). In fact, the target course was at capacity ten days before the "open registration" date for new students.

The table below simulates how many students would be excluded at each prerequisite level, assuming that the students who were registered and on waiting lists in 2011 have a similar distribution of preparation levels as the students who enrolled in Fall 2009. Essentially, we are asking if there would be enough wait-listed students with the prerequisite to fill the course after the students without the prerequisite are removed. We apply the known 2009 preparation distribution to the enrollments and wait-lists to get approximate numbers of students at each preparation level. As above, we tally the number of students, who would be excluded at each prerequisite, replacing some of the excluded students with those on wait-lists that we assume will meet the prerequisite. Adding 647 wait-listed to 1,401 enrolled yields the denominator of 2,048 used for the percentage calculation. This time, the percentages of excluded students at all levels are substantially lower—and only 5.9% would be excluded if the prerequisite were at 1 level below transfer English.

Table 4. Estimated Numbers and Percentages of Students Excluded after Prerequisite Implementation (2011 data)

If the Prerequisite Were:	Expected Number Excluded (assumption)	Expected Number Replaced (from waitlist)	Net Expected Excluded (A)-(B)	Expected Percentage of Total Sample Excluded (n=2048)
Transfer Level English	595	275	320	15.6
1 level below Transfer English	224	103	121	5.9
2 levels below Transfer English	67	31	36	1.8
3 levels below Transfer English	12	6	6	0.3

Although this estimate is imperfect, it is probably a reasonable scenario, given the information available. The analysis and results presented in Table 4 illustrate the importance of considering wait-listed students when estimating the percentage of students who would be denied access to the target course.

<u>Example #2 -</u>
Estimating Enrollment Impact of Prerequisite using Wait Lists
Estimating the Impact of the Calculus Prerequisite on Physics Enrollments

(Adapted from Steve Spurling, City College of San Francisco, Prerequisite Validation, Disproportionate Impact and the Effect of the Institution of the Prerequisite on Student Enrollment and Success)

Title 5 regulation section 55003 requires that colleges ensure that the prerequisite courses required to teach the required skills are reasonably available. While the focus is on pre-collegiate courses, for purposes of illustration, the availability of Calculus I will be determined over the pre- and post-implementation timeframe.

Table 5. The Percent of Students Closed or Wait Listed in Calculus I in the Three Semesters Pre and Post Implementation of the Prerequisite for Physics 4A.[6]

Implementation	Waitlisted or Closed Percent	Term	Year	Total	Registered	Registration n-Drop	Waitlisted	Closed Section
Pre	24%	Spring	2009	777	500	48	187	0
	27%	Fall	2009	848	556	30	216	16
	30%	Spring	2010	878	507	57	261	4
Post	31%	Fall	2010	876	555	21	265	3
	26%	Spring	2011	956	582	51	250	3
	34%	Fall	2011	966	537	51	322	7

The percent of students attempting to register for Calculus I who are wait listed or closed out of the course ranges from a low of 24% of the registration attempts in spring 2009 to a high of 34% in fall 2011. One would have to conclude that this course is not reasonably available as required by section 55003 of Title 5. It was not sufficiently available pre-implementation and the situation is worse post-implementation.

[6] Small numbers of additional outcomes have been excluded from this table so numbers do not add up to total.

Appendix F: Examination of Math-101 as a Prerequisite to Geol-1

(Adapted from Fresno City College's Office of Institutional Research, Assessment, and Planning, January 2012)

Sample

One thousand two hundred twenty two students (n=1,222) made their first attempt in GEOL-1 and earned a grade on record during Fall 2008, Spring 2009, Fall 2009, Spring 2010, Fall 2010, and Spring 2011. Of those, 657 (54%) students were successful. To meet the proposed prerequisite, students must successfully complete Math-101 or be placed into Math 103 or higher prior to taking GEOL-1. Among the total 1,222 students in the sample, 514 (42%) of them met the prerequisite.

Methodology

Comparison of Performance in the Target Course of Students Who Did and Did Not Meet the Prerequisite:

Using the RP Group definitions that have been adopted by the Chancellor's Office, the FCC Office of Institutional Research, Assessment, and Planning used student data to initially identify all students who earned a grade on record (A, B, C, CR, D, F, FW, NC, I, or W) in the target course, GEOL-1, for Fall 2008, Spring 2009, Fall 2009, Spring 2010, Fall 2010, and Spring 2011. While a student may have taken the target course multiple times, for purposes of prerequisite validation, only the first attempt in the target course was examined. Further coding was created to identify students who were successful (earned an A, B, C, or P or CR grade) or unsuccessful (earned a grade of D, F, FW, NC, I, or W) in the target course. Successful grades were divided by total grades earned on record to compute success rate.

Once this step was completed, course outcomes for students who successfully completed the prerequisite course, or tested at an equivalent math assessment level prior to completing GEOL-1 were merged into the target course file. For prerequisite courses, the best attempt (i.e., the highest grade earned in the prerequisite course) was identified and merged into the target file. Using the aforementioned definitions, a student was identified as having met the prerequisite if he/she earned a successful grade on record in the prerequisite course or the student earned a sufficiently high placement recommendation on the assessment test. Conversely, students who did not meet the prerequisite were identified as students who: a) did not take the prerequisite course; b) the highest grade earned on record in the prerequisite courses was a non-successful grade; or c) did not score at an equivalent level on the assessment test.

Once the target course outcome of prerequisite completers and non-completers was identified, the Office of Institutional Research, Assessment, and Planning conducted independent samples of the t-test and chi-square test to determine whether statistically significant differences in target course outcome existed between prerequisite completers and non-completers. This study will examine the overall success rates and grades in the target courses, the success rates and grades of students who met the prerequisites, the success rates of students who did not meet the prerequisites, the percentage of students in the target courses who met the prerequisite, and whether the success rates of completers/non-completers were identified as statistically significantly different ($p < .05$).

Effect Size and Average Percent Gain

Recognizing that statistically significant differences are often an artifact of sample size (with large samples, only minimal differences can produce statistically significant results; conversely, with small samples large outcome differences may not be identified as statistically significantly different), effect size and average percent gain were also examined. In essence, effect size measures the strength of a relationship between two variables, controlling for the influence of sample size.

Since t-tests were initially used to explore whether statistically significant differences existed between prerequisite completers and non-completers, the logical measure employed by the Office of Institutional Research, Assessment, and Planning to determine effect size was Cohen's *d*. Cohen's *d* is defined as the difference between the two means divided by the pooled standard deviation for the two means. Obtaining basic statistical data about the populations in question (means and standard deviations) researchers can easily calculate effect size. While interpretations vary, the most commonly accepted interpretations suggest that a *d* of 0.20 indicates a small effect, 0.50 a medium effect, and 0.80 or higher a large effect. Recognizing the difficulty in identifying a relationship between two variables in a quasi-experimental environment like post-secondary education, for the purposes of the current study, sufficient evidence was considered to exist if an effect size of 0.20 or higher was observed.

Correlation Coefficient

Correlation coefficients are another method of examining the strength of a relationship between two variables. For the purposes of the current study, researchers employed what is probably the most frequently used correlation coefficient, Pearson's Product Moment Correlation Coefficient, more commonly known as Pearson's *r*. Pearson's *r* employed in the current study examined the relationship between performance in the prerequisite course and performance in the target course. Again, recognizing the quasi-experimental nature of post-secondary education, the Chancellor's Office has established a rule of thumb for obtaining what are considered to be valid correlation coefficients. While usually considered a moderate association, the Chancellor's Office has established a positive correlation coefficient of .35 as sufficient evidence that a relationship exists between a prerequisite course and a target course, assuming that $p < .05$.

Appropriateness of Prerequisites:

Three measures were examined between prerequisite completers and non-completers:

1. GPA in GEOL-1
2. Success rate in GEOL-1
3. Correlations between GEOL-1 GPA and Math-101 GPA

Following is the summary of the results.

GPA in GEOL-1

Table 1. Grades in GEOL-1

	Successfully Completed Math-101 or Higher	Did Not Successfully Completed Math-101 or Higher
A	85	58
B	125	99
C	129	161
D	43	58
F	70	198
W	62	134
Total	**514**	**708**
Mean GPA	**1.98**	**1.28**
T-Value	**8.542**	
Sig (P-value)	**0.000**	
Cohen's *d*	**0.50**	

To determine if student's GPA in GEOL-1 is significantly different by the two groups, a t-test of independent groups was performed. Data indicated that students who successfully completed Math 101 had a statistically significantly higher GPA in GEOL-1 than those who did not complete Math 101 ($p<0.001$). The effect size was 0.50 indicating a sufficient impact on success if students successfully completed Math-101 prior to enrolling in GEOL-1.

Success Rate in GEOL-1

Table 2. Success Rate in GEOL-1

	Completed Prerequisite Math-101 or Higher		Total
	Yes	No	
Successful	**339**	**318**	**657**
Unsuccessful	**175**	**390**	**565**
	514	**708**	**1222**
Success Rate	66%	45%	54%

Chi-square = 53.023, df =1, p=0.000

To determine if student's success rate in GEOL-1 is significantly different by the two groups, a chi-square test was performed. Data showed that students who successfully completed Math-101 or higher had a statistically significantly (p = .000) higher success rate (65%) in GEOL-1 than students who did not successfully complete Math-101 (45%). The current GEOL-1 success rate is 54% and would increase to 66% with Math-101 as a prerequisite (an 11% increase).

Correlations between GEOL-1 GPA and Math-101 GPA

Table 3. Correlations between GEOL-1 GPA and Math-101 GPA

		Math-101 GPA	GEOL-1 GPA
Math-101 GPA	Pearson Correlation	1	**.365****
	Sig. (2-tailed)		.000
	N	1221	151
GEOL-1 GPA	Pearson Correlation	**.365****	1
	Sig. (2-tailed)	.000	
	N	151	151

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's *r* employed in the current study examined the relationship between performance in the prerequisite course (Math-101) and performance in the target course (GEOL-1). The Chancellor's Office has established a positive correlation coefficient of .35 as sufficient evidence that a relationship exists between a prerequisite course and a target course, assuming that $p < .05$. Pearson's *r* was 0.365 for this study, indicating sufficient evidence that a relationship exists between the performance in Math-101 and performance in GEOL-1.

Conclusion

For the current prerequisite validation study, three measures were examined in the target class GEOL-1: GPA in GEOL-1, success rate, and correlation between grades in target class and prerequisite class. T-test, chi-square, and correlation analysis were performed. All three measures were statistically significant and met the Chancellor's Office established criteria. Therefore, it is concluded that sufficient evidence exists to enforce Math-101 as a prerequisite of GEOL-1.

Disproportionate Impact Analysis

To examine whether a disproportionate impact existed, data were generated for prerequisite course/target course combination. The last column in the following tables ("Disproportionate Impact") identify whether a disproportionate impact was observed ("Yes" if disproportionate impact was observed).

Table 4. Disproportionate Impact by Age

Age	Completed Math-101 or higher		Total	% of Completed Math-101	Disproportionate impact
	YES	NO			
19 or Younger	98	243	341	29%	YES
20-24	309	328	637	49%	49%*80%=39%
25-29	59	77	136	43%	NO
30-34	16	27	43	37%	YES
35-39	13	8	21	62%	Sample too small
40-49	15	18	33	45%	NO
50+	4	7	11	36%	Sample too small
Total	514	708	1222	42%	

Chi-square = 39.908, df =6, p=0.000 (significant at p<.05)

Table 5. Disproportionate Impact by Ethnicity

Ethnicity	Completed Math-101 or higher		Total	% of Completed Math-101	Disproportionate impact
	YES	NO			
African-American/non-Hispanic	32	47	79	41%	NO
American Indian/Alaskan Native	2	7	9	22%	NO
Asian/Pacific Islander	94	94	188	50%	
Hispanic	203	273	476	43%	NO
Race/ethnicity unknown	37	66	103	36%	NO
White/non-Hispanic	146	221	367	40%	NO
Total	514	708	1222	42%	

Chi-square = 8.836, df =5, p= 0.116 (not significant at p<.05)

Table 6. Disproportionate Impact by Gender

	Completed Math-101 or higher		Total	% of Completed Math-101	Disproportionate impact
	YES	NO			
Female	223	314	537	42%	NO
Male	239	390	679	43%	NO
Unknown	2	4	6	33%	
Total	514	708	1222	42%	

Chi-square = .224, df =2, p= 0.894, (not significant at p<.05)

Table 7. Disproportionate Impact by Disability

DSPS	Completed Math-101 or higher		Total	% of Completed Math-101	Disproportionate impact
	YES	NO			
NOT DSPS	494	664	1158	43%	NO
DSPS	20	44	64	31%	NO
Total	518	704	1222	42%	

Chi-square = 3.24, df =1, p= 0.072, (not significant at p<.05)

<u>Results on Disproportionate Impact</u>

Tables 4 to 7 in the previous pages identify the disproportionate impact when Math-101 is the prerequisite for GEOL-1.

Chi-square tests revealed there is a significant difference between age groups. Overall, 42% of students who enter GEOL-1 successfully complete the Math-101 prerequisite. However, 29% of students age 19 years or younger who entered GEOL-1, successfully completed the Math-101 prerequisite. Conversely, 49% of students age 20-24 years (the majority group) who entered GEOL-1, successfully completed the Math-101 prerequisite. When applying the 80% rule, 49%*80%=39%. According to Glasnapp and Poggio's (2001) 80% rule, any group which falls below 39% indicates a disproportionate impact. Table 4 shows that two groups (19 or younger and 30-34) fell below 39%. **This finding represents an observed disproportionate impact by age.**

Chi-square tests indicated no statistical differences between groups by ethnicity, gender, and/or disability; therefore, no observed disproportionate impact exists by ethnicity, gender, and/or disability.

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Appendix G: Chi Square and T-Test Examples

(Adapted from Katherine McLain, Cosumnes River College)

Using Chi Square to evaluate the potential benefit and/or impact of the proposed prerequisite

Basic Definitions and Assumptions

Chi-square is a statistic that can be used to determine whether or not one variable (e.g., success in a target class) is independent of another variable (e.g., completion of prerequisite course).

Success can be measured in a variety of ways such as receiving a passing (A, B, C, or P) midterm or final grade, or at some other milestone that makes sense given the nature of the target and prerequisite courses. Some discussion should occur about whether students who receive Ws should be included as non-successful grades in the study.

Assumptions

- In general, there should be at least 30 students who have completed the prerequisite course and 30 students who have not completed the prerequisite course. In addition, the cell sizes should each be at least 5.
- It is assumed that teaching methods have stayed fairly consistent over the course of the study and that the enrollment of students in the prerequisite and target classes are random.
- If a student has taken a target class multiple times, only their first enrollment results are included in the study.

Overview of the Test

When conducting the chi-square test, you will represent the data using a 2 x 2 matrix of the following form:

Table 1. Chi-square 2 X 2 Matrix Example

Completed Designated Prerequisite	Non-Success in Target Class	Success in Target Class
Yes	Number with prerequisite who are not successful	Number with prerequisite who are successful
No	Number without the prerequisite who are not successful	Number without the prerequisite who are successful

The assumption here is that there is no difference in course success rates in the target class based on completion or non-completion of the designated prerequisite course. The chi-square test will give you a value for chi square and a related p value. These values measure whether any differences you observe in course success (for completers versus non-completers) are significant. If the chi-square is relatively small and the p value is relatively large (generally greater than or equal to .01) the differences you observe are not significant. However, if chi-square is relatively large and the p value is small en7ough (generally less than .01) then you will conclude that the observed differences in course success (for completers versus non-completers) are statistically significant.

Example: Let the following represents the data collected from two semesters (to ensure assumptions are met):

Table 2. Chi-square 2 X 2 Matrix with Sample Data

Completed Designated Prerequisite	Non-Success in Target Class	Success in Target Class
Yes	20 (36%)	35 (64%)
No	30 (66%)	15 (34%)

It would appear that course success is different depending on whether a student has completed the designated prerequisite. A calculation gives chi-square = 9.091 and p = .003. Since $p < .01$, we can conclude that the difference in success rates in the target class based on completion or non-completion of the designated pre-requisite is statistically significant.

Notes and caveats

If a designated prerequisite contains multiple criteria joined with an "and" then each prerequisite course needs to be investigated separately. If a designated prerequisite contains multiple criteria joined with an "or" then completion of the prerequisite should include students who have completed one or both of the courses.

Although the chi-square test can indicate whether the observed differences in success in the target class are statistically significant, it does not firmly establish a relationship between completion of a designated prerequisite and success in a target class. You may wish to augment your chi-square test with a Pearson Correlation test comparing the GPA of the students in the study in the designated prerequisite course with their GPA in the target course. If r is sufficiently large (greater than or equal to .35) and p is sufficiently small, you can conclude that there is a correlation between completion of the prerequisite course and success in the target course.

Since large or small sample sizes can impact the validity of statistical test, you may also want to conduct a t-test comparing the GPA of the students in the target class who have successfully completed the designated prerequisite with the GPA of the students in the target class who have not successfully completed the designated prerequisite. If the t value is relatively large and the p value is relatively small, and the Cohen's d test indicates that the effect size is sufficiently large (greater than or equal to .5), you can conclude that completion of the prerequisite has a significant impact on success in the target class.

Using a t-test to evaluate the potential benefit and/or impact of the proposed prerequisite

Basic Definitions and Assumptions

The t-test can be used to determine whether the average of two samples is statistically different. To use the t-test to evaluate the potential benefit/impact of a prerequisite we will compare the GPA in the target class of students who completed the designated prerequisite with students who did not complete the designated prerequisite.

Assumptions

- In general, there should be at least 30 students who have completed the prerequisite course and 30 students who have not completed the prerequisite course.
- It is assumed that teaching methods have stayed fairly consistent over the course of the study and that the enrollments of student in the prerequisite and target classes are random.
- It is assumed that the distribution of the grades for each population is normal and the variances in each population are the same.
- It is assumed that the groups of students who have and who have not completed the prerequisite are independent.
- If a student has taken a target class multiple times, only their first enrollment results are included in the study.

Overview of the Test

In order to use the t test to investigate the impact of a prerequisite, you will need to collect grades of all students in the target class at some designated point in the semester. You will then need to divide these students into two groups – the group of students who completed the designated prerequisite and the group of students who did not complete the designated prerequisite. Some discussion should occur about whether students who receive Ws should be included in the study. In addition, P/NP grades will need to be converted to letter grades.

The assumption here is that there is no difference between the GPAs of each group. After calculating the averages for each group, you use the averages to compute the t-test statistic and the related p value. These values measure whether any differences you observe in course GPA (for students who completed the prerequisite versus students who did not complete the prerequisite) are significant. If the t value relatively small and the p value is relatively large (generally greater than or equal to .01) the differences you observe are not significant. However, if t value is relatively large and the p value relatively small (generally less than .01) you will conclude that the observed difference in average GPA (for prerequisite completers versus prerequisite non-completers) is statistically significant.

Example: Let the following represent the data for a class

Table 3. Using T-Test to Investigate the Impact of a Prerequisite (Course, Grade, GPA)

Grade in the Target Course	Number of students who completed the designated prerequisite	Number of students who did not complete the prerequisite
A	49	26
B	60	58
C	69	81
D	21	32
F	32	100
W	20	77
N	*251*	*374*
Course GPA	*2.13*	*1.26*

It would appear that target course GPA is different depending on whether a student has completed the designated prerequisite. A calculation gives $t = 7.746$ and $p < .0001$. This means we can conclude that the difference in the target course GPA based on completion or non-completion of the designated prerequisite is statistically significant.

Notes and caveats:
If a designated prerequisite contains multiple criteria joined with an "and" then each prerequisite course needs to be investigated separately. If a designated prerequisite contains multiple criteria joined with an "or" then completion of the prerequisite should include students who have completed one or both of the courses.

Although the t test can indicate whether the observed differences in target class GPA are statistically significant, it does not firmly establish a relationship between completion of a designated prerequisite and success in a target class. You may wish to augment your t-test with a Pearson Correlation test comparing the GPA of the students in the study in the designated prerequisite course with their GPA in the target course. If r is sufficiently large (greater than or equal to .35) and p is sufficiently small, you can conclude that there is a correlation between completion of the prerequisite course and success in the target course.

Since large or small sample sizes can impact the validity of statistical tests you may also want to conduct a Cohen's d test to assess the strength of your finding. If $d > .5$, you can be reasonably confident about your conclusion about the observed differences.

Glossary of Terms

Advisories – a condition of enrollment that a student is advised, but not required, to meet before or in conjunction with enrollment in a course or educational program.

Content Review – a rigorous, systematic process that is conducted by a faculty-driven committee charged with identifying the necessary and appropriate body of knowledge or skills students need to possess prior to enrolling in a course, or which students need to acquire through simultaneous enrollment in a co-requisite course. Content Review has the following elements:

1. Careful review of the course outline of record
2. Review of syllabi, sample exams, assignments, instructional materials, grading criteria for the target course, student learning outcomes (SLOs), required and recommended reading, essay requirements and other assignments as needed to evaluate the appropriateness of the prerequisite course being proposed.
3. Direct involvement of the discipline faculty
4. Using the course outline of record, identification of required skills/knowledge students must have prior to enrolling in the target course AND matching those skills/knowledge to the proposed prerequisite course(s).

Content Review with Statistical Validation - content review (as defined in subdivision (c) of section 55000) accompanied by compilation and analysis of data according to sound research practices to determine the likelihood that a student will succeed in the target course given that he/she has met the proposed prerequisite or co-requisite.

Corequisite - a condition of enrollment consisting of a course that a student is required to enroll in simultaneously with a target course.

Disproportionate Impact – occurs when the percentage of persons from a particular racial, ethnic, gender, age or disability group who are directed to a particular service or placement based on an assessment instrument, method, or procedure is significantly different from the representation of that group in the population of all persons being assessed. For observed differences to be considered an issue, they must not be justified by empirical evidence demonstrating that the assessment instrument, method or procedure is a valid and reliable predictor of performance in the relevant educational setting [CCR §55502(d)].

Educational Program - an organized sequence of courses leading to a defined objective, a degree, a certificate, a diploma, a license, or transfer to another institution of higher education.

Evidence Based on Test Content - the degree to which all the accumulated evidence supports the intended interpretation of a test.

Health and Safety Mandated Prerequisites – deemed necessary to protect the health or safety of students or others.

Mixed-Methods - the use of both qualitative and quantitative techniques.

Necessary and Appropriate (as it relates to Content Review) - means that a strong rational basis exists for concluding that a prerequisite or corequisite is reasonably needed to achieve the purpose that it purports to serve. This standard does not require absolute necessity.

Prerequisite – refers to a condition of enrollment that a student is required to meet in order to demonstrate current readiness for enrollment in a course or educational program.

Proposed Prerequisite - the course that is being examined as a possible requirement prior to enrolling in the target course.

Target Course - the course being examined to increase success through the establishment of a prerequisite requirement.

Sequence of Courses – courses within a discipline that may or may not be sequential in number, but that have sequential skills needed to be successful as students' progress through the sequence.

Statistical Review – differs from statistical validation. It is a process in which researchers compare historical data to justify a prerequisite or to determine recommended action on review and revisions of prerequisites, corequisites and advisories.

Statistical Validity – the degree to which results can be relied upon and are not attributed to random error.

Student Success – completion of a course with a letter grade of P (CR), C, B, or A. In addition, in prerequisite validation studies, mid-term or end-of-term grades may be used.

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