2018

ACSA White Paper on Architectural Education Research and STEM

ASSOCIATION OF COLLEGIATE
SCHOOLS OF ARCHITECTURE

White Paper on Architectural Education/Research & STEM

1. INTRODUCTION

Architecture is a diverse field that draws from multiple areas. Many architecture programs can and do include STEM-related content and a segment of architecture faculty already conduct research in STEM-related areas of interest. Taking advantage of this can offer potential to schools of architecture in both the education and research components of their mission.

The intention of this paper is to:

- Introduce STEM;
- Outline potential benefits to Architecture programs if STEM designated;
- Describe the distinction between STEM research and the Federal STEM designation given through a CIP code;
- Present survey results describing STEM in current Architecture programs; and
- Offer Case Studies and resources related to STEM; and
- Offer a position paper on Architecture and STEM.

1.1 History of STEM

The term "STEM education" refers to teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels—from pre-school to post-doctorate—in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings. Federal policymakers have an active and enduring interest in STEM education and the topic is frequently raised in federal science, education, workforce, national security, and immigration policy debates.

The term has been in place for decades, but gained more traction after the publication of *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (2007). This report prioritized ten actions that federal policy makers could implement in order to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of twenty-first century. Over the past decade, funding for STEM educational programs and research activities has increased dramatically.

A proposal for the next decade of STEM education was drafted in 2015. That report develops the initial recommendations from the 2007 publication.

1.2 Audience

The audience of this paper is two-fold. It is intended to help educate faculty and administration regarding STEM designation. The paper is also intended to help educate Federal Agencies on the existing and potential STEM-related research that is ongoing in architecture programs.

2. BENEFITS OF STEM

The following sections summarize these benefits for both architectural education and architectural research. Existing barriers and risks are also identified.

2.1 OPT Extensions and Recruiting

Optional Practical Training (OPT) is temporary employment directly related to a F-1 student's major area of study. All eligible international students receive up to 12 months of OPT employment authorization to remain in the United States before or after completing their academic studies. STEM Optional Practical Training (OPT) Visa extensions Program administered by the Department of Homeland Security (DHS) can be seen as a significant benefit for recruiting international students who wish to stay and work in the US post-graduation. As of 2016, non-US students who have earned degrees in certain science, technology, engineering and math (STEM) fields, may apply for a 24-month extension of their post-completion OPT employment for a total of 36 months.

To be able to remain and work in the US for additional 24 month is very attractive for international students as it provides additional time to seek H-1B visa, a highly competitive and time consuming process which may lead to further opportunity for a green-card.

DHS maintains a complete list of fields that fall within the regulatory definition of "STEM field" that qualifies certain degrees to fulfill the extension requirement. In order to distinguish STEM from non-Stem disciplines, Department of Homeland Security adopted the pre-existing Classification of Instructional Programs (CIP) codes. The codes, used for reporting graduation rates and other program information to IPEDS, are not intended to be a regulatory device. Further information on CIP codes is in section 3 of this paper.

Currently, the STEM designated list does not include the CIP Code 04.0201: Architecture, of which most architecture related programs are filed. However, the list includes 04.0902: Architectural and Building Sciences/Technology, a new designation added to the taxonomy during the 2010 CIP code revision. Note that there is no known process to petition the inclusion of 04.0201: Architecture in the DHS's STEM Designated Degree Program list at this time.

Some architecture programs have changed their CIP code and now file under CIP code 04.0902. These programs are positioned to take advantage of STEM OPT extension. Considering the fact that most of the professional programs have been in existence long before CIP code 04.0902 was added in 2010, we speculate that they changed the CIP code from 04.0201 to 04.0902, presumably, to take advantage of the STEM OPT extension. Announcements on the program pages confirm this point. The effect of this change is yet to be analyzed. Tracking enrollment of international students before and after the CIP code change will be of interest.

A list of architecture programs with CIP code 04.0902 and link to the web pages are in the appendix section of this paper.

2.2 Research

The increased focus on STEM in research has led several funding agencies, particularly federal agencies, to develop funding programs that either give preferences to STEM-designated disciplines or in some cases are limited to those disciplines. For example, the NSF Graduate Research Fellowship Program, GRFP (NSF, 2018) is limited only to disciplines designated by NSF as STEM-related. A search of NSF funding opportunities showed more than 70 current STEM-related programs. Other agencies offering STEM-related funding opportunities include Department of Education, Department of Energy. Environmental Protection Agency, National Institutes of Health, among others. STEM-focused funding opportunities are also available through several national foundations and industry sources. Currently, architecture is not recognized as one of those disciplines. Being recognized as a STEM-discipline by funding agencies will allow architectural faculty to pursue these funding programs as well as increase their chances of success in obtaining funding in general. It will also further strengthen the potential of developing interdisciplinary collaborations in which architecture faculty play a leading role. It is worth noting that NSF designates several humanities and social sciences fields such as urban and regional planning, anthropology, psychology, sociology, and political science, as STEM-disciplines even though these disciplines are not typically thought of as STEM-related.

Additionally, schools of architecture almost invariably include faculty who conduct STEM-focused or STEM-related research. Out of the 22 faculty research areas of interests identified by ACSA in their index of scholarship, seven directly relate to STEM research including Building Systems, Digital Fabrication, Prefabrication, Industrial + Product Design, Materials Research, Structural Design, Sustainability + High Performance Built Environment, and Prefabrication + Modular Construction. Several others offer potential for STEM-related research depending on project focus and methodology. Analysis of the survey presented in section 4 shows that STEM-related architectural research projects address all 22 research areas of interest identified by ACSA, thus illustrating the strong potential they offer for schools of architecture. All of this indicates both the need and the opportunity for ACSA to advocate for leading federal agencies to designate architecture as a STEM discipline.

2.3 Diversification

One of the key components in the development of STEM programs are the opportunities made available for under-represented groups and individuals. STEM grants are provided by the US government for Hispanic Serving Institutions (HSI), Historically Black Colleges and Universities (HBCU), as well as programs intended to support Asian American/Pacific Islanders, and Native American/American Indians. Although participation in STEM fields by minorities has grown over the past decade, they are still very much in the minority. That a majority of US High School students identify as Hispanic, means there is an opportunity for these students' participation in STEM related fields to increase dramatically.

2.4 Community College Connections

Opportunities exist for two-year and four-year collaborations, specifically dealing with articulation agreements between STEM designated programs. Also, funding opportunities and industry collaborations exist. One recent example is the project developed by Tesla and East Los Angeles College (ELAC) to develop a drone field.

2.5 Barriers and Risks

From the point of view of research, Architecture is currently not recognized by federal agencies as a STEM discipline. This limits the access of architectural researchers and schools of architecture to funding designated for STEM-related topics, as well as impacts the evaluation of proposals from architecture researchers by program officers in different agencies. To address this, ACSA should continue its efforts to engage funding agencies and have them recognize architecture as a STEM discipline.

With regard to academic programs, the general CIP code for architectural programs is currently not recognized as STEM-related. This eliminates the option for an OPT extension for graduates of these programs and could potentially negatively affect recruitment as international applicants continue to seek programs that offer this opportunity.

Two potential solutions to remedy this risk are to change the CIP codes for individual programs, or, to lobby for the Architecture CIP code to become STEM designated.

Each school has a Designated School Official (DSO) that reports program-specific CIP codes to the Integrated Postsecondary Education Data System (IPEDS). The DSO also works with the Student Exchange Visiting Program (SEVP) to coordinate with foreign students requesting OPT extensions. Schools can change the CIP code for individuals as well as programs in the Student and Exchange Visitor Information System (SEVIS). The SEVP, however, cautions programs when doing so to make the change program-wide so that it applies to all students and be sure to document the curricular changes made to justify the CIP code change.

3. CLASSIFICATION OF INSTRUCTIONAL PROGRAMS (CIP) CODES

The intent of this section is to provide an overview of applicable CIP codes for various architecture programs, clarify the relationship between CIP codes and Department of Homeland Security's STEM Designated Degree Program List and to outline a path for CIP code change.

3.1 Definition of Classification of Instructional Programs (CIP) Codes

The Classification of Instructional Programs (CIP) provides a taxonomic scheme that supports the accurate tracking and reporting of fields of study and program completions activity. CIP was originally developed by the U.S. Department of Education's National Center for Education Statistics (NCES) in 1980 with revisions occurring in 1985, 1990, 2000, and 2010.

The CIP is the accepted federal government statistical standard on instructional program classifications and is used in a variety of education information surveys and databases. Since it was first published in 1980, the CIP has been used by NCES in the Integrated Postsecondary Education Data System (IPEDS) and its predecessor, the Higher Education General Information Survey (HEGIS) to code degree completions. It is also used by other Department of Education offices, such as the Office for Civil Rights, the Office of Vocational and Adult Education, and the Office of Special Education, and serves as the standard on instructional programs for other federal agencies, including the National Science Foundation (NSF), the Department of Commerce (Bureau of the Census), the Department of Labor (Bureau of Labor Statistics), and others. The CIP is used by state agencies, national associations, academic institutions, and employment counseling services for collecting, reporting, and analyzing instructional program data.

The CIP titles and program descriptions are intended to be generic categories into which program completions data can be placed, not exact duplicates of a specific major or field of study titles used by individual institutions. CIP codes are standard statistical coding tools that reflect current practice, and are not a prescriptive list of officially recognized or permitted programs. The CIP is not intended to be a regulatory device. CIP codes, for the most part, are not intended to correspond exclusively to any specific degree or program level. In most cases, any given instructional program may be offered at various levels, and CIP codes are intended to capture all such data.

The vast majority of CIP titles, however, correspond to academic and occupational instructional programs offered for credit at the postsecondary level. These programs result in recognized completion points and awards, including degrees, certificates, and other formal awards.

3.2 CIP Codes in Architecture

Most architecture related programs are filed under primary 2 digit CIP Code 04 - Architecture and Related Services, defined as "Instructional programs that prepare individuals for professional practice in the various architecture-related fields and focus on the study of related aesthetic and socioeconomic aspects of the built environment."

The ten sub-categories are;
04.0201: Architecture
04.0301: City/Urban, Community and Regional Planning
04.0401: Environmental Design/Architecture
04.0501: Interior Architecture
04.0601: Landscape Architecture
04.0801: Architectural History and Criticism, General
04.0901: Architectural Technology/Technician
04.0902: Architectural and Building Sciences/Technology
04.1001: Real Estate Development
04.9999: Architecture and Related Services, Other

See Figure 1 for the distribution of programs per CIP code. Note that the chart is based on the publicly available NCES/IPEDS 2015-16 data online. It includes all post-secondary education programs and non-accredited programs. The data is not tied to the exact duplicates of a specific major or field of study titles used by individual institutions.

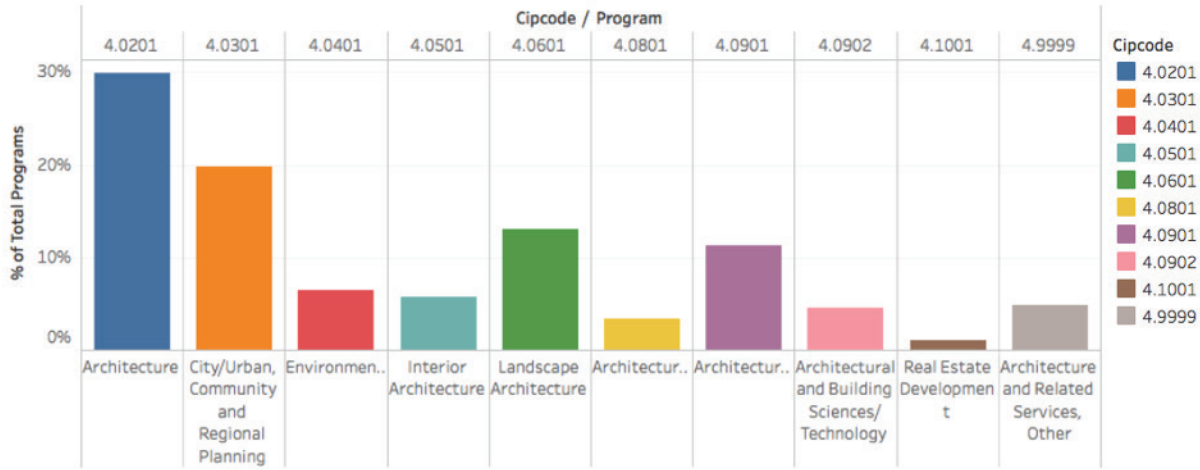


Figure 1
Distribution of architecture related programs as per CIP Code.

Figure 2 excludes Planning, Landscape Design, Interior Design, Real Estate and Other related services as well as vocational training represented in the 04.0901: Architectural Technology/ Technician to focus on the distribution of professional, pre-professional and architecture programs per CIP code.

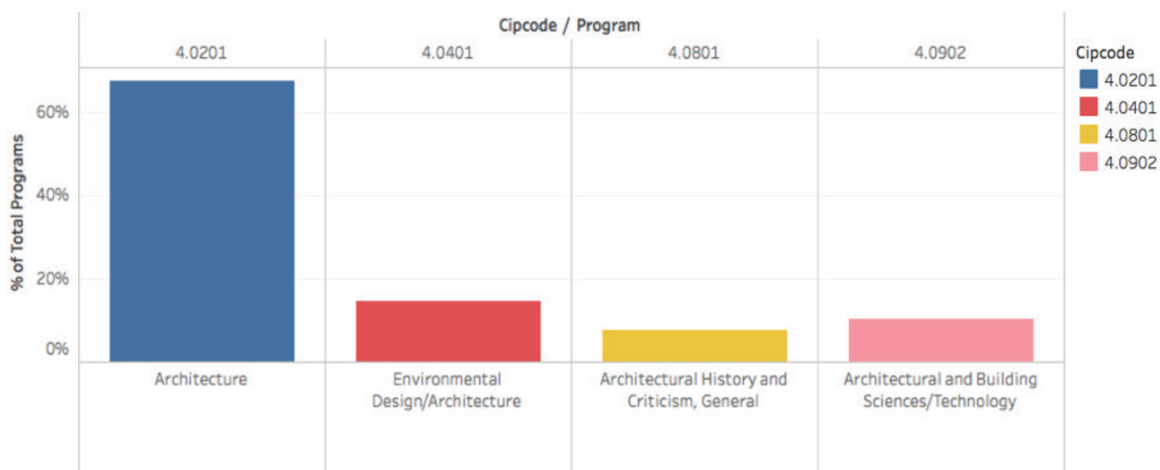


Figure 2
Distribution of Architecture programs (accredited and non-accredited) per CIP Code.

A quick comparison of individual data samples against degree programs offered at the universities reveals that many B. Sci. Env. Des. type programs are filed under CIP code 04.0401. History /Theory focused Bachelors, Masters and Ph.D. programs are filed under CIP code 04.0801.

Many recently established post-professional Master of Science programs focused on computation, building performance and sustainable technology are filed under 04.0902: Architectural and Building Sciences/Technology. There are more than half a dozen professional M. Arch. programs and a few pre-professional undergraduate architecture degrees are under this category.

IPEDS data do not track what degree program is filed under which CIP code. As stated earlier, the CIP titles and program descriptions are intended to be generic categories into which program completions data can be placed, not exact duplicates of a specific major or field of study titles used by individual institutions. Thus, the general interpretation of the data presented here relies on the comparison between IPEDS data which reveals how many programs are field under certain CIP code per institution and the program information available on the web. The committee recommends ACSA to conduct a member-schools survey on which program is filed under what CIP code. It may also be beneficial for NAAB to include CIP codes in the Annual Report Submission that schools of architecture are required to complete.

3.3 Navigating CIP Changes

As stated in the previous section, in order for the international students graduating from the architecture related program to be eligible for STEM OPT extension, the CIP code must be 04.0902: Architectural and Building Sciences/Technology. Thus, if you seek to make your program eligible for the privilege, you either change the CIP code to 04.0902 or to transition into a “new program” with the CIP code 04.0902.

Institutions are responsible for assigning and maintaining the CIP codes for IPEDS and other data collection and reporting duties. When establishing a new major or degree program, proposing the proper CIP code is often the program director or department chair’s charge. The new program proposal will then go through the standard approval process unique to the institution, including the review of the proposed CIP code. Generally, the chief academic officer (the University Provost) of the institution have the authority in approving the initial CIP code.

The process for CIP code change varies amongst the institutions. For private institutions, it may be as simple as a review and approval by the University Registrar and/or the Chief Academic Officer. Some institutions maintain an ad-hoc review committee with appropriate representations such as the University Registrar, Office of Academic Affairs, Associate Deans from Schools/Colleges. The committee may consult with other service units within the institution such as the Office of Institutional Technology, International Students and Scholars and Financial Aid to take short-term and long term impact of the change into account.

In the case of Public Institutions, State Board of Higher Education may have the authority in approval as the CIP codes are often tied to the state reporting responsibilities as well as state funding schemes. STEM programs are funded at a significantly higher level then Humanity programs, another reason for architecture programs to be considered for STEM designation. In certain cases, from the perspective of approval process, it may be less onerous to simply propose a new program with the preferred CIP code as opposed to changing them for the already established program.

Once the CIP code change is approved, it is effective immediately to all students enrolled in the program.

3.4 Grounds for the CIP Code Change

The following points may be useful in arguing for the CIP code change (from CIP code 04.0201: Architecture to CIP code 04.0902: Architectural and Building Sciences/Technology) for NAAB accredited Professional M. Arch. and B. Arch. programs.

3.4.1 The CIP code change will not affect the current nor future accreditation status. National Architecture Accrediting Board (NAAB) states that the NAAB Conditions for Accreditation do not require programs to operate under a specific CIP code.

1.1.2 Instructions in Building Sciences and Technology addressing the proficiency in the area of civil and structural engineering, mechanical engineering, computational tools are a significant part of the architecture curriculum reflecting the NAAB Student Performance Criteria. Generally, a third of the required courses (in credit hours) are building science and technology related, equivalent to the design instruction courses in NAAB accredited professional programs. Program definition for CIP code 04.0902 annotated with the corresponding NAAB SPC is in the appendix section of this paper.

1.1.3 Example of peer and aspirational programs who has already made the change.

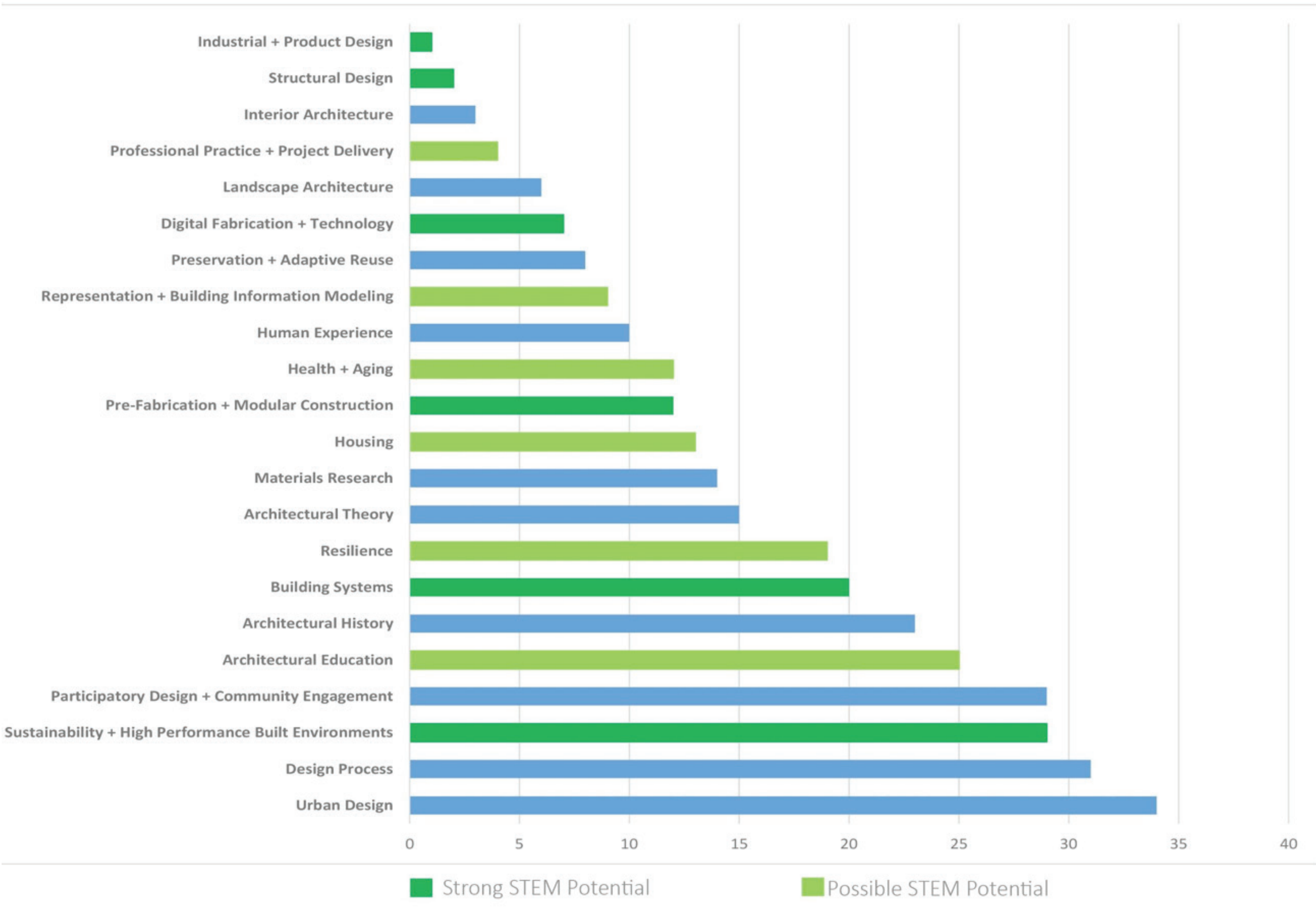
4.0 ARCHITECTURAL RESEARCH AND STEM: SURVEY RESULTS

In Fall 2017, the ACSA Research + Scholarship Committee conducted a survey of externally-funded projects in schools of architecture. External funding could include national, state or local grants, as well as industry partnerships, but defined as coming from outside one's home university system. Faculty and administrators from all ACSA member schools were invited to participate with information regarding projects from the last three academic years (2014-15, 2015-16, and 2016-17). This survey yielded 110 responses from faculty at ACSA member schools with 207 projects represented and 37% of the participants listing multiple projects. Upon examining the responses, 21 projects were excluded either because they only listed internal sources of funding or did not list any funding sources. The remaining 186 projects from 101 faculty were analyzed and the results are discussed below.

Out of the 186 submitted projects, 55%, 102 projects, self-identified as interdisciplinary in nature. The participants' titles ranged from Adjunct to Dean. Associate Professor was the most frequent (34), with Professor (29) next, and finally Assistant Professor (22). The respondents were 33.6% female and 66.4% male. The participants represented 62 different institutions, with 35 (56%) being recognized by Carnegie Classifications as "R1: Doctoral Universities – Highest research activity." With a membership of over 5000 faculty members and 200-member schools with 56 being R1 institutions.

Respondents were asked to identify up to three research areas of interests for themselves. However, 26 of the 101 respondents identified more than 3 areas with a maximum of 9 areas identified by two respondents. Research areas options were based on the classification used for the ACSA Index of Scholarship. Areas of research interest identified most by the survey respondents include Urban Design (34), Design Process (31), and Sustainability + High Performance (29). In all, 50 out of the 101 respondents self-identified as having at least one research area of interest with strong STEM potential. Figure 3 includes a listing of all research areas and the number of respondents who self-identified with it.

Figure 3
Faculty Research Areas of Interest



It needs to be noted that the responses received from the survey cannot be considered a representative sample. What is presented here and the corresponding conclusions are based only on the data received and not able to be generalized to the larger architectural academic profession. However, the survey respondents demonstrate that architectural researchers are conducting funded research and architectural research projects are being awarded grants by the top governmental and private foundation funders in addition to local and state partners. The 101 respondents have reported more than $33,575,000 in funding, with eight projects not reporting a specific funding amount.

Since the intent of this white paper is to examine STEM research in architecture, and in particular those funded by external agencies, following the analysis above, the responses were filtered to STEM-related projects only, based on faculty self-identification as well as an analysis by the authors. As will be described in more depth below, these two characteristics were used to narrow the responses to a pool of 91 projects from 52 faculty members. These faculty members represent 36 institutions with 24 (67%) being classified as R1. These projects represented approximately $23,930,000 of external funding, or 71.3% of the total funding amount reported by the survey respondents. The analysis that follows is based on those survey results that meet this classification.

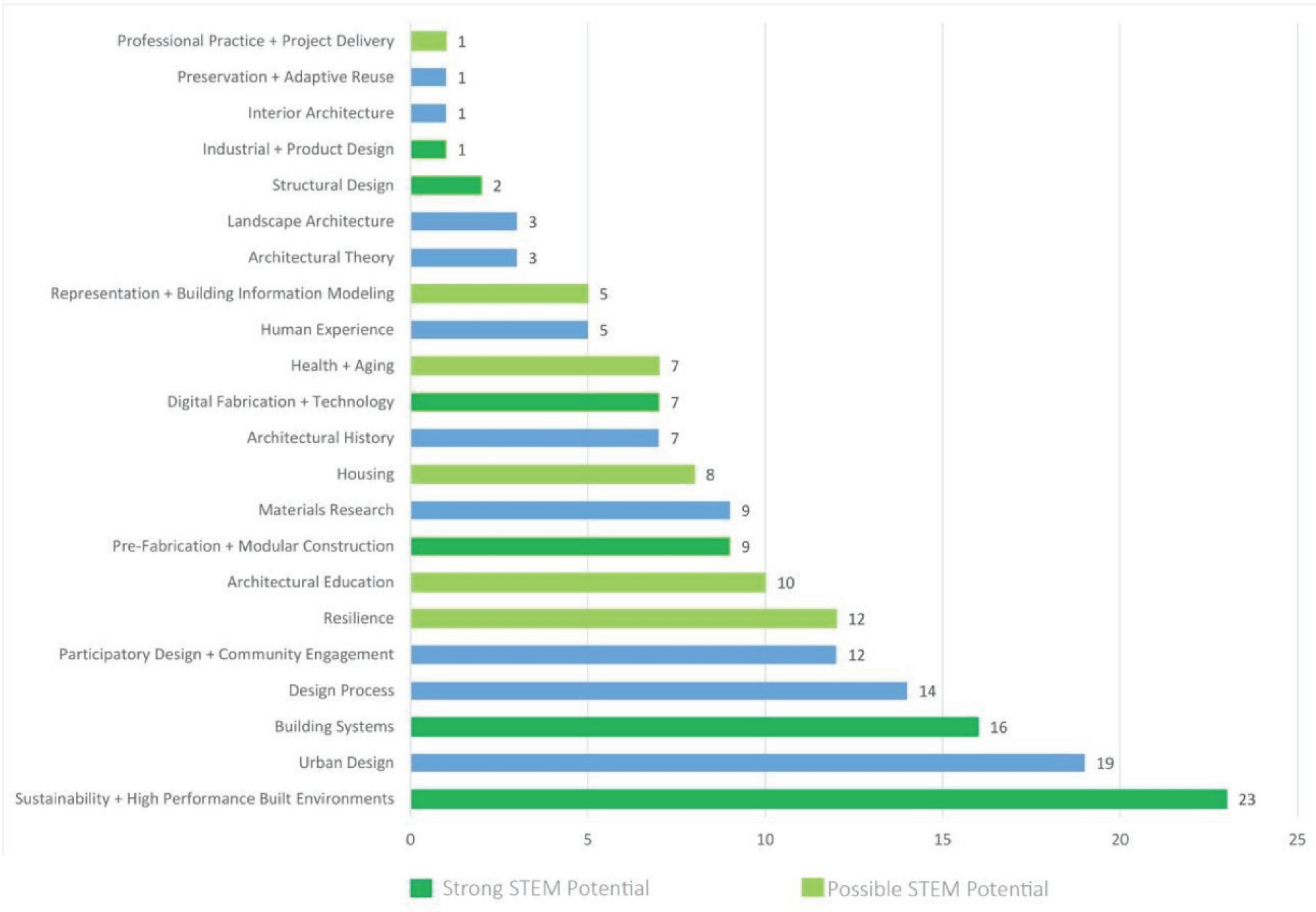
4.1 STEM / Non-STEM

The identification of STEM-related projects was based on both respondent self-identification as well as an analysis of the project title, project research areas, and project abstracts. Out of the 91 projects identified in this analysis as STEM-related, 72 were self-identified as such, 16 were identified by the respondents as non-STEM and reclassified by the authors as STEM-related, and 3 that were not classified by the respondents. The reclassification was based on the federal definitions of STEM-related research areas. The relatively large number of projects not identified as STEM-related by the respondents when they do offer this potential may indicate a need to clearly define the term STEM to architecture faculty and to find methods of addressing any potential apprehensions architecture faculty may have against describing their work as STEM-related.

4.2 Research Areas of Funded STEM Projects

Survey respondents were asked to identify up to three research areas for each project. Research areas identified the most for the STEM-related projects were Sustainability and High Performance (23), Urban Design (19), and Building Systems (16). However, each of the 22 possible research areas were identified at least once including design process (13), architectural history (7), and architectural theory (3). This indicates that STEM-related projects could offer potential beyond the traditional areas typically associated with them. Figure 4 provides a listing of the research areas and the number of projects that are included.

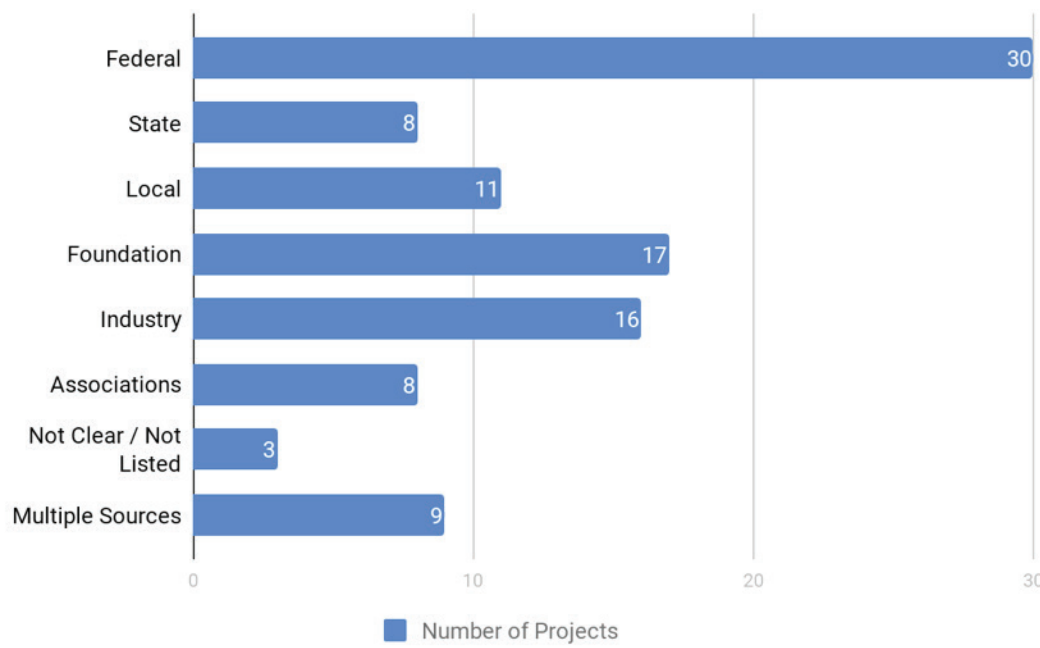
Figure 4
STEM-Related Projects Research Areas



4.3 Funding Sources for STEM Projects

With regard to funding sources, the survey showed that STEM-related architectural research projects receive funding from a wide range of funding sources including federal agencies, foundations, associations, industry, and well as state and local sources. Figure x shows the number of projects which received funding from each category of funding sources. Thirty projects (33%) received funding from federal agencies, including 25 from federal agencies in North America. Funding from federal agencies in North America totaled approximately $10,000,000. Out of those, 13 projects were funded by the National Science Foundation (NSF) with a total funding of $4,300,000. Other Federal sources included NIH, NPS, the US Dept. of the Navy, US DOE, US DOT, and The Social Sciences and Humanities Research Council of Canada. Foundations such as the Alfred P. Sloan Foundation, the Auerbach Theater Architecture Fund, Graham Foundation, and others were listed as the second most common source of funding with 19% (17) of the projects noting these. Industry grants from Autodesk and Ford Motor Company and grants from Associations such as the AIA were other notable contributors for research funds. A variety of state and local sources were also listed in 19 of the projects.

Figure 6
STEM Related Projects Sources of Funding

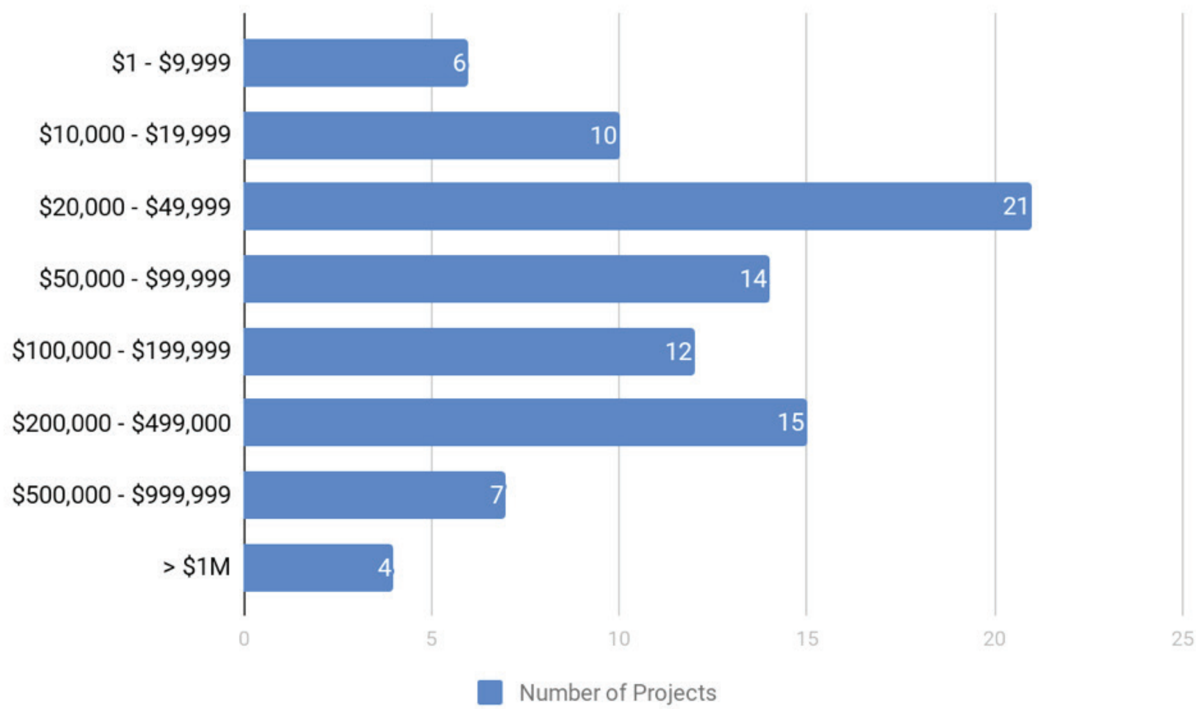


4.4 Classification of Project by Funding Levels

Analysis of the funding amounts received by the STEM-related research projects showed that the most common level of funding is between $20,000 and $49,999, with 24% (21) of the projects receiving funding at this level. While this level of funding was most common, between 12 and 15 projects also received funding in each of the three funding levels that follow ($50,000 - $99,999), ($100,000 - $199,999), and ($200,000 - $499,999). It is noteworthy that 7 projects received funding between $500,000 and $1 million and another 4% (4) projects received over $1 million in funding each. Figure x shows the distribution of the projects by funding level. Two projects did not specify a funding amount.

The majority of these projects list only a single source of funding as contributing to the reported amount. As such, it cannot be determined whether any prior seed funding had been received from internal university grant sources. In the case of 9 STEM related projects, multiple sources of funding comprise the reported amount including external and internal sources.

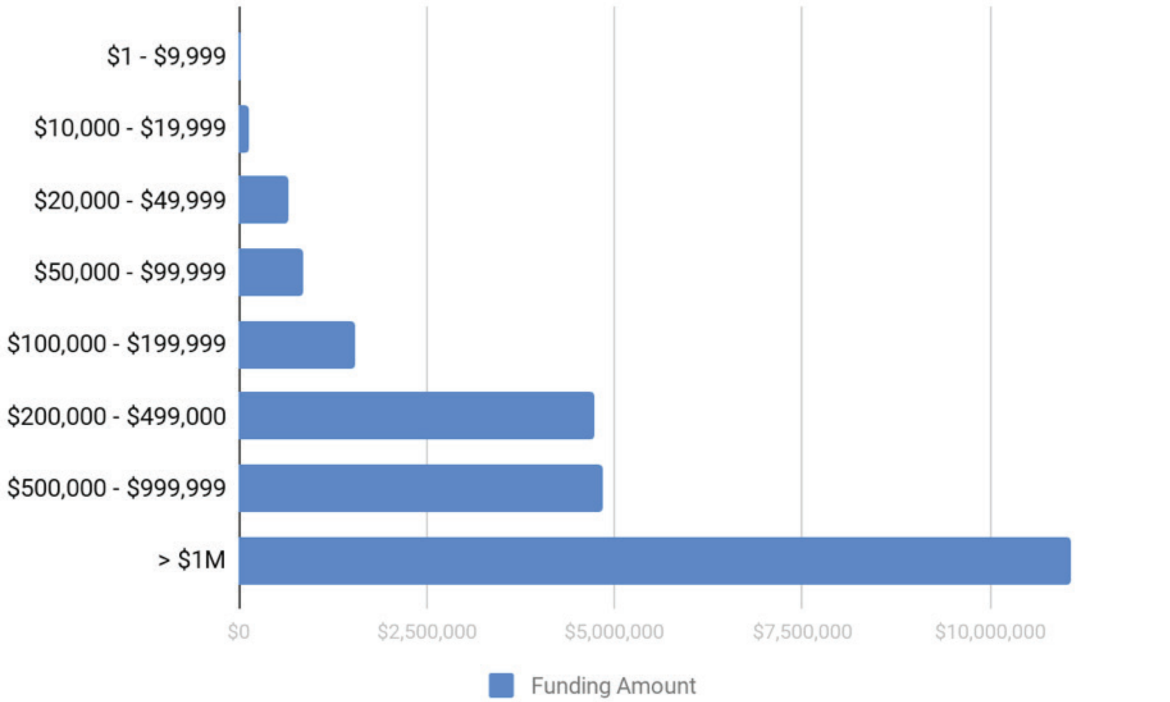
Figure 7
Number of STEM Projects by Level of Funding



The greatest amounts of funding were granted primarily by Federal sources and corporate / anonymous donations. Single projects in receipt of more than $1 million received funds from the US DOE and NIH, respectively, and also through combined funding from EPA, NEA, Sloan Foundation, and other sources. A number of NSF grants as single sources of project funding were also awarded within the funding levels of $500K - $1M and $200K - $499K.

Other major sources of funding included the Social Sciences and Humanities Research Council of Canada, Ford Motor Company, W.M. Keck Foundation, Charles Pankow Foundation, the BM-M Barr Foundation, the WK Kellogg Foundation, and local state and city agencies. While larger projects ($200,000 and above) only constitute only 29% (26) of the STEM-related projected reported in the survey, they represent 86% of the total funding amount as shown in figure x, with a total funding of $20.65M. This indicates the potential offered by STEM-related projects in obtaining large funding sources for schools of architecture. It is worth noting that only 10 externally funded projects not identified as STEM-related fall into this funding category, with a total funding of approximately $6M. Therefore, STEM-related research projects in the survey were considerably more successful in receiving larger numbers and amounts of funding.

Figure 7
STEM-Related Projects Funding Amounts by Funding Level



4.5 Interdisciplinary Research and Research Partners

Participants in this study have demonstrated a strong potential of architectural contributions to research in a wide range of topics ranging from engineering and science on the one hand to arts and humanities on the other. Out of the 91 STEM-related projects, 59 self-identified as interdisciplinary projects, representing almost 65% of the projects submitted. The issue of the role of architecture and architectural; researchers in interdisciplinary projects was also explored. Out of the 59 self-identified interdisciplinary projects, 39 projects were identified as architecture-led, and an additional 10 as architecture-supporting. An analysis of the other disciplines identified in the survey indicates that engineering offers the most potential for interdisciplinary collaboration with 29 projects. Other notable partner disciplines include Biology (7), Urban Planning (6), landscape Architecture (6), and Material Science, Computer Science, and Public Administration (5 each). In total, 47 disciplines were listed as partners. A listing of all these disciplines is included in Figure 8.

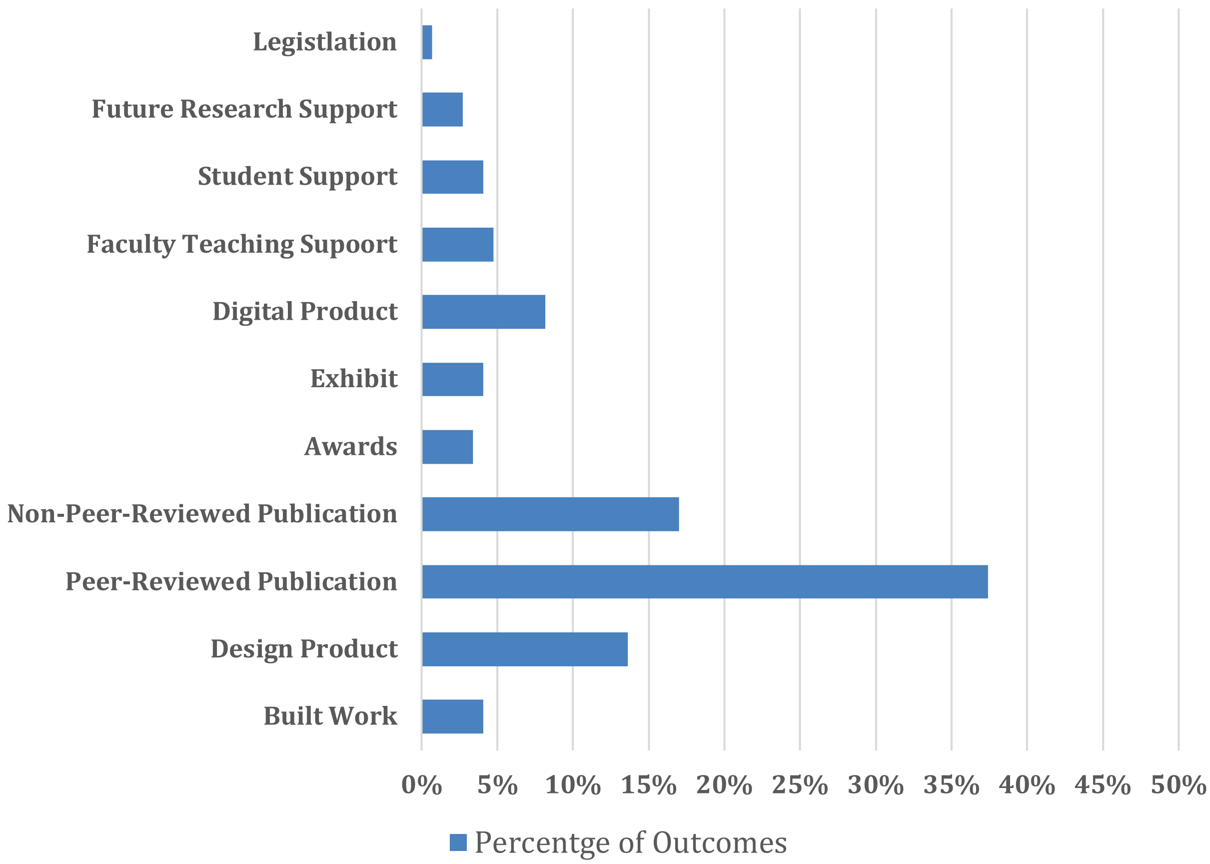
Figure 8
Disciplinary Partners for Architectural Researchers

Disciplinary Partners of Architectural Researchers	
Advanced Manufacturing	Industrial Design
Aquatic Ecology	Information Studies
Architectural Engineering	Interior Design
Art	Material Science
Arts Management	Mechanical Engineering
Behavioral Sciences	Medicine, Health Professionals
Biological and Agricultural Engineering	Landscape Architecture
Biology	Law
Building Science	Library Science
Business	Media Studies
Civil Engineering	Power Engineering
Computer Science	Public Administration
Construction Science	Public Health
Cultural Studies	Public Policy
Drama	Sociology
Ecology	Spatial Sciences
Education	Statistics
Electrical & Computer Engineering	Structural Engineering
Environmental Sciences	Systems Engineering
Geography	Textiles/Textile Engineering
German Studies	Transportation Planning
History	Urban Planning
History of Science	Wood Science
History of Technology	

4.6 Reported Outcomes of Research Projects

The reported and expected outcomes for architectural STEM research projects are education-based, publication-focused, or relate directly to the work of architects. Funding was given for student scholarships, post-doctoral fellowships, and to create other support structures for students. Participants were funded to write courses, to sponsor a studio, or for completion of design-build projects. Teaching and research laboratories were supported as was travel for graduate students to conferences and the hiring of student researchers. Dissemination of research came through conference papers, articles, and book publication. Research reports or design guidelines were frequent outcomes with exhibitions, software development, and building documentation as other types of products. Prototypes, proof-of-concept models, or material testing start to demonstrate more architectural forms of research results. Research was also incorporated into the building prototype designs and plans of urban environments. Culminating events including a research symposium and community outreach workshops. Notably, some architectural researchers were able to construct buildings that incorporated research findings or design guides. Respondents listed awards they had won for their design work, built or conceptual, alongside articles about this same work. An analysis of the outcomes reported in the survey responses is included in figure 9 below.

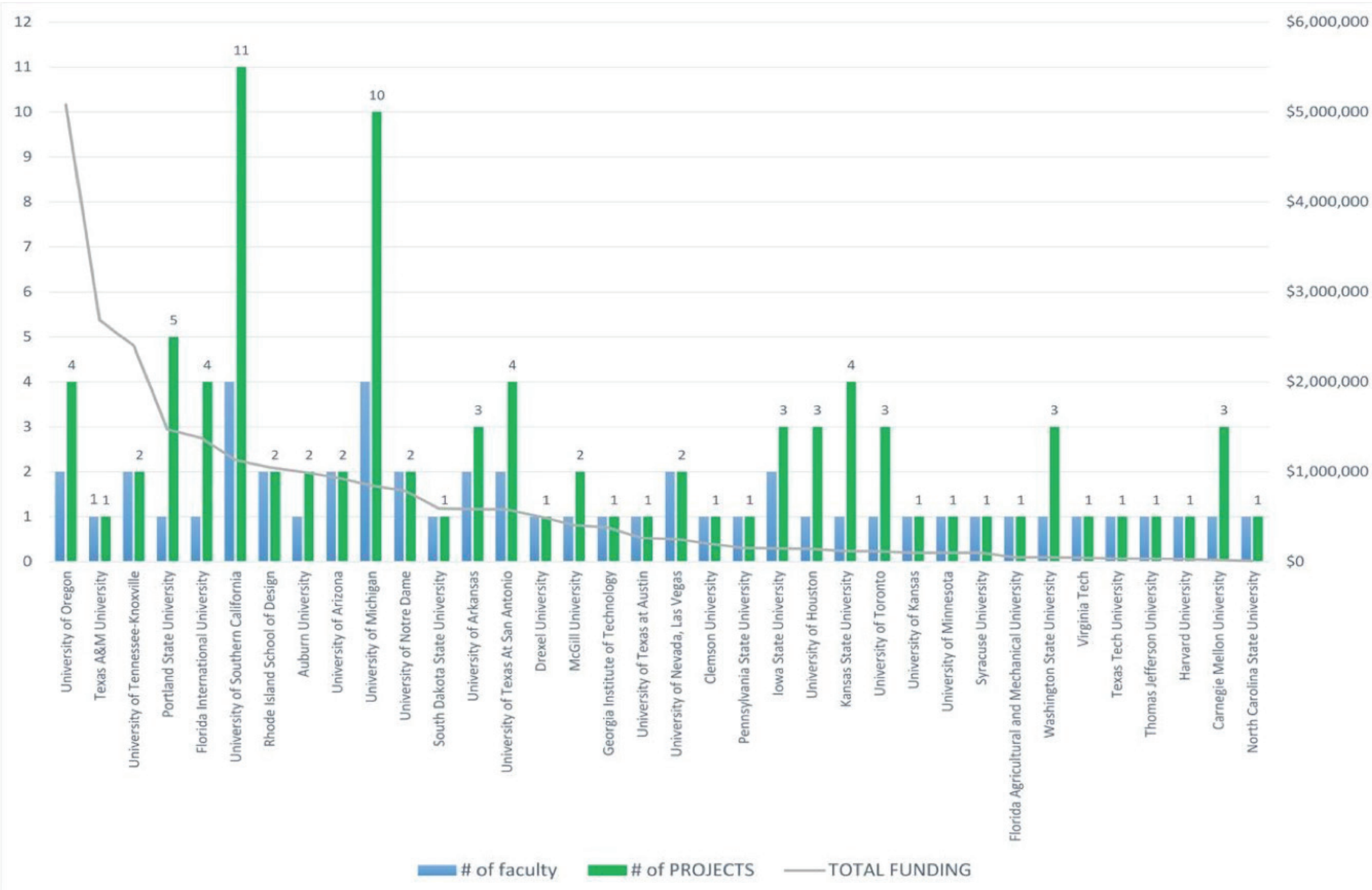
Figure 9
Analysis of Reported Outcomes for STEM-Related Research Project



4.7 Relationship between STEM Designated Architectural Academic Programs and Research Funding

While faculty from all of the universities listed in Figure 9 reported projects that were STEM related, only seven of those universities have programs filed under CIP code 04.0902. In fact, none of the institutions reporting funding which totaled more than $1 million have STEM designated architectural academic programs. As it is not yet adopted widely by architectural institutions, it remains to be seen whether STEM designations for architectural academic programs will lead to greater research funding amounts or vice versa. With many granting organizations and federal agencies demonstrating a preference for STEM related research, official STEM program designations can only be seen as advantageous. it is worth noting that adopting CIP code 04.0902 is program specific and therefore does not necessarily indicate a STEM-designation for all academic programs in a school. Nor does it indicate a specific STEM focus for the that school. It could however be indicative that the topic of STEM is being actively discussed or considered within a school. As Figure 10 also shows, a stronger correlation seems to exist in the sample analyzed between STEM-related externally-funded projects and the research designation of the university, with 25 of the 37 schools of architecture which reported funding from STEM-related projects located in R1 universities.

Figure 10
Total Funding awarded per Institution with faculty reporting STEM-related projects



4.8 Survey Conclusions

The following summarizes the major conclusions that can be drawn from the survey responses received. It is worth noting again that these conclusions are only based on the responses received (101 faculty reporting on 186 projects, representing 62 institutions). However, the size of sample is sufficiently large to make some preliminary conclusions and indicate possible trends in the larger architectural academic community.

Analysis of the survey results indicates that STEM-related externally funded architectural research projects represent a significant portion of the larger population of externally-funded architectural research projects in terms of numbers, 91 out of 186 or 49%, and much more so in terms of funding amount, $23.9M out of a total of $33.6M or 71.3%. STEM-related projects also appear to be more successful in receiving funding from federal agencies, with 30 STEM-related projects receiving funds from these sources compared to only 10 from non-STEM-Related ones. Furthermore, STEM-Related projects also appear to be more successful in obtaining larger funding amounts with 29 of these projects receiving funding at the $200,000 or above level totaling $20.65M or 86% of the total funding received by STEM-related projects. In comparison, only 6 non-STEM projects received funding at this level with a total funding of approximately $6M. This indicates that STEM-related projects can offer strong potential for schools of architecture in securing more and larger externally-funded projects.

The survey indicated that STEM-related projects are typically not limited to the conventional, technically oriented, areas. In fact, STEM-related projects included in this analysis addressed all research areas of interests identified in the ACSA Index of Scholarship. Similarly, faculty reporting STEM-related projects have self-identified as having a wide range of research areas of interest including both STEM-related and non-STEM areas. Both of these observations indicate that STEM-related research funding can support both STEM and non-STEM faculty and research areas. Additionally, STEM-related projects reported a relatively high percentage of interdisciplinary collaboration with a very wide range of disciplines not only from scientific fields but also from the humanities, social sciences and arts. This adds to the potential that STEM-related projects can offer to schools of architecture.

Finally, the survey results suggest that while there are some significant sources of funding available for non-STEM related projects related to large scale planning, housing, and community development, faculty seeking such grants for this and other scales of work may benefit from collaborating with other STEM disciplines, while maintaining an architectural focus in the research. It is also clear from the survey results that architectural faculty in a number of ACSA member schools have, in fact, been awarded a fair amount of high level grants in recent years, despite the common belief that the architectural discipline in academia lags behind other STEM disciplines in yielding research dollars to their institutions. Architecture, as a discipline, is well poised to emerge as a leader in a number of research areas moving forward. Having this level of achievement on the part of architectural faculty and schools become more recognized by funding agencies, especially federal ones, will further increase their potential and the benefits they can offer to schools of architecture and to the architectural academic community in general. ACSA may be the best organization to attempt to establish such a level of recognition.

5. CASE STUDIES OF STEM FUNDING IN ARCHITECTURAL RESEARCH

This section will highlight individual grants to show where opportunities exist for other architecture faculty members to obtain funding for STEM-related architectural research. The case studies presented here represent a range of possible project types and funding sources. They also include both direct research funding as well as funding for studio-based design research activities and scholarships.

5.1 Funding for Architectural Research

5.1.1 Development of an Integrated Analytical Framework for Urban Sustainability

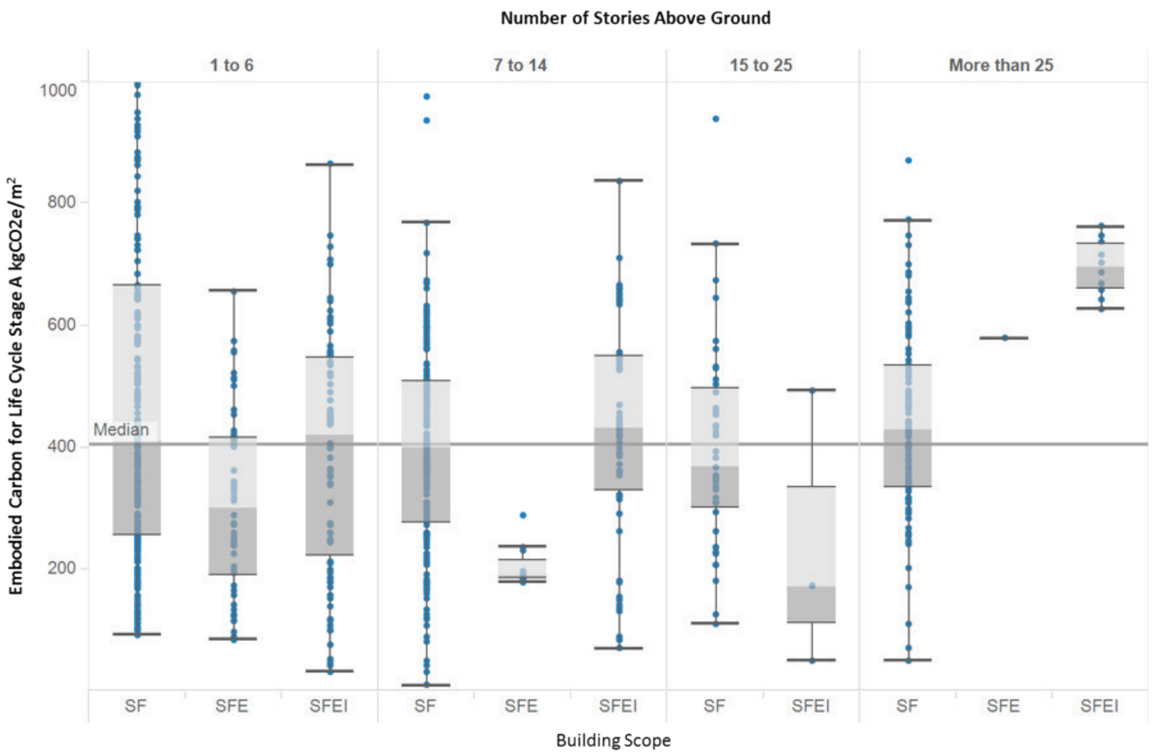
image credit: Nabila Iqbal

PI: Simi Hoque, PhD, PE
Location: University of Massachusetts, Amherst (now at Drexel University)
Funding source: National Science Foundation, Faculty Early Career Development Program (CAREER)
Amount: $508,000

At the time she received this grant, Dr. Hoque was an Assistant Professor in the Department of Environmental Conservation and is now an Associate Professor in Architectural Engineering at Drexel University. With a PhD in Architecture, M.Arch. and M.S. in Civil Engineering, she is using her CAREER grant to develop an Integrated Urban Metabolism Analytical Tool (IUMAT) to evaluate and predict the impacts of energy and water use, land use, and transportation systems at an urban scale. IUMAT is designed to systematically quantify aggregate impacts in terms of performance metrics, such as GHG emissions and energy use. NSF's CAREER program supports junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education and the integration of education and research in the context of the mission of their organizations and is highly sought after by junior faculty in STEM disciplines. While the CAREER program requires the recipients to have a PhD and hold a tenure-track, Assistant Professor position, Dr. Hoque demonstrates that an architecture research topic aligned with an NSF program, in her case Environmental Sustainability, can lead to a CAREER grant.

For more information about this grant:
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1554531

5.1.2 Life Cycle Assessment (LCA) for Low Carbon Construction



Embodied carbon per m² according to number of building stories above ground, subdivided by each LCA building scope data subset; SF = Structure and Foundation; SFE = Structure, Foundation, and Enclosure; SFEI = Structure, Foundation, Enclosure, and Interiors. (image credit: Kathrina Simonen)

PI: Kathrina Simonen, AIA, SE
Location: University of Washington, Carbon Leadership Forum
Funding source: Charles Pankow Foundation
Amount: $150,000

This project provides guidance to industry professionals looking to integrate carbon into life cycle based decision making through the creation of an environmental life cycle assessment (LCA) practice guide and establishment of embodied carbon benchmarks of buildings. This practice guide will focus on aiding carbon reduction in the building construction sector (both new construction and renovation) through the use of whole building LCA. The guide will integrate concurrent work developed by others into one common practice guide document. An interactive visualization of the embodied Carbon Benchmark results and LCA Practice Guide (draft) are available on the Carbon Leadership Forum website.

For more information about this grant: http://www.pankowfoundation.org/grants.cfm

5.1.3 Reflective Roofing Research

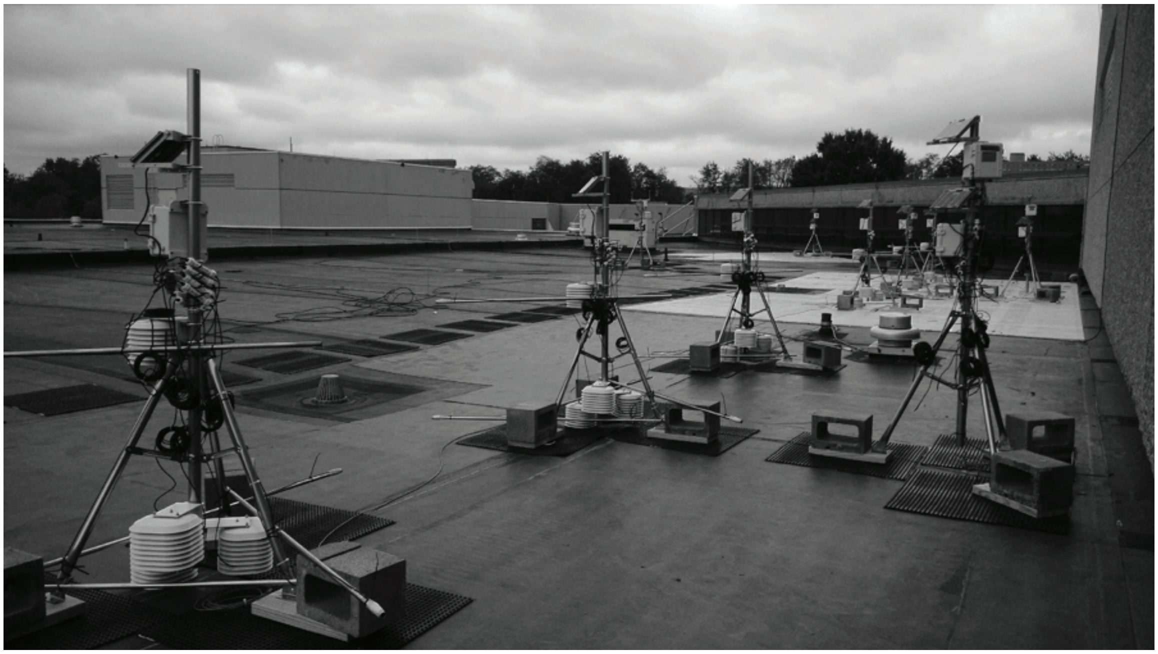


image credit: Elizabeth Grant

Co-PI: Elizabeth Grant, Ph.D., RA
Location: Virginia Polytechnic Institute and State University
Funding source: RCI Foundation
Amount: $45,000

The design of a roof system has important ramifications beyond the performance of the roof itself. There have been a number of recent papers indicating that white roofs may not create lower temperatures than other types of roofing at areas surrounding the roof surface. To help answer emerging questions about the thermal effects of roof color on the neighboring built environment, a research project was conducted by the Center for High Performance Environments at Virginia Tech with the support of the RCI Foundation. Temperatures were recorded at the surface of black ethylene propylene diene monomer (EPDM) and white thermoplastic polyolefin (TPO) membrane overlay areas; in the air and at electrical metallic tubing (EMT) above them; and at opaque and glazed wall surfaces adjacent to them. The surface of the EPDM roof was significantly hotter than the TPO roof by 36°C and 26°C on two test dates. Air temperatures were 2°C higher above EPDM versus TPO up to 14 cm, with no significant differences above this height. Temperatures were 2°C higher at EMT above the TPO surface than above the EPDM. A precast concrete panel wall was 3–5°C warmer adjacent to TPO versus EPDM. Exterior glazing surface temperatures were 2°C warmer adjacent to TPO versus EPDM. The study contributes to the literature by offering experimental data useful to researchers seeking to anticipate the thermal effects of roof systems. The results are also of interest to practitioners curious about these impacts.

For more information about this research: https://vtnews.vt.edu/articles/2017/10/CAUS-Black-White-Roofing.html and "The influence of roof reflectivity on adjacent air and surface temperatures."

For more information about this funding source: http://www.rcifoundation.org/

5.1.4 Life-cycle Assessment of Resiliency and Sustainability of Buildings

image credit: Aimee Buccellato

Co-PI: Aimee Buccellato
Location: University of Notre Dame
Funding source: National Science Foundation, Structural and Architectural Engineering Program (now Engineering for Civil Infrastructure Program)
Amount: $398,883

In this interdisciplinary grant, Professor Buccellato serves as a Co-PI with her colleague in Civil Engineering serving as the PI. Their project will develop an integrated life-cycle assessment capturing the dependencies between multi-hazard resilience and sustainability, across the multiple contributing dimensions of environmental impact. The computationally efficient assessment will take advantage of (i) simulation-driven approaches, (ii) sample-based tools, (iii) soft-computing techniques, and (iv) new environmental impact toolsets that will mine publically available data to quantify the building's operational and embodied energy. Through sensitivity analyses on actual buildings, the framework will reveal which design aspects truly drive environmental impact and how this is affected by the consideration of lifetime exposure. The transfer of this newfound understanding is further facilitated by engaging practicing engineers and architects directly in the research effort. As the NSF values the broader impact of the proposed research as much as the intellectual merit, architecture faculty members can contribute significantly to expanding and explaining the broader impact of engineering research focused on buildings.

For more information about this grant: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1537652

5.2 STEM Funding for Architectural Education

While the majority of STEM funding reported in the survey was related to research, there was funding recorded for architectural education including design studio research and NSF scholarship programs.

5.2.1 Lane County Courthouse Mass Timber Studio

image credit: Spencer Boragine, David Moreno, Josh Rosenthal, Zachary Sherrod, students; Professor Judith Sheine and Associate Professor Mark Donofrio, instructors

PI: Judith Sheine
Co-PI: Mark Donofrio
Location: University of Oregon
Funding source: Lane County, Oregon
Amount: $50,000

Five student projects that explored the design of a new courthouse using mass timber structural systems and sustainable principles were presented to the County. These student projects will be used to inform the public and the RFP process about the possibilities of designing with mass timber.

For more information about this similar research studios:
http://tallwoodinstitute.org/mass-timber-design-studios

5.2.2 NSF S-STEM Program

The NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) Program provides funding for scholarships to 1) increase the number of low-income academically talented students with demonstrated financial need obtaining degrees in STEM and entering the workforce or graduate programs in STEM; 2) improve the education of future scientists, engineers, and technicians, with a focus on academically talented low-income students; and 3) generate knowledge to advance understanding of how factors or evidence-based curricular and co-curricular activities affect the success, retention, transfer, academic/career pathways, and graduation in STEM of low-income students. There are currently three active NSF S-STEM grants related to building science totaling over $1.7M. These include the Green Building Scholars Program at Portland State University (NSF Grant No. 1356679), the Sustainable Building Science Technology program at South Seattle Community College (NSF Grant No. 1406320), and the Augmented Reality and Collaborative Problem-Solving for Building Sciences project between Florida International University, University of Arkansas, and Missouri State University (NSF Grant No.1504898).

APPENDICES

Appendix A

ACSA Statement of Support for Architectural STEM Researchers

The Association of Collegiate Schools of Architecture (ACSA) is a nonprofit association of over 200 member schools. These include all accredited architecture degree programs in institutions of higher education in the United States, as well as government-sanctioned schools in Canada. Through this membership, over 5,000 faculty members in architecture and allied disciplines are represented. Serving as the voice of architectural educators, ACSA is the forum for ideas and issues that will affect architectural education and practice, design and building industry research, policy development, and liaison with allied professionals.

The Board of Directors of the ACSA respectfully asks federal and state governments, funding agencies and foundations to include Architecture as a discipline in their consideration of the Science, Technology, Engineering and Math (STEM) fields. Architectural education includes the study and application of building science, mechanical engineering, structural engineering, and building construction technology to the design of buildings. This breadth of STEM content in our discipline is necessary as architects lead multidisciplinary teams of designers, engineers and consultants to efficiently integrate building systems and improve the public health and welfare.

Architecture is also critical to STEM-related research that has far reaching impacts on our society beyond the design and construction of buildings. Architectural faculty are addressing energy, public policy, resiliency, and urban design through utilizing robust scientific and engineering knowledge and methods in their research projects. Green building strategies and materials research are tested in university-led laboratory simulations or post-occupancy analysis of cutting edge buildings. STEM-based architectural research is vital to improving the quality of the built environment, reducing energy consumption, and health and well-being.

Architectural researchers bring distinct qualities to research such as an inherent applied-research focus, interdisciplinary projects, and design-based thinking. Researchers are disseminating their work in traditional publication venues and simultaneously, applying their findings into projects for communities, housing, and transportation. Researchers are creating design guides and software to reduce factors that cause asthma, to increase water efficiency, and to sustainably plan projects. Architectural training enables faculty to lead interdisciplinary research projects and partnering with such fields as engineering, ecology, and medicine, paralleling the design of buildings where the expertise and priorities of multiple fields are incorporated to create something larger together. An additional benefit of architectural research is that it can be quickly incorporated and tested in their intended use. ASCA members are constructing prototype buildings, wall assemblies, and new materials that are being used to continue their research and at the same time winning design awards.

Architecture is a STEM discipline, though not obviously apparent in the acronym. Science, technology, engineering, and math are essential to the education, practice, and researchers in the field. A 2017 internal study by ACSA found that members are already engaged in over $23 M of STEM-related research from sources including the National Science Foundation, US Department of Energy and the National Institutes of Health. The Associated Collegiate Schools of Architecture supports this work and once again requests that architecture be recognized for its contribution to STEM and for the potential of architectural research.

Appendix B

ACSA Statement of Support for inclusion of CIP code 04.0201 Architecture on Department of Homeland Security's STEM Designated Degree Program list

The Association of Collegiate Schools of Architecture (ACSA) is a nonprofit association of over 200 member schools. These include all accredited architecture degree programs in institutions of higher education in the United States, as well as government-sanctioned schools in Canada. Through this membership, over 5,000 faculty members in architecture and allied disciplines are represented. Serving as the voice of architectural educators, ACSA is the forum for ideas and issues that will affect architectural education and practice, design and building industry research, policy development, and liaison with allied professionals.

Architecture is a STEM discipline. The Board of Directors of the ACSA respectfully asks Department of Homeland Security to include CIP code 04.0201 Architecture on the STEM Designated Degree Program list.

CIP code 04.0201 is assigned to the majority of professional architecture programs accredited by National Architectural Accrediting Board (NAAB). First-professional Bachelor and Master of Architecture degrees from NAAB accredited programs are prerequisites for licensure and practice in most states in the US and Canada.

NAAB Conditions for Accreditation requires architecture programs to demonstrate student's proficiency in building science, mechanical engineering, structural engineering, and building construction technology, well-accepted STEM disciplines. In fact, 10 out of 26 Student Performance Criteria (SPC's) are directly about each discipline or application/ integration of these disciplines into the architectural design. This breadth of STEM content in our discipline is necessary as architects lead multidisciplinary teams of designers, engineers, and consultants to efficiently integrate building systems and improve the public health and welfare.

Architecture is a STEM discipline, though not obviously apparent in the acronym. Science, technology, engineering, and math are essential to the education, practice, and researchers in the field. Moreover, it is one of the key disciplines to address energy and climate change issues critical to the technology enterprise for US to successfully compete, prosper, and be secure in the global community of the twenty-first century.

Appendix C

Funding Agencies and Programs

Federal Funding Agencies
National Science Foundation (x 12)
NSF CAREER
Social Sciences and Humanities Research Council of Canada
DOE
NEA (x 3)
Chinese government
National Endowment for the Humanities
National Institutes of Health

Governmental Organizations
National Institute of Standards and Technology of the US Department of Commerce
U.S. Deptartment of Housing and Urban Development (x 2)
United States Environmental Protection Agency (x 3)
Department of State
Department of the Navy (x2)
US Department of Transportation
Centers for Disease Control and Prevention (CDC) (x 2)
Parks Canada
National Park Service

Industry
Autodesk (x 2)
Ford Motor Company (x 5)
Precast/ Prestressed Concrete Institute Foundation (x 4)
Perkins & Will
AECOM/Stantec
Takenaka Construction (Kyoto, Japan)

National Organization
American Institute of Architects (x 5)
The Nature Conservancy
American Philosophical Society
Canada Council for the Arts
Social Sciences and Humanities Research Council (x 2)
Social Sciences and Humanities Research Council of Canada
Society of Architectural Historians
Canadian Centre for Architecture (x 2)
Council on Tall Buildings and Urban Habitats
Landscape Architecture Foundation

Private Foundations
National
Andrew Mellon Foundation (x 4)
WK Kellogg Foundation
Graham Foundation (x 6)
Charles Pankow Foundation
Alfred P. Sloan Foundation (x 2)
Kresge Foundation
Knight, John S. and James L., Foundation
W.M. Keck Foundation
MacArthur Foundation, Housing Matters
Regional
Barr Foundation

Appendix D

List of Programs filed under CIP code 04.0902

Institution	CIP Code	Graduate Degree	Undergrad Degree	Confirming Display on Website
Arizona State UniversityTempe	4.0902	MARCH		https://design.asu.edu/degree-programs/architecture-march
Ball State Univ.	4.0902	Graduate Certificate in Digital Design and Fabrication		https://cms.bsu.edu/-/media/www/departmentalcontent/factbook/1617pdfs/cip%20codes%20by%20college%20and%20department%20for%20fact%20book_2016-17.pdf?la=en
Carnegie Mellon University	4.0902	MSBPD/PhD-BPD/MSSD/MSCD/PhD-CD (STEM Designated)		https://soa.cmu.edu/graduate/
Colombia GSAPP	4.0902	MARCH		https://www.arch.columbia.edu/admissions
Georgia Institute of Technology	4.0902	MARCH/MSARCH		https://arch.gatech.edu/news/georgia-tech-master-architecture-now-stem-degree-program
University of Michigan	4.0902	MARCH/MSARCH/MUD/MURP		https://taubmancollege.umich.edu/architecture/degrees/master-architecture https://taubmancollege.umich.edu/architecture/degrees/master-science-architecture http://taubmancollege.umich.edu/architecture/degrees/master-urban-design https://taubmancollege.umich.edu/urbanplanning/degrees/master-urban-and-regional-planning
Philadelphia University (Thomas Jefferson Univ)	4.0902	MSARCH/MSSD		http://www.philau.edu/msarch/ http://www.eastfalls.jefferson.edu/green/index.html
Rensselaer Polytechnic Institute	4.0902	MARCH, MSARCH, and MSAS		http://www.arch.rpi.edu/academic/graduate/
Savannah College of Art and Design	4.0902	MARCH	BFA Arch	https://www.scad.edu/sites/default/files/PDF/SCAD-Majors-by-CIP-Code-degrees.pdf
University of Massachusetts Amherst	4.0902	MARCH	BFA ARCH	https://www.umass.edu/architecture/news/stem-designation
University of Minnesota Twin Cities	4.0902	MSARCH (various concentration)		http://arch.design.umn.edu/programs/msrp/
University of Pennsylvania	4.0902	MARCH/MEBD/MS-Des/MSHP/MUSA		https://www.design.upenn.edu/news/post/five-penndesign-programs-earn-stem-designation
University of Washington Seattle Campus	4.0902	MARCH-HPB (Post P) MSARCH MSCM		http://grad.uw.edu/admissions/find-a-program/

Appendix E

Program definition for CIP code 04.0902 annotated with the corresponding 2014 NAAB SPC
***courtesy of Andrew Vernooy, Montana State University**

CIP Code 04.0902
Architectural and Building Sciences/Technology

Definition: A program that focuses on the application of advanced technology to building design (A.2, A.4, A.5, B.2, B.3, C.3) and construction (B.4, B.5, B.6, B.7, B.8, B.9), retrofitting existing buildings, and efficient operations of buildings (D.1), including lighting and daylight design (B.6, B.7), acoustics (B.6), solar design (B.2, B.6), building conservation, and energy conscious design (B.2 B.3, B.6). Includes instruction in architecture (All Design Studios above 1st Year), building technology (B.1 through B.9, C.1 through C.3), civil and structural engineering (B.2, B.5), mechanical engineering (B.6), environmental control systems (B.6), sustainability (B.2, B.3, B.6, C.2), and computer tools applications (A.1, B.4, C.2).

Links to Additional Information

STEM 2026
https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf

OPT Information
https://www.uscis.gov/working-united-states/students-and-exchange-visitors/students-and-employment/optional-practical-training

OPT information
www.nafsa.org/stemoptrule

STEM Designated Degree Program list
https://www.ice.gov/sites/default/files/documents/Document/2014/stem-list.pdf

STEM and Diversity
https://www2.ed.gov/about/inits/list/hispanic-initiative/stem-factsheet.pdf

Information on CIP/SEVIS
https://www.nafsa.org/Resource_Library_Assets/Regulatory_Information/Managing_The_Transition_From_CIP_2000_to_CIP_2010_Codes_In_SEVIS/

CIP Codes
https://nces.ed.gov/ipeds/cipcode/Files/Introduction_CIP2010.pd

National Science Foundation (NSF). 2018. GRFP, NSF Graduate Research Fellowship Program Primary Fields.
https://www.nsfgrfp.org/applicants/application_components/choosing_primary_field

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