

Mixed Methods in Built Environment Research

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Built environment research problems often require a combination of research tactics and strategies that span across multiple disciplines. A mixed methods approach, which draws upon both quantitative and qualitative research methods from multiple disciplines, is often the most appropriate approach for design and construction research. A mixed methods research design offers a platform to mix both qualitative and quantitative methods from varying disciplines to best solve even the most complex interdisciplinary research problems. One of the key challenges of mixed methods research is how to best select and mix research tactics to answer the hypothesis and research questions effectively. It is important to find literature and precedent if possible to justify the selection of research tactics. This paper introduces the context and rationale for the use of mixed methods, defines the most common types of mixed methods research designs (and associated challenges and limitations), and also provides an example of how mixed methods research can be utilized in interdisciplinary built environment problems.

Key Words: Mixed methods research, High-performance buildings, Interdisciplinary, Sequential explanatory

Disciplinary Perspectives and Research Designs

In general, disciplines fall under one of three overarching disciplinary categories: natural science, humanities and social science. Each disciplinary realm is typically associated with particular epistemological views and methodological approaches (Repko, 2008). For the sake of clarity, this discussion will only refer to three primary views: positivist, interpretivist or postmodernism. In many cases, built environment research is housed in the social sciences or humanities, however, some built environment research may fall under the area of natural sciences (e.g. effects of lighting on circadian rhythm or indoor air quality, construction materials and the effects on human health).

Depending on the research focus, researchers in the social sciences, humanities, or natural sciences may embrace a positivist, interpretivist or postmodernism epistemological view. These epistemological views inform how and what one studies, much of the literature, and the methods used for research inquiry. It should be noted that these epistemological approaches are not exhaustive, and there are other recognized terms for varying systems of inquiry (constructivist, naturalist, emancipatory, etc.); additionally, terminology may differ since built environment research often crosses into other disciplinary boundaries.

Each discipline has a differing worldview and accepted set of assumptions that guides the preference for qualitative or quantitative methods research designs. However, the differentiation between quantitative and qualitative research is slowly shifting, especially so in interdisciplinary studies. “In reality, the quantitative/qualitative distinction is becoming increasingly blurred...interdisciplinary programs that take interdisciplinarity itself as a focus tend toward a much broader coverage of methods” (Repko, 2008, p.111).

Groat and Wang (2002) posit that it is more precise to identify the overarching research *strategy* (method) and subsidiary *tactics* (techniques) when creating a research design, as tactics are blind to strategies. Oftentimes, built environment research problems call for a combination of methods that span across multiple disciplines, so a mixed methods approach, which draws upon both quantitative and qualitative research methods from multiple disciplines, is often the most appropriate approach for design and construction research. A mixed methods research design offers a platform in which to mix both qualitative and quantitative methods from varying disciplines to best solve the

problem at hand. However, it is important to understand that differing disciplinary assumptions, literature, and theories profoundly affect the selection of research methods, so special care should be taken when mixing methods. Mixed methods research is defined as a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative data during a single study, either concurrently or sequentially, to gain a better understanding of the research problem (Creswell, 2009; Tashakkori, & Teddlie 2003). The rationale for mixing both quantitative and qualitative methods in a research design is grounded in the notion that neither method is sufficient by itself (Plano Clark, & Creswell, 2008).

This paper first introduces the context and rationale for the use of mixed methods, defines the most common types of mixed methods research designs (and associated challenges and limitations), and also provides an example of how mixed methods research can be utilized in interdisciplinary built environment problems.

Mixed Methods Research Defined

In mixed methods research, researchers must consider three issues when choosing the most appropriate route for the overall design: 1) priority, 2) implementation, and 3) integration (Creswell, Plano Clark, Guttman, & Hanson, 2003; Tashakkori, & Teddlie, 1998). Ivankova (2002) clearly differentiates between these aspects.

> Priority refers to which method, either quantitative or qualitative, is given more emphasis in the study. Implementation refers to whether the quantitative and qualitative data collection and analysis comes in sequence or in chronological stages, one following another, or in parallel or concurrently. Integration refers to the phase in the research process where the mixing or connecting of quantitative and qualitative data occurs. (p.44)

Mixed methods research has significantly evolved from its start in the 1950's, and it is becoming more widely acknowledged as a valid research approach (Tashakkori, & Teddlie, 2009).

Types of Mixed Method Designs

There are many types of mixed methods research designs that one can implement (Creswell, 2003, 2009; Creswell, & Plano Clark, 2011; Tashakkori, & Teddlie, 2003; 2010). Different variations and names for design types do exist, but this paper will follow those outlined by Creswell and Plano Clark (2011).

Each of these design types have inherent strengths and weaknesses. Following are the primary strengths and weaknesses for several mixed methods research designs. The following list is not exhaustive, but is representative of the common research design strengths and weakness as identified by several authors (Creswell, 2009, 2010; Creswell and Plano Clark, 2011; Tashakkori, & Teddlie, 2010).

Convergent design. The convergent design has many strengths as it is intuitive and efficient in nature because both phases of data collection can occur at the same time. Data analysis can also happen concurrently, which can save valuable time. However, there are also many challenges with this particular research design. First, it can be very challenging to merge two sets of different data types successfully. Second, researchers must consider the research outcome if the two data sets do not agree with one another. Lastly, much effort and expertise is required in data collection in both quantitative and qualitative phases; for this reason, team research is suggested (Creswell, 2011; Tashakkori, & Teddlie, 2010).

Sequential explanatory. The advantages of this research design include the following: (1) it is easy to implement because of the distinct two-phase structure; (2) it appeals to quantitative researchers as it begins with this phase, (3) it is straightforward in nature, and (4) the design is easier to describe and report than other mixed method designs because of the two separate sections. However, the major weakness of this study design is the length of time it takes to complete since the quantitative and qualitative phases must be completed separately (especially if the phases are given equal weight). Additionally, it may be difficult to get IRB approval with this design type, as the researcher cannot specify the how participants will be selected in the qualitative phase prior to the start of the study. (Creswell, 2009, p.210; Creswell, 2011, p.83).

Sequential exploratory. The advantages of this design are similar to the sequential explanatory type due to its straightforward nature. Also, this research design is more likely to appeal to researchers more confident in qualitative methods, and the inclusion of a quantitative phase can make the research more valid in the eyes of quantitative-based researcher. The inherent challenges are also similar to those in the sequential explanatory type in that it is very time consuming, and IRB approval can be difficult to secure because not all participants can be identified at the study start (Creswell, 2011).

Embedded design. One major strengths of the embedded design is that it is less time consuming because the researcher does not have to place equal emphasis on both phases, and both data sets can be collected simultaneously. In addition, two separate sets of questions make it easier to publish results in two separate works. The challenges to the embedded design are very similar to those of the concurrent design. Probably the most difficult aspect of this design type is that it can be difficult to combine and analyze two totally separate datasets in a meaningful way (Creswell, 2009, 2011).

Transformative design. Many of the advantages of this design align with those previously mentioned. However, one strength unique to transformative design is its ability "to empower individuals and bring about change and action" (Creswell, 2011, p.99). This method allows researchers to involve the participants and the community in the research process. However, this design can easily fail if participants do not trust the researcher, possibly nullifying the results. Also, there are few examples in the literature of this design type for guidance (Creswell, 2011).

Multiphase design. The strengths of the multiphase design lie in its flexibility and ability to conduct multiple, iterative studies over a several-year period. Some of the challenges of this approach include the large amount of time and focus involved. Also, because the multiphase design oftentimes occurs over a long period time, and through many phases, the researcher may have to apply for IRB approval multiple times.

The following section provides an example of a sequential explanatory mixed methods design in the context of built environment research.

Mixed Methods Research Example

Understanding high performance buildings: the link between occupant knowledge of passive design systems, corresponding behaviors, occupant comfort and environmental satisfaction (*see Day & Gunderson 2014).*

High performance building strategies have the potential to both greatly reduce building energy use and positively impact occupant productivity, satisfaction, and comfort if operated as intended (Edwards & Torcellini, 2002). However, negative outcomes can arise from uninformed or unintentional interactions with the high-performance building systems. These challenges are further compounded by poor occupant understanding of building design strategies and their intent and use. The literature suggests that building occupants and their interactions with the building have the potential to either squander or contribute to energy efficiency goals (Day & Gunderson, 2014). If occupants understand the building and environmental control systems, then they may contribute to lower building energy use and increase overall satisfaction with their work environment (Janda, 2011). Alternatively, if users do not understand building controls, then energy use may increase if systems are overridden incorrectly or occupants may be less satisfied with their environment due to decreased thermal or visual comfort. Therefore, it is critical that building occupants understand how to use their buildings effectively for maximum energy savings and comfort.

The Research Purpose

Ultimately, occupants' behaviors within their environment can have a tremendous impact on a building's overall energy savings potential. Since lighting, heating and cooling are such a large component of energy demands in office settings, this research specifically focused on user interactions with (and comprehension of) daylight controls, electric lighting, and thermal controls (including both natural ventilation and mechanical controls if applicable). The problem of effective occupant education in high performance buildings is a highly complex issue and cannot be solved by one discipline alone. The purpose of this research was to better inform future occupant education efforts in

high performance buildings. Therefore, this study used an interdisciplinary and mixed methods approach to identify and assess existing occupant educational strategies, occupants' overall satisfaction, and occupants' comprehension of varying high-performance building strategies.

Since this research blended both qualitative and quantitative research tactics, both a hypothesis and research questions were used to guide the research. Some of the research questions were best answered with qualitative data and analyses, some with quantitative data and analyses, and some utilized a mixture of both.

H_1: Occupants who received training for high performance building strategies (such as blinds, natural ventilation, thermal controls, or electric lighting) will demonstrate an increased level of reported environmental satisfaction when compared to individuals who did not receive any kind of training.

- RQ1: Did building occupants receive any training or education surrounding high performance building systems?
- RQ2: Do occupants understand how to effectively control, change or override the building controls?
- RQ3: What are the types of delivery methods for occupant training, and which were most effective?
- RQ4: Were trainings delivered one time, continuously, or intermittently?
- RQ5: How do individuals best learn a new concept?
- RQ6: Is there a difference between an occupant's reported learning style and the assessment of the effectiveness of the training they received?
- RQ7: Is there a difference between the building size and effectiveness of training?
- RQ8: In general, what were the most common high-performance building complaints and appraisals? **
- RQ9: Is there a difference between the climate type and thermal satisfaction or visual satisfaction? **
- RQ10: Are individuals who reported health issues more or less satisfied with their office environment? **
- RQ11: How did satisfaction appraisals differ among groups?
- RQ12: Why do occupants interact with the blinds, electric lighting or thermal controls?
- RQ13: For what reasons do occupants choose *not* to interact with high performance building features?
- RQ14: How often do occupants interact with, change or override the blinds?

This research required an interdisciplinary and mixed-methods approach since no one discipline alone could effectively study the effectiveness of existing occupant training programs in high performance buildings. This research borrowed from many disciplinary perspectives and corresponding research tactics. Therefore, it was crucial the selected mixed methods research design embraced the various disciplinary methodologies, and mixed the selected tactics appropriately. For example, quantitative Post Occupancy Evaluation (POE) surveys are typical in both the design and architectural fields, while qualitative interviews and thematic coding are frequent in the discipline of education. Blending these techniques provided a deeper understanding of the research problem.

Justification for a Mixed-Methods Approach

A mixed-methods research design offers a platform in which to incorporate both qualitative and quantitative methods from varying disciplines to best solve the problem. This research study utilized a mixed-methods design for three primary reasons: 1) to best suit the interdisciplinary nature of the research, 2) to better understand the research problems by identifying both broad qualitative trends and detailed quantitative results, and 3) to collect documentation and conduct interviews to help explain the results found in the quantitative phase (Creswell, 2009). The next section of this paper presents the overall research design. Subsequent sections will define these phases and tactics in more detail.

This research followed a sequential explanatory mixed-methods design. The first phase of the study included open-ended interviews with experts in the field, examination of records, databases and literature to determine the population for the second, quantitative, phase of the study. The second phase of the study implemented a large-scale survey, which was distributed online via email to individuals in high performance office buildings. Additional quantitative data were collected during the study including building energy use data (when available), as well as climate data. In the third phase of the study, semi-structured phone and email interviews with facility managers, occupants, and architects were conducted, and building specific documents such as photographs, site plans, green building certification documentation, and architectural drawings were also collected.

This research could have been approached in multiple ways, but a sequential explanatory mixed-methods design was the most logical choice for the research questions posed in this study. Much of the current research in the area of high performance buildings is highly quantitative in nature, and therefore, fails to thoughtfully address the subjective human aspect of building performance. Through review of the literature, practice, and experience, it has become evident that much of the research in energy efficiency views the occupant as a hindrance to optimal building energy use, rather than a solution. It is important to understand *how* and *why* occupants interact with building systems since humans play such a large role in energy efficiency (Janda, 2011); therefore, it was imperative the subjective opinions and actions of occupants were also studied and understood. The survey results from the quantitative phase allowed the researcher to gain a broader understanding of existing educational programs in high performance buildings, which helped to identify buildings for follow-up occupant interviews and case studies. It should be noted that while there are many advantages to the selected methodology, there were also limitations.

Sequential explanatory advantages and limitations. The advantages of this research design include the following: (1) it is easy to implement because of the distinct phased structure; (2) it appeals to quantitative researchers as it typically begins with this phase (which is not the case in this research), (3) it is straightforward in nature, and (4) the design is easier to describe and report than other mixed-method designs because of the separate sections. However, the major weakness of this study design is the length of time it takes to complete since the quantitative and qualitative phases must be completed separately (especially if the phases are given equal weight). Additionally, it may be difficult to get IRB approval with this design type, as the researcher cannot specify how participants will be selected in the qualitative phase prior to the start of the study (Creswell, 2009, p. 210; Creswell, 2011, p. 83). However, in this instance, IRB approval was granted in two weeks.

An Overview of the Mixed Method Design

The first phase of this sequential explanatory protocol was qualitative in nature and included interviews with experts in the field and the compilation and coding of a high-performance database. The second, quantitative, phase of the study primarily consisted of a web-based survey, and the third phase included interviews and document analysis. The survey responses and *occupant* interviews, gathered sequentially, were the primary means of data collection. However, it should be noted that even though it was initially intended that the research occur in two distinct phases, at times varying research tactics were implemented and mixed throughout the study as necessary. For instance, qualitative interviews with experts in the field (n=3) occurred prior to the quantitative phase of the study to help identify the sample population for the survey distribution. All of the phases were mixed throughout, but the results were integrated at the conclusion of the study and the qualitative results were used to explain and interpret the quantitative findings.

Also, it was difficult to exclusively collect quantitative or qualitative data during the study, and sometimes the information was collected simultaneously as required. For instance, a request to a building owner for survey participation often led to an interview during an initial request. Even though tactics were mixed throughout as needed. Figure 1 (based on Creswell & Plano Clark, 2011) illustrates the overall methodological approach, including the primary phases (qual, QUAN & QUAL), procedures and corresponding products, for this research.

Data Collection

Both quantitative and qualitative data were collected from a total of 56 buildings; 53 of the buildings were scattered throughout the United States, one building was in Canada, and two were selected from Europe as examples of exemplar occupant training programs. Also, two additional interviews of experts in the field were conducted during the qualitative phase, but their responses did not necessarily correspond with a particular building, but rather, the idea of occupant education in buildings in general. A concentrated effort was made to obtain a wide range of data from diverse climates and buildings. Although the sampling technique shifted during the study, some data were still collected from high performance buildings in almost nearly climate type.

Data collected included location, zip code and climate zone for each building. Additionally, energy use, surveys, interviews, photographs, architectural drawings, educational materials, existing reports, other documentation, and

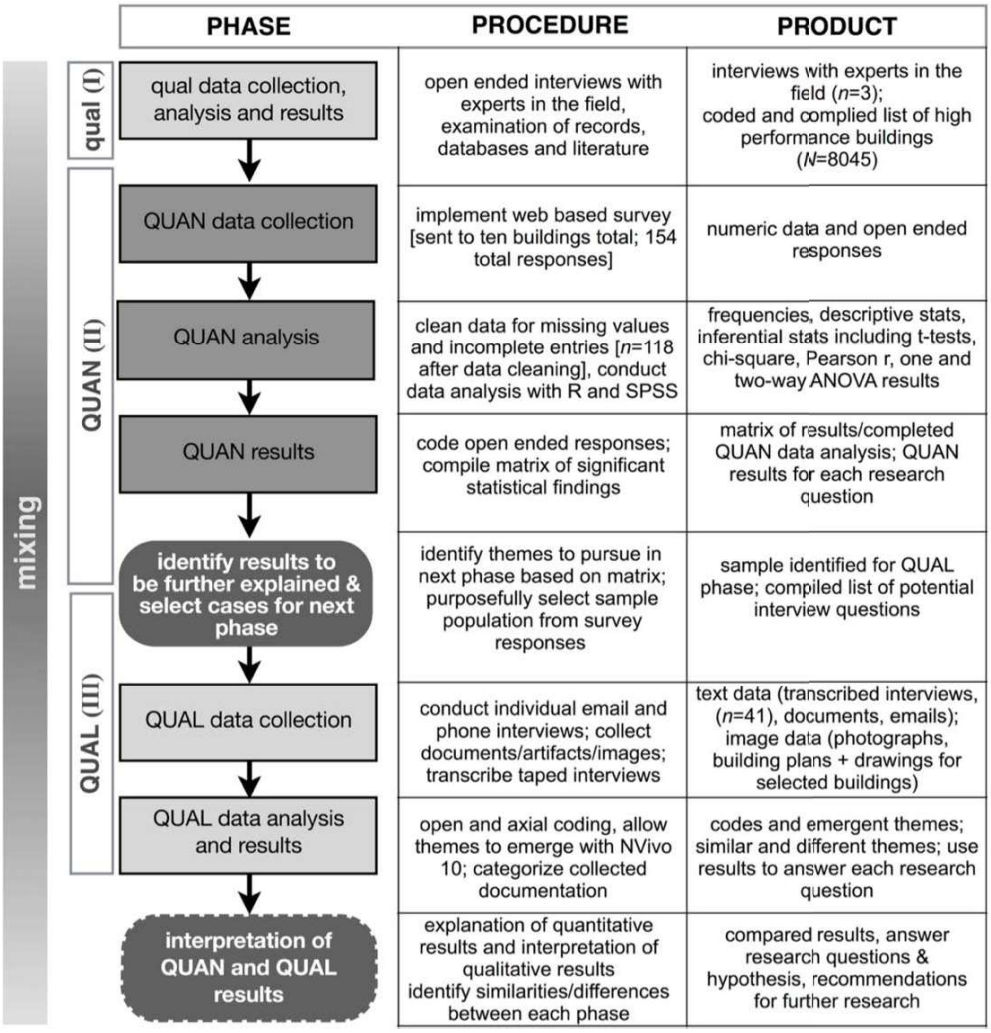
presentations or online lectures were gathered for buildings when possible. The majority of analyses focused on the survey and interviews, but the other data collected helped to supplement individual responses. While this section has provided an overview of how data were collected, the next section breaks down the participants, data collection and data analyses for each phase of the research.

Phase I | Qualitative

The first phase of this sequential explanatory study was qualitative in nature and included interviews with experts in the field and the compilation and coding of a high-performance database. It was necessary to conduct this phase prior to the quantitative phase because appropriate high-performance buildings had to first be located for the survey.

Phase II | Quantitative

The quantitative component of this research implemented an online survey. The primary quantitative research design was non-experimental in nature and sought to gather information about occupants *in-situ* through the online survey. This type of design is seen as the weakest in terms of internal validity in quantitative research. However, this particular study did not seek to find a causal relationship, so internal validity was not relevant (Trochim & Donnelly, 2008). In addition, it is important to point out that when conducting built environment research, it can be difficult to establish and measure validity in a purely scientific way – oftentimes there are variables that cannot be controlled. In these cases, researchers should report these limitations clearly when disseminating new knowledge.



PHASE	PROCEDURE	PRODUCT
qual data collection, analysis and results	open ended interviews with experts in the field, examination of records, databases and literature	interviews with experts in the field (*n*=3); coded and complied list of high performance buildings (*N*=8045)
QUAN data collection	implement web based survey [sent to ten buildings total; 154 total responses]	numeric data and open ended responses
QUAN analysis	clean data for missing values and incomplete entries [*n*=118 after data cleaning], conduct data analysis with R and SPSS	frequencies, descriptive stats, inferential stats including t-tests, chi-square, Pearson r, one and two-way ANOVA results
QUAN results	code open ended responses; compile matrix of significant statistical findings	matrix of results/completed QUAN data analysis; QUAN results for each research question
identify results to be further explained & select cases for next phase	identify themes to pursue in next phase based on matrix; purposefully select sample population from survey responses	sample identified for QUAL phase; compiled list of potential interview questions
QUAL data collection	conduct individual email and phone interviews; collect documents/artifacts/images; transcribe taped interviews	text data (transcribed interviews, (*n*=41), documents, emails); image data (photographs, building plans + drawings for selected buildings)
QUAL data analysis and results	open and axial coding, allow themes to emerge with NVivo 10; categorize collected documentation	codes and emergent themes; similar and different themes; use results to answer each research question
interpretation of QUAN and QUAL results	explanation of quantitative results and interpretation of qualitative results identify similarities/differences between each phase	compared results, answer research questions & hypothesis, recommendations for further research

Figure 1: Model for sequential explanatory mixed methods design.

The independent and dependent variables being compared varied depending on the research question. However, typically, the environmental satisfaction ratings represented the dependent variables whereas others, such as building size, type of training received, and learning style, characterized the independent variables.

Survey Design. In total, there were 51 questions on the survey. The survey was divided into five main categories to better understand the following: (1) office attributes, (2) the presence and type of training for *(a) manual blinds, (b) automatic blinds, (c) natural ventilation, (d) temperature controls, and (e) electric lighting*, (3) satisfaction with the office environment, (4) learning styles, and (5) demographics. Both open-ended and closed-ended questions were included on the survey. Satisfaction responses were assessed through a seven point Likert scale, which ranged from 'strongly disagree' (1) to 'strongly agree' (7). A five-point scale, from never (0) to always (4), was used for frequency ratings under the learning style section. Multiple choice and yes/no responses were used throughout the survey. Before data analysis, each of the questions within the survey was coded as nominal, ordinal, categorical, interval or open-ended so the appropriate statistical tests could be selected.

Additional quantitative data collected included climate and energy use data. Climate data were easy to locate based on a building's location; however, it was not possible to collect energy data for all buildings. In addition, much of the energy data gathered were either representative of differing years or forms of measurement, so it was not possible to directly compare the building occupants' survey responses with actual energy use data.

Phase III | Qualitative

The qualitative phase included semi-structured and open-ended interviews, along with collection of building specific documentation. The interview responses, visual data and documents were collected to help answer the *how* and *why* aspects of the research questions as presented in the previous section. While each building was unique, collecting data across varying types of climates and high-performance buildings helped to strengthen the overall generalizability of the qualitative results. Furthermore, these results, coupled with the quantitative data, helped to reinforce the overall research design and validity (Creswell, 2009).

Interviews. The most prominent method of data collection was through semi-structured and open-ended interviews with occupants, owners and building managers via telephone and email. Semi-structured interviews fall somewhere between fully structured interviews, which are inflexible in nature, and unstructured interviews, which are not typically preconceived before an interview. As such, questions were developed before the interviews as a guide, but they remained flexible based on the occupants' knowledge of the building, the types of strategies used in the building, and the nature of the conversation (Willig & Stainton-Rogers, 2008). This approach allowed for more flexibility during the interview, and it also allowed for some responses to emerge that may not have with a more defined set of questions. The majority of telephone interviews were taped and later transcribed. Extensive notes were taken for the un-taped interviews; it was the researcher's intention to record all interviews, but some were not recorded due to equipment failure or inopportune callbacks from previously contacted interviewees. Interview questions varied widely and were based on individual answers from the survey, or the questions were specific to the building the occupant represented. Other means of qualitative data collection included the acquisition of photographs, maps, architectural documents and plans, and training materials if available.

Establishing validity, reliability and credibility. Rigorous data analysis techniques were used for all phases of this research, but it is important to point out that the criteria for measuring validity and reliability differs in quantitative and qualitative research. In quantitative research, validity means participants' assessments are meaningful indicators of the particular construct being measured (Creswell & Plano Clark, 2011). Qualitative *reliability* means that both the researcher's methods (Creswell, 2009) and the participants' responses are "consistent and stable over time" (Creswell & Plano Clark, 2011, p.211). Four respected methods were used to validate the qualitative findings to establish credibility and rigor during the second phase of the study: (1) *triangulation* – comparing different types of information (transcripts, documents, survey responses) (2) rich, *thick description* of the results; (3) identification of *disconfirming evidence* to confirm the accuracy of the findings (Creswell & Plano Clark, 2011; Creswell, 2009); and (4) *member checking* – a method of providing summaries to participants to see if the researcher's interpretation of their conversation was "right" (Marshall, & Rossman, 2011).

Discussion

Ultimately, findings from the mixed methods study outlined above contributed to new knowledge in the field. Most importantly, the study found that occupants who had received training on building elements were more satisfied with their environments and work place when compared to those who had not received training. This example illustrates just one way to utilize mixed methods in built environment research, specifically in a sequential explanatory design. There were limitations in this study. For example, the survey sample was challenging due to low response rates in some buildings and the shift from randomized sampling to purposeful convenience sampling (see Day & Gunderson 2014 for further information). Additionally, one of the challenges of mixed methods research is how to best select and mix research tactics to answer the hypothesis and research questions effectively. It is important to find literature and precedent if possible to justify the selection of research tactics. Ultimately, mixed methods can be useful in understanding complex interdisciplinary problems, especially within the context of built environment research.

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