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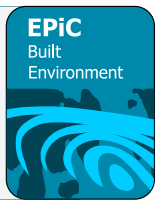

Case Study: Development and Implementation of a Programmable Assessment Matrix

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Abstract

This research details the design and implementation of a programmable assessment matrix that helps educational institutions coordinate their programs for assessment missions. The assessment matrix was developed and applied to support the accreditation of the Construction Management program recently developed at the University of Wyoming. It is organized in a x-y axis format where users can archive and review required assessment documentation over time including grades, instructor's evaluation, course evaluation feedback (indirect assessment), and student work (direct assessment). Observations such as simplicity of reviewing information for each course and holistic display of the curriculum are recurrent advantages identified by instructors and administrators in the program, which led to course and curriculum reviews on a semester-by-semester basis. Drawbacks pertaining to the sophistication of the matrix can be solved by working alongside with computer programming personnel and developing a tutorial video. A utility function of the matrix demonstrated that students not always have an accurate perception of understanding of a specific Student Learning Outcome, which prompted modifications to the course curriculum and assessment surveys. The assessment matrix can be used to enhance any academic program in its accreditation mission.

1 Introduction

Thousands of students dedicate their academic careers to a specific field of study in hopes of acquiring the skills necessary to find successful employment after graduation. Such employment can be based on the composition and measurement of a well-developed degree program. A well-developed degree program should provide evidence of multiple aspects of a student's learning experience, including but not limited to how the student was recruited and admitted to the university and specific program, the cost of study, currency, relevance, and rigor they receive during their

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academic journey. Educational institutions, through the programs they offer, serve a public purpose, and should keep themselves accountable on the quality of education students receive. Various learning commissions and accreditation entities establish guidelines in how to effectively evaluate institutions and their programs on learning; however, benchmarked guidelines can fall short of a quality education. The goal established by learning commissions and accreditation entities is to encourage and impose assessment guidelines to comply with federal and industry standards. Therefore, the purpose of accreditation assessment (to demonstrate students' learning quality based on measurable outcomes according to the stipulations of an accreditation entity) is essential in the continuous improvement of learning which should reflect the involvement of faculty at all levels of learning and the evaluation of ancillary activities. Accreditation assessment should be well grounded in measured evidence of learning through a peer-review process based on high standards to advance the quality of learning. Education institutions and programs, which engage in accreditation assessments, are given the freedom to provide evidence of measures suitable to their unique structure. Thus, accreditation assessment takes on various blueprints that can be a daunting experience to administrators and accreditation reviewers. This research details the development and implementation of a programmable assessment matrix which can be customized to help support educational institutions and programs in their assessment missions. The design of the matrix was prompted by the lack of a customizable assessment platform available to education institutions and programs in their pursuit towards a successful accreditation experience and outcome.

2 Literature Review

2.1 Problem

Literature shows that many higher education institutions and programs in the country meet the requirements stipulated by accreditation entities; however, a lot of them struggle to illustrate a clear representation of the curriculum and measure of learning when requested by those bodies (Tingerthal et al., 2012). The focus of this literature review is to provide support on the need for a programmable assessment matrix capable of illustrating a clear representation of program (ongoing process of gathering information and measuring outcomes for the program as a whole) and student assessment (ongoing process of evaluating students' individual abilities).

The challenge for educational institutions and programs to demonstrate clear representation of their curricula is prevalent across already accredited and new programs seeking accreditation (Veltri et al., 2012; Leathem, 2018; Wijngaards-de Meij & Merx, 2018). In most cases, the documentation to satisfy the needs for accreditation are only archived for institution officials, but not organized nor displayed intelligibly for third parties like accreditation entities (Badiru et al., 2010). Often, programs and curricula designs are simply listed independently without any connections to visualization of the progress in terms of Student Learning Outcomes (SLOs) (Felder & Brent, 2003).

Previous research on assessment matrix platforms has been conducted by Felder & Brent (2003) and Rodriguez-Marek et al. (2008) for accreditation purposes in Accreditation Board for Engineering and Technology (ABET). In their research, the assessment matrix was used to organize the association between courses (rows) and learning outcomes (columns) based on a weighted system (low, medium, or high). Likewise, additional graphical displays to organize Construction Management curricula were proposed by Tingerthal et al. (2012). One of the graphical approaches is to list the courses of the curriculum in a flowchart. This allows students and observers to see the course of study in a time-ordered manner by showing the predecessors and successors of each course. A float-space graphic was also proposed to cope with the unfamiliarity of industry advisory on the format of course design. Additionally, a tree format graphic was introduced to facilitate the

association of an SLO to a course without losing perspective of the program. This format not only highlights the learning outcomes for each course but also illustrates the effect of the respective learning outcomes at the program level. Despite the efficiency and simplification of these approaches, their respective assessment platforms do not allow storage of data which may fall short for purposes of accreditation. Thus, a solution for the above shortcomings is to develop a programmable and interactive assessment matrix that allows the storage of data in a methodological sequence over time.

2.2 Applied Fields like Construction

The challenge to comply with accreditation requirements is especially true in applied fields of study like Construction Management. This is the discipline which provided the motivation for the development of a programmable assessment matrix that is steering the focus of this study.

With the expansion of the construction sector, the need to succeed in the construction profession is no longer the same as required in the past. According to reports solicited from the construction industry, construction professions not only require a strong technical foundation of construction skills but also demand other competencies such as leadership, collaboration, creativity, and problem-solving skills (Ahn et al., 2012). As a result, accreditation entities such as ABET, and the American Council for Construction Education (ACCE) are stipulating accreditation guidelines to institutions and Construction Management programs in order to ensure that these competencies are taught in academia. Also, achieving accreditation status is an assurance of the quality of education in a program, its administration, marketing, finance, accounting, and other factors (Arditi & Polat, 2010). The accreditation process encompasses a plethora of planning, implementation and tracking of student learning progress over time and therefore, requires a systematic method to organize the program.

An assessment matrix constitutes to a unifying framework in support of program development and continuous assessment tracking and has the ability to integrate the organization of SLOs relative to each course offered in a program. It contrasts with traditional assessment platforms that lack standardized methodology for collecting and analyzing large amount of data associated with assessment collection and data processing (Mason & Dragovich, 2010). Thus far, no research on an assessment matrix has been conducted for the accreditation of Construction Management programs by ACCE. Understanding the need for a well-developed accreditation matrix, the College of Engineering at the University of Wyoming has developed a programmable assessment matrix that is capable of integrating the organization of the twenty ACCE SLOs to each course offered in the program through a single interface platform.

2.3 ACCE to Bloom's

Accreditation requirements for already accredited and new programs need to record SLOs, which are translated as skills, knowledge, and behaviors that students are expected to acquire over the course of the program (Anwar & Richards, 2018). In support of this requirement, ACCE formally approved an assessment cluster based on different SLOs. Students who graduate with a Bachelor of Science in Construction Management degree from an ACCE accredited program must demonstrate the ability to execute all twenty SLOs (Mehany & Gebken, 2017). ACCE, in collaboration with industry practitioners and construction educators, adopted the "Bloom's Taxonomy of Educational Objectives" (shortened to Bloom's Taxonomy) as a valid benchmark of measuring the different levels of learning and understanding. The Bloom's Taxonomy divides student learning and understanding into six levels of cognitive domains. Each level increases in complexity in the following order as demonstrated in Figure 1: Remember (lowest), Understand, Apply, Analyze, Evaluate, and Create (highest) (Dymond et al., 2020).

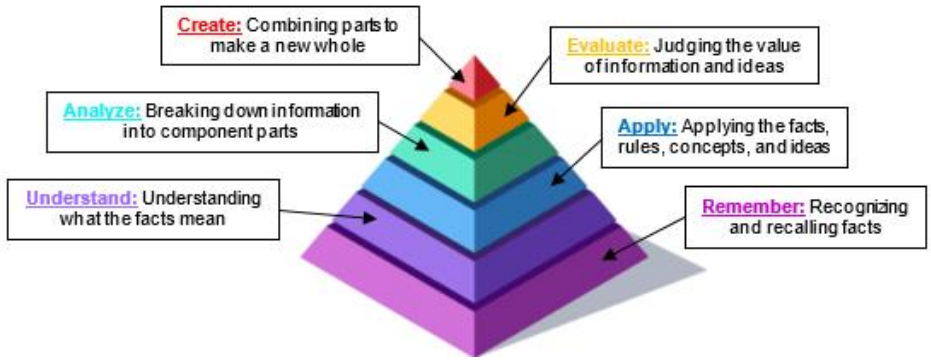

Figure 1: Bloom's Taxonomy in classifying student learning and understanding into six levels of cognitive domains in order of complexity and specificity

The Bloom's Taxonomy suggests that educators should strive to guide their students to the higher levels of the taxonomy, if possible. Regardless the mechanism, a successful assessment platform must provide some measure of how much students are learning with respect to the required SLO (Mason & Dragovich, 2010). A framework for such implementation is to require instructors to include course specific SLOs in every class (Dymond et al., 2020). To assess the effectiveness of a class, successful programs often use a variety of learning assessment schemes, which include indirect measurements such as surveys (where opinions of the students are asked), and direct measurements such as tests and homework (where the performance of the students is evaluated) (Bai & Pigott, 2004). These learning assessment schemes should be analyzed and displayed in an integrated fashion through an assessment platform like a programmable assessment matrix.

3 Programmable Assessment Matrix

The Civil and Architectural Engineering and Construction Management (CAECM) department in the College of Engineering at the University of Wyoming has committed to the development of a four-year Bachelor of Science in Construction Management degree program and to steer the program towards full national accreditation status by the ACCE in 2022 upon graduation of its first senior class. The development of this degree program is intended to eliminate the shortage of a qualified construction workforce in the state. The development and implementation of this degree program required academic administrators to identify and integrate, a total of 40 classes over a four-year period that equates to 120 academic credits needed to fulfill the requirements for a bachelor's degree. Ancillary to the development and implementation of the course work is the integration of a continuous assessment plan that should be capable of measuring the learning and teaching performances of students and instructors towards achieving their respective educational goals. This prompted the program to develop a programmable assessment matrix.

The main interface of the matrix is organized as a mapping between the twenty ACCE SLOs on the y-axis and the Construction Management courses on the x-axis, in which the SLOs are integrated, taught, and measured across all the courses in the program. The matrix was developed through the utilization of C# and JSX programming languages.

The assessment matrix allows users to customize the addition and removal of any course, as well as the order by which they are displayed, preferably in sequence of freshman, sophomore, junior, and senior status. Besides the required Construction Management courses, additional courses in Math and Science, Business, University required, and optional electives courses are also listed across the x-axis.

The programmable uploading function keeps record of course changes over time. For each course, the matrix requires instructors to upload the corresponding syllabus and instructor's evaluation. On the matrix platform, it also requires the instructors to upload the students' feedback data about the course (indirect assessment) and students' work (direct assessment) so that all these documents can be later accessed and visualized in original and full format. This information is important especially to administrators and instructors in support of continued program and course improvements. With the interactive features of this assessment matrix, the display is not restrained by problems related to space, unlike existing mapping platforms, whose interface is either too populated or too simplified. Course evaluations and assessment data on non-construction courses are not uploaded in the matrix. On the y-axis, the twenty SLOs are displayed in different colors, corresponding to the different levels of learning according to the Bloom's Taxonomy pyramid that is displayed at the top left corner of the matrix. The Bloom's Taxonomy pyramid is interactive by providing users with a description of specific student learning measures at each level. The different functionalities of the matrix are illustrated in Figure 2.

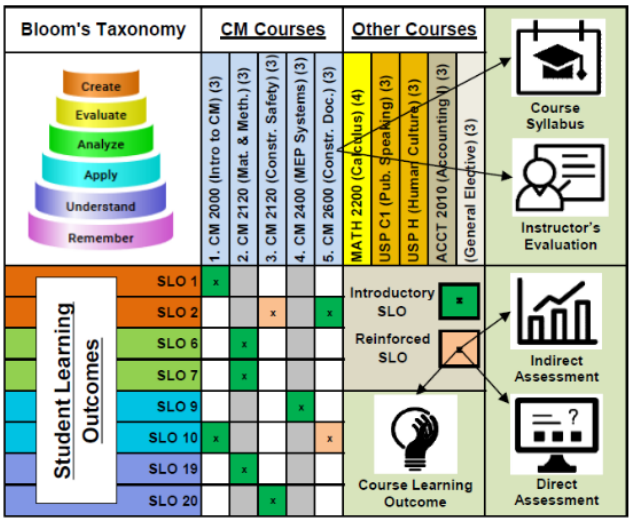

Figure 2: Different functionalities of the assessment matrix (Course Syllabus, Instructor's Evaluation, Indirect Assessment, Direct Assessment, SLOs, and Course Learning Outcomes)

For each of the twenty SLOs, corresponding Course Learning Outcomes (CLOs) were defined as part of the ACCE accreditation requirement. These CLOs were determined by IAB (Industry Advisory Board) members who provided an extensive list of skills, knowledge, and behaviors that they believe would be beneficial for students to learn before entering to the construction industry. The list of CLOs was narrowed down to three per SLO, by allowing instructors to extrapolate upon the listed three CLOs if see fit.

The matrix utility allows users to view the three corresponding CLOs if they press on any one of the listed SLOs. Each of the SLOs with its three corresponding CLOs are integrated across the construction courses taught in the program and reflected on all course syllabi. Each of the twenty program SLOs are first introduced in a course (where students are introduced to the concepts) and then reinforced in an advanced course (where students are tested on the concepts). This sequence is indicated in green (introduced) and in salmon (reinforced) across the matrix. The matrix has the ability to rack assessment data (direct and indirect assessments) associated with each listed SLOs over time by clicking on the interception cells. This utility provides users with access to student work (art effects including exams, quizzes, and projects) as well as indirect assessment data (pre- and post-course survey data) by administering a Qualtrics survey on student's perception of learning in all

courses. The pre- and post-course survey data is illustrated in a bar chart for every time a course is taught (Figure 3). It is expected that at the end of a semester (after), there would be an increase in the students' learning perception as compared to the beginning of a semester (before). This difference (Δ) on the students' learning perception is indicated on the matrix in a graphic representation. Additionally, the instructor's evaluation can be extracted from each course. In this document, observations regarding to the positive and negative aspects of the class based on the perception of the instructor are included as well as the class grade distribution for each SLO.

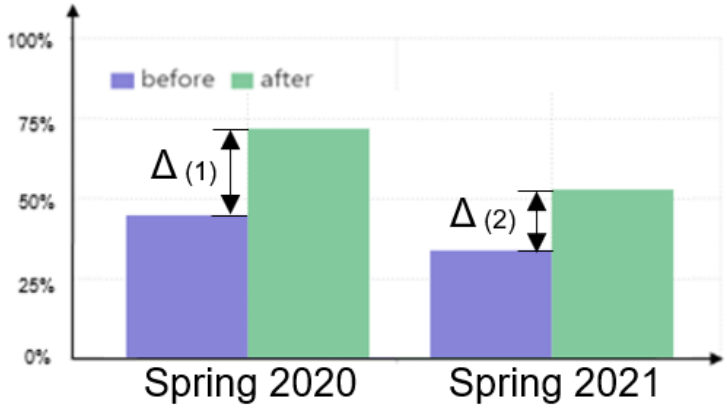

Figure 3: Difference (Δ) between results of an SLO obtained at the beginning and end of the semester for different semesters

4 Results

The functionalities of the assessment matrix were evaluated based on feedback collected from professors and administrators responsible for the Construction Management program at the University of Wyoming for the semesters of Spring 2020, Fall 2020, and Spring 2021. The feedback was obtained during the end-of-semester assessment meetings, where all faculty in the program provided their input on the course their taught. Besides discussing topics on student learning and potential improvements to the courses, their general viewpoint about the matrix was also inquired.

It was reported that two of the most notable benefits of the matrix are its ability to the display the big picture of the curriculum and its simplicity in reviewing all documents associated to each course. These benefits not only allowed the instructors to prepare for the organization of successive courses by revisiting the existing syllabi and art effects for the precedent courses, but also helped administrators to make appropriate changes and improvements on the already taught courses for the following years based on the students' learning perception (indirect assessment) and the instructor's evaluation feedback. Other advantages include the orderly organization of program information, customization of the courses and SLOs, and mutual understanding of the curriculum by different parties involved across the program.

In this program, the holistic matrix display allowed administrators to develop a visual understanding of the student learning experience in the program. This understanding helped in the development of appropriate electives to potentially enhance the current curriculum framework. For instance, two elective courses (CM 3140: Build Environment Market and CM 3230: Construction Economics) were added to the program as students' feedback in previous courses showed an interest in learning more about topics regarding to real estate and construction finance.

In addition, the matrix further highlighted a need to increase student contact hours of the CM 3200: Statics and Structural Systems based on pre- and post-course survey results and instructor's feedback obtained in Fall 2020. Assessment evidence revealed that students had some difficulty in the course especially with reference to SLO 19 (Understand the basic principles of structural behavior) since the average grade for this SLO was only 80% in contrast to the average grade in the class (84%). In addition, the course pre- and post-course survey data showed that there was only a 16% increase in the students' learning perception from before and after taking the course, which is relatively lower than the average (20%) among all reinforced SLOs across the program. As a result of these observations, the program decided to attribute an additional credit to the course and prompted the instructor to make modifications to the course syllabus with specific reference to SLO 19 the next time the course is taught in Fall 2021.

Despite the advantages detailed above, some challenges were encountered during the implementation of the matrix. Due to the sophistication of programming languages used to develop the matrix, only people with expertise in C# and JSX computer languages can troubleshoot bugs and correct malfunctions on the platform. Additionally, because the program is in constant improvement, the personnel with computer language expertise would need to work alongside with the administrators to continuously update the curriculum. Another challenge that the administrators came across was the initial course population of the matrix. Unlike a simplified Excel spreadsheet, a new user would need some guidance to fully understand the different functionalities. In solving this problem, a tutorial video was developed which explains the step-by-step procedure in how to build a curriculum using this assessment matrix.

A more specific problem surfaced where students sometimes do not have an accurate perception of their level of understanding of a specific SLO. In the pre-course surveys administered to students on a Likert scale between 1 (very little) and 5 (very high), an overestimation was frequently observed. This observation was found in many courses where students selected the option 5 even before taking the course. It was also found that several students were not cooperative in this assessment as they spent little time taking the survey before submitting it. These challenges were addressed by removing potentially erroneous data (e.g., students that selected option 5 in all the questions, students who took less than 10 seconds to complete the survey, etc.) before populating the matrix. Moreover, with the intent to collect more accurate results, the survey Likert scale between 1 and 5 was replaced by a scale line that ranges between 0 and 100, where students are required to physically engage in reporting their results by dragging the indicator to the option that corresponds to their learning perception (instead of just clicking on an option in a limited scale).

5 Conclusions and Future Research

Construction Management programs that seek accreditation are required to prepare a self-evaluation study which details information relative to the institution, curriculum, student policies, financial resources, industry among others, to demonstrate full accreditation compliance. Many higher education institutions in the country meet the requirements stipulated by accreditation entities like ACCE; however, most institutions and programs struggle to illustrate a clear representation of their curriculum and measure of learning as requested by accreditation entities.

This research paid attention to the above shortcoming through the development of a programmable assessment matrix that is capable of supporting the measures of learning in a methodological sequence over time, in order to comply with accreditation requirements and standards. To clearly illustrate the curriculum, the main interface of the assessment matrix is organized as a mapping between the ACCE SLOs on the y-axis and the Construction Management courses on the x-axis where syllabi and instructor's evaluation are archived. On the interception cells between SLOs and

courses, student art effects (direct assessment) and students' learning perception data (indirect assessment) are stored so that improvements on the program can be made based on these results.

According to the feedback received, the holistic display of the matrix and simplicity in having access to the course documentation are the most significant benefits identified by the instructors and administrators responsible for the Construction Management program at the University of Wyoming. However, due to the sophistication of the matrix, personnel with computer programming skills would be required to work alongside with the program administrators to make potential updates. In addition, the development of a tutorial video would be essential to guide new users in populating the matrix. Furthermore, a utility function of the matrix showed that students not always have the most accurate perception of their understanding in a specific SLO. As result, solutions to solve this problem include the removal of erroneous data and modification of the Likert scale from 1 to 5 to a 0 to 100 scale line that requires students to physically drag the indicator to the option that corresponds to their learning perception. A summary table with the advantages, disadvantages, and proposed solutions for the disadvantages are shown in Table 1.

Advantages	Disadvantages	Solutions
- Holistic display - Easy revision of documentation	- Requires computer programming expertise	- Work with personnel with programming expertise
- Orderly organization	- Sophisticated functionalities	- Development of a tutorial video
- Customizable - Easily understood by different parties	- Students' inaccurate perception on SLOs	- Removal of erroneous data; modifications on the survey

Table 1: Advantages, disadvantages, and solutions for the disadvantages on the use of the assessment matrix

For future research, more updates will be made based on the suggestions provided by the accreditors during the ACCE accreditation site visit for the Bachelor of Science in Construction Management degree program at the University of Wyoming that will take place in Spring 2022. Additionally, several other ACCE Construction Management programs in candidate status expressed an interest in using the programmable assessment matrix to help organize their curricula. Thus, a website is being developed through which all participating programs can access their respective matrix platforms, with a tutorial video that shows all the functionalities and support contact information. With anticipated minor adjustments, the universal interface platform can contour the specific needs of other academic programs such as nursing, engineering, and music. In fact, plans were already made to use the assessment matrix to organize a Civil and Architectural Engineering program accredited by ABET. In sum, the matrix design and implementation can be viewed as ongoing in nature in providing academic institutions and programs with a formalized assessment platform, which is essential in support of continuous improvement as required by the different accreditation entities.

References

Ahn, Y. H., Pierce, A. R., & Kwon, H. (2012). Key competencies for U.S. construction graduates: industry perspective. Journal of Professional Issues in Engineering Education and Practice, 138(2), 123-130.

Anwar, A. A, & Richards, D. J. (2018). Comparison of EC and ABET accreditation criteria. Journal of Professional Issues in Engineering Education and Practice, 144(3), 06018001.

Arditi, D., & Polat, G. (2010). Graduate education in construction management. Journal of Professional Issues in Engineering Education and Practice, 136(3), 175-179.

Badiru, A. B., Slagley, J. M., & Smith, D. A. (2010). Project management application for engineering program accreditation preparation. Journal of Professional Issues in Engineering Education and Practice, 136(1), 39-47.

Bai, Y., & Pigott, R. (2004). Assessing outcomes using program assessment portfolio approach. Journal of Professional Issues in Engineering Education and Practice, 130(4), 246-254.

Dymond, B. Z., Swenty, M., & Carroll, J. C. (2020). Comparing exam performance in a reinforced concrete design course with Bloom's Taxonomy levels. Journal of Civil Engineering Education, 146(1), 04019001.

Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. Journal of Engineering Education, 92(1), 7-25.

Leathem, T. M. (2018). "A curriculum review of a construction management program for consideration of accreditation by the American Council for Construction Education." Ph.D. thesis. Department of Curriculum, Instruction, and Special Education. Mississippi State University.

Mason, G, & Dragovich, J. (2010). Program assessment and evaluation using student grades obtained on outcome-related course learning objectives. Journal of Professional Issues in Engineering Education and Practice, 136(4), 206-214.

Mehany, M. S., & Gebken, R. J. (2017). Construction faculty's perception of the American Council for construction education's Bachelor Degree student learning outcomes. Proceedings of Associated Schools of Construction of the 53rd Annual International Conference, USA, http://ascpro0.ascweb.org/archives/cd/2017/welcome.htm

Rodriguez-Marek, E., Koh, M., & Talarico, C. (2008). Connecting the dots in assessment: from course student learning objectives to educational program outcomes to ABET assessment, Proceedings of ASEE 2008 Annual Conference & Exposition, June 22-25, 2008, Pittsburgh, PA, 316.

Tingerthal, J., Roger, T., & Mead, S. (2012). Visualizing construction curriculum. Associated Schools of Construction Proceedings of the 48th Annual International Conference, Birmingham, U. K., http://ascpro0.ascweb.org/archives/cd/2012/welcome.htm

Veltri, N. F., Webb, H. W., Matveev, A. G., & Zapatero, E. G. (2011). Curriculum mapping as a tool for continuous improvement of IS curriculum. Journal of Information Systems Education, 22(1), 31-42.

Wijngaards-de Meij, L. & Merx, S. (2018). Improving curriculum alignment and achieving learning goals by making the curriculum visible. International Journal for Academic Development. 23(2), 1-13.