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Evaluating the benefits of using the Building Code Calculator app for design educators and industry professionals

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Abstract

Technology has transformed the field of interior design, improving efficiency through the use of digital tools. However, calculating building codes remains a complex, time-consuming, and error-prone task. Mobile apps have demonstrated their ability to facilitate complex tasks such as calculating clinical scoring systems and medication dosage in the medical field. Despite this potential, user-friendly solutions for building code compliance remain limited. Therefore, this study aims to explore the experiences and challenges faced by design professionals when working with building codes and to assess their willingness to adopt a new mobile app designed to help with building code calculations. Using a mixed-methods approach, 31 participants from the Midwest and South Central regions, including industry professionals and instructors, were interviewed about their experience with building codes. Participants were then introduced to the Building Code Calculator (BCC) app and surveyed using the innovation diffusion theory framework. The interviews revealed that professionals and students experience challenges with the current available resources and traditional calculation methods. Professionals also recognize the potential of the BCC app in improving efficiency and enhancing students' learning. Survey results indicated strong agreement among instructors regarding the app's relative advantage, image, ease of use, result demonstrability, visibility, and trialability, indicating a high willingness to adopt the tool. In addition, statistical analysis using the one-sample Wilcoxon test suggested a significant difference between the observed median and the hypothesized median for all survey questions. These findings suggest that the BCC app can potentially enhance efficiency in professional practice and serve as a teaching aid in classroom settings.

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1. Introduction

1.1. The role of building codes

Interior design aims to create spaces that protect the health, safety, and well-being of the occupants while meeting their needs. Designers are responsible for various tasks, including space planning, egress, fire safety, lighting, material and finishes selection,

and accessibility. In addition, they are required to possess a diverse range of knowledge and skills to work on various types of buildings, as each building has its own set of requirements.¹

To ensure safety and compliance, interior designers must follow building codes and regulations. Codes are a set of laws and acts established by local, state, or national authorities to protect the public, such as the Americans with Disabilities Act, occupancy load, and egress.¹ The International Code Council developed building codes that are widely used throughout the United States to ensure safety and fire prevention in residential and commercial buildings.² These codes are often found in text documents (i.e., textbooks) and written in natural language for human interpretation. However, they can be ambiguous, causing confusion in understanding what the code requires.³

The design process begins with programming, where designers identify the client's needs. In the schematic stage, preliminary designs are produced before the development stage. Subsequently, construction drawings are provided to contractors during the construction phase.⁴ These documents must follow building and fire codes, municipal codes, and other jurisdictional regulations to obtain a building permit. Throughout this process, architects and designers collaborate with consultants and engineers to ensure that the design is both compliant and practical.^{1,4}

Similar to architects and engineers, interior designers share the same responsibility of protecting society's well-being. Therefore, their work is regulated to ensure safety, requiring professionals to have knowledge about building rules and regulations.¹ The National Council for Interior Design Qualification certifies individuals as professional interior designers through experience and examination. This examination assesses designers' knowledge of codes and regulations essential to occupant safety. Designers are also responsible for selecting fabrics that comply with fire codes and furnishings that meet Occupational Safety and Health Administration standards.¹

1.2. Challenges with building codes

Conventionally, checking for code compliance is done manually and after the design is completed. This method creates challenges since it heavily requires human intervention and interpretation, making it costly, time-consuming, and prone to errors. If the design is non-compliant, corrections could create challenges, as it may involve various modifications and would require rechecking for compliance.^{2,3} There have been various efforts to create automated building code checking systems, especially for Building Information Modeling. For instance, CORENET was the first automated building

code checking system that was used by the Architecture, Engineering, and Construction industries. DesignCheck was developed to automatically check against accessibility, while SMARTcodes aimed to convert text-based building code documents into computer-readable formats for automated checking.⁵ Altıntaş and İlal⁵ developed an automated code compliance checking system for zoning codes to improve the manual process. However, these tools, such as Solibri Model Checker, CORENET ePlanCheck, and DesignCheck, contain a fixed set of rules that require programming experience to create new or modify existing rules, making it difficult for non-programmers to understand and edit. Therefore, Sydora and Stroulia³ argued that computer-readable rules and guidelines could improve the evaluation process by automatically checking for code compliance and placing items according to design codes and guidelines.

1.3. Technology in interior design

Technology has vastly evolved in the field of interior design, transitioning from hand drafting and rendering to the use of design software that saves time, effort, and labor, such as AutoCAD, Virtual Reality, Sketchup, Revit, and Photoshop.⁶ Digital technology can also enhance cognitive skills and abilities, such as creativity and design thinking.^{4,6} Therefore, designers should stay updated with current trends and explore emerging technologies that can accomplish design tasks more quickly and more efficiently by reducing effort, time, and labor costs.⁶ For instance, Almaz *et al.*⁴ argued that architects must adapt and learn how to use new technologies, such as artificial intelligence (AI), in both professional practice and architectural education to prepare students for the increasingly digitized industry.

1.4. Usage of smartphones and apps for work

Smartphones are widely used for both personal and professional purposes, offering numerous benefits in the workplace. Studies have found that smartphones promote autonomy, improve relationships among colleagues, and enhance knowledge-sharing, which increases job satisfaction and promotes work efficiency. Smartphones with internet access allow individuals to perform various tasks on their devices.⁷ This tool also helps facilitate flexible, on-the-go learning.⁸ Apps are software programs designed to perform specific tasks on computers and mobile devices.⁹ For instance, the use of smartphones in the medical field has increased due to their ability to run applications such as medical calculating apps. These apps can help calculate complex clinical scoring systems that assess the severity or risk of diseases.¹⁰ Similar to building codes, these clinical scores involve complex formulas and

are manually calculated, making them time-consuming and error-prone. Other medical apps assist in calculating proper drug dosages.⁹ These apps provide instant results and are often used multiple times a day by doctors.¹⁰ Based on these findings, similar technology could be used in interior design for building code calculations to provide professionals with instant and accurate results.

1.5. Interior design apps

In interior design, most apps mainly focus on augmented reality (AR) to help visualize furniture in a physical space. For instance, Pranav *et al.*¹¹ developed an app that used AR to overlay virtual objects onto the real world, allowing users to see how the object would look in the physical world. Similarly, Dsouza *et al.*¹² developed an AR application for visualizing interior decor to improve decision-making. Sandu and Scarlat¹³ developed an AR app that scanned the room and allowed the removal of existing objects and the placement of virtual objects to help both clients and interior designers communicate their designs.

Miri¹⁴ developed an app to help lighting designers, professionals, and students conduct lighting analysis, allowing a quick and easy analysis compared to other methods that are time-consuming and prone to errors. In addition, Atwal *et al.*¹⁵ explored occupational therapists' perspectives on the use of virtual reality interior design applications to collaborate with patients in designing safe pre-discharge homes that met their needs.

1.6. Current building code-related apps

The Apple App Store and Google Play feature a few apps related to building codes. For instance, the International Code Council developed a digital code app designed to eliminate navigating through multiple code books, offering a faster way to search codes, organize notes, and collaborate more seamlessly (Figure 1).

Building Tools is another example; this app displays the Australian National Construction Codes through interactive diagrams, as shown in Figure 2, to reduce costly mistakes and increase efficiency. This app covers most of the codes used by designers, except for the occupancy load. It includes a critical icon feature that explains code requirements, along with references from the National Construction Codebook. In addition, the app allows users to share code information with others and is available on both platforms.

Another example is OneClick Code-Roofing Codes, an app that provides quick access to roofing building codes across the United States. It helps roofing contractors, insurance adjusters, and estimators save time and reduce

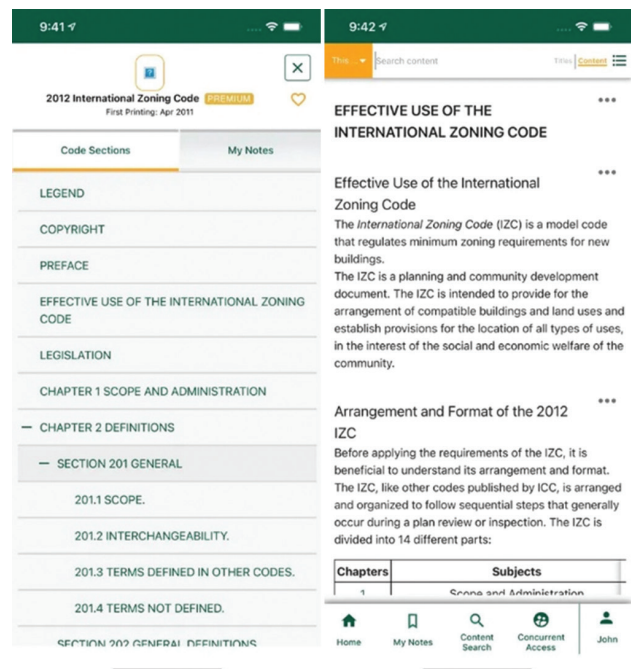


Figure 1. The International Code Council digital code application

costly errors. The app can calculate ice and water shield, waste, and ventilation requirements, and allows users to create and share detailed reports (Figure 3).

The Heights and Areas Calculator is an app that calculates the maximum allowable heights and areas for buildings based on different occupancies and fire protection requirements from the International Building Code. Figure 4 shows the basic and advanced forms of the calculator.

Trax Codes is an app that digitizes the Ontario Building Codes and the National Building Codes of Canada, offering the Architect, Engineer, and Construction professionals easier, on-demand access to up-to-date regulations, with the use of AI technology. Similarly, Building Codes Made Easier (Figure 5) is an app for property and liability claims, restorations, and legal professionals. This app helps legal professionals find and understand codes by providing them with simple answers, responses to frequently asked questions, and the ability to consult with code experts.

Despite advancements in automated compliance tools, there remains a gap in developing accessible building code solutions for interior designers. Although there are various attempts to create automated compliance checking systems—such as the system by Nguyen and Kim,² which utilized Autodesk Revit for collaborative compliance tracking—there are no apps designed to assist designers with building code calculations.¹⁶

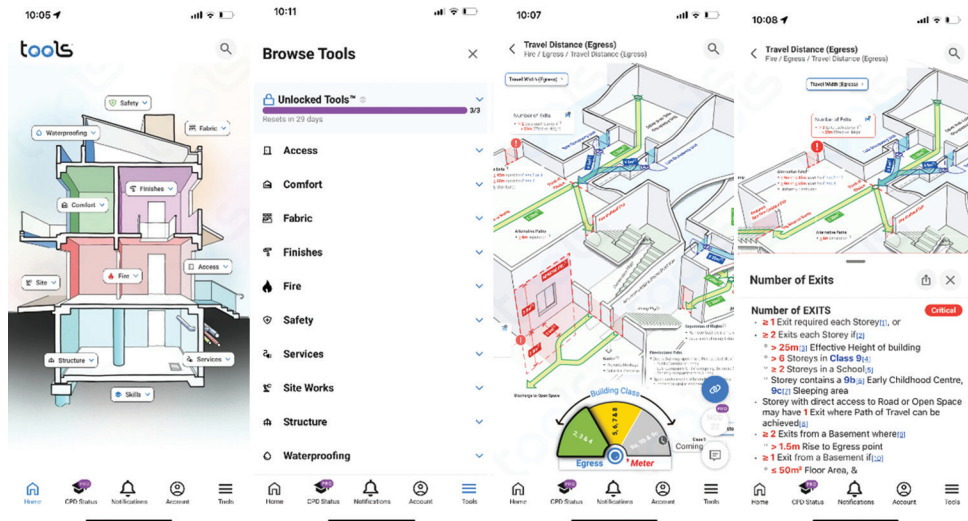


Figure 2. The Australian National Codes Building Tools application

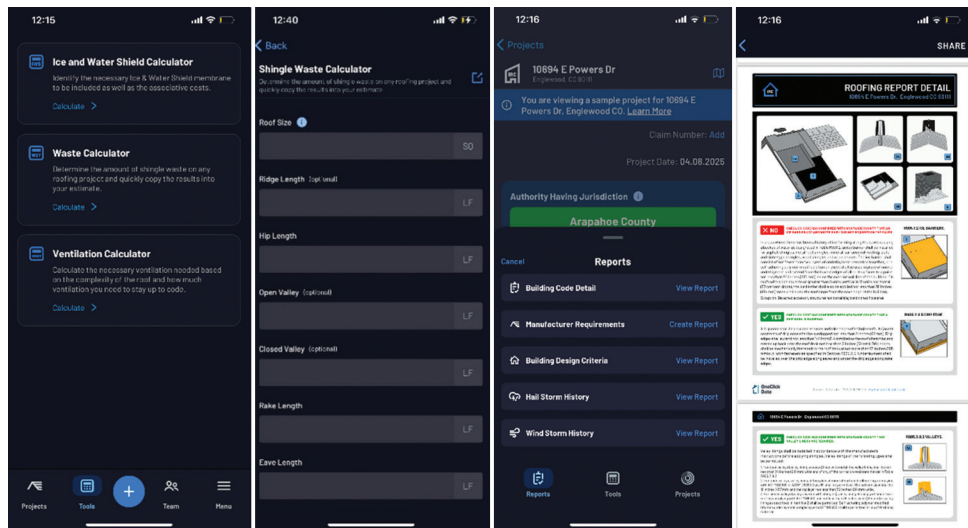


Figure 3. The OneClick Code-Roofing Codes application

1.7. Unique advantages of the Building Code Calculator (BCC) app

1.7.1. Support for creativity in the early design stage

One of the key differentiators of the BCC app is its emphasis on providing quick, real-time answers during the schematic design phase. Designers can use the app to check code compliance during initial sketches, allowing them to explore creative possibilities without worrying about overlooking code requirements. This capability is particularly useful during client meetings or when working on the fly, especially when the designer is away from a desktop computer.

1.7.2. Aid for student learning

In addition to aiding professionals, the BCC app is designed to support educational goals. Its visually appealing structure,

with step-by-step guidance and interactive visuals, makes it an ideal tool for students learning about building codes. Unlike other tools that present building code data in complex, text-heavy formats, the BCC app uses visuals and simplified workflows, making the learning process more intuitive and accessible.

1.7.3. On-the-go use for designers

Another key feature that differentiates the BCC app from other compliance-checking tools is its mobility. Designers can use the app on mobile devices while on-site, allowing them to check code compliance in real time without needing their computers. Whether answering a client’s question during a site visit or making quick adjustments to a design based on client feedback, the app facilitates fast, real-time decision-making.

1.7.4. Ease of communication between entities

The BCC app enhances communication between design teams, clients, and contractors by generating detailed PDF reports that include both input data and the results of compliance calculations. This feature ensures transparency and simplifies discussions, as all stakeholders can easily review the calculations and their underlying assumptions. By providing a clear, professional report, the app streamlines project management and ensures that everyone is on the same page, reducing the potential for miscommunication or misunderstandings.

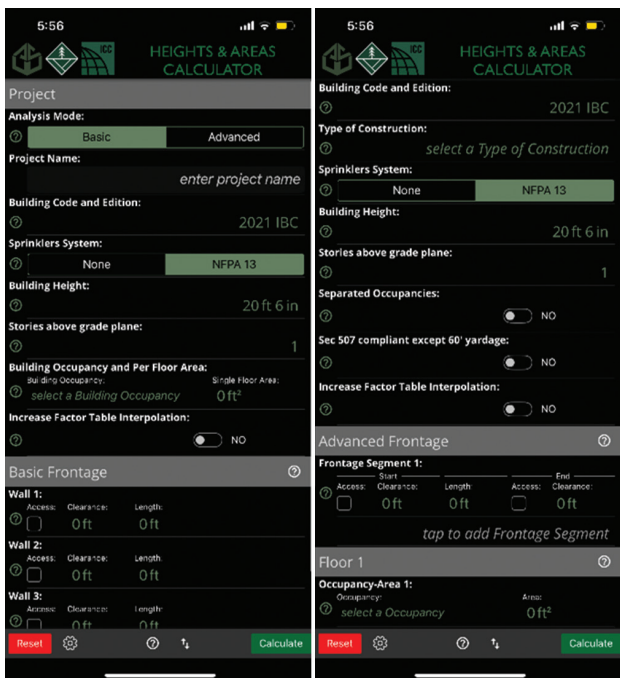


Figure 4. The Heights and Areas calculator application

1.8. Theory of technology adoption

The technology acceptance model explains users' motivations, attitudes, and responses toward the acceptance and usage of technology. When individuals are presented with a new technology, their intention to use and their actual use are influenced by perceived usefulness and perceived ease of use. Perceived usefulness is how individuals believe the new technology will help them complete a task. Perceived ease of use is the belief that using a new technology will require minimal effort.¹⁵ The innovation diffusion theory identifies five attributes that influence the acceptance of a new technology:

1.8.1. Relative advantage

The perspective that new innovations are better than previous ones.

1.8.2. Compatibility

The perception that innovation aligns with the potential adopters' values, needs, and past experiences.

1.8.3. Complexity

The perceived difficulty of using innovation.

1.8.4. Observability

The visibility of the benefits of using innovation.

1.8.5. Trialability

The ability to experiment with an innovation before adoption.¹⁷

2. Methodology

The BCC app was developed to help calculate complex building codes. At present, the BCC app addresses the

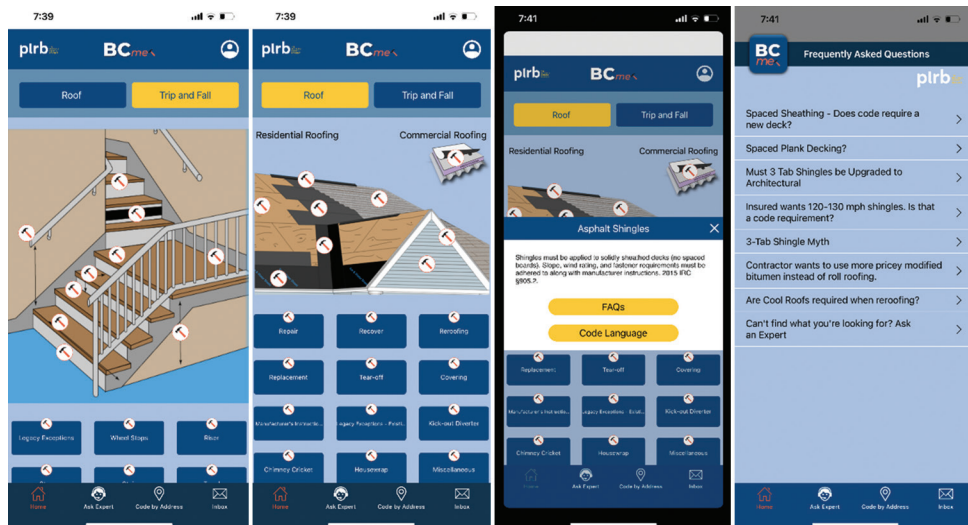


Figure 5. The Building Codes Made Easier application

occupant load calculation—a common challenge for design professionals, as it requires consideration of variables such as floor area, egress routes, and occupancy classification. The BCC app automates this process, allowing professionals to quickly determine the maximum occupancy for a space, ensuring compliance with safety regulations. In a typical scenario, the app could be used to calculate the occupant load for a dining space. For instance, the app will allow the designer to input dimensions and occupancy type, such as a dining area, and then automatically calculate the maximum number of people allowed in that room based on fire safety codes. This functionality saves time and reduces the risk of errors compared to manual calculation methods, which require interpreting complex tables and formulas from the building code. To explore how interior design educators and industry professionals perceive the benefits and usability of the BCC app, this study employed a mixed-methods approach, combining qualitative interviews and quantitative surveys.

2.1. Participant recruitment

The mixed-methods study recruited 31 participants, including instructors from universities in the Midwestern and South Central regions, as well as industry professionals from different sectors, such as interior designers, architects, fire marshals, code officials, sales representatives, and individuals working in finance. These participants were recruited through snowball methods, personal interceptions, personal contacts, and emails.

2.2. Study location and platform

The study took place in a south-central university. The interviews were conducted in person and virtually. In-person interviews took place in different settings, such as at networking events, conferences, and at institutions, while virtual interviews took place through Zoom. These sessions were recorded for transcription and analysis.

2.3. Data collection

Data were collected through interviews and surveys. Interviews were conducted with instructors and industry professionals to understand their perspectives, challenges, frequency of use, available resources, and implementation of building codes in their companies or classroom settings. The interview questions are outlined in Tables 1 and 2. The interviews were recorded, and field notes were taken when transcription was not feasible within the study's timeframe. Toward the end of the interview, participants were shown a tutorial demonstrating how the app functions and were given the opportunity to trial the prototype. Subsequently, surveys were conducted to understand instructors' perceptions

Table 1. Instructors' interview questions

No.	Interview questions
1	Which institution are you affiliated with?
2	What is your current position?
3	Do you teach/do research, or both?
4	What classes/levels do you teach?
5	Do you teach building code?
6	Can you tell me more about the building code components that you teach?
7	Can you walk me through a building code exercise that your students work on?
8	What did you like about the teaching experience related to building code?
9	What did your students like about their building code learning experience?
10	What is frustrating about building code teaching experience for you?
11	What is frustrating about the building code learning experience for your students?
12	Have you ever thought of looking up existing building code apps?
13	Have you ever had students mess up their building code calculations at a late stage in the design process? If yes, can you describe that experience to me?
14	How much would you/or your students pay to make this problem go away?
15	What other features would you like to see incorporated into the BCC app?

of the app, including its relative advantage, compatibility, complexity, observability, and trialability.

2.4. Interview procedure and app demonstration

After providing consent for recording and participation, participants were interviewed about their use of and challenges with building codes. They were then shown a video demonstrating how the BCC app functions. Following the demonstration, the participants were allowed to try the app on their personal devices by scanning a QR code. Finally, instructors were asked to complete a survey assessing their perceptions of the app, with items derived from the innovation diffusion theory. The interviews took approximately 20–30 min.

2.5. Data analysis

Both qualitative and quantitative data were collected in this study. Transcriptions of the interview recordings were obtained through Otter (version 3.57), an AI transcription tool. All transcriptions were carefully reviewed to correct errors and to understand the overall meaning of the responses. These transcripts were then analyzed in NVivo

Table 2. Industry professionals' interview questions

No.	Interview questions
1	Which company do you work for?
2	What is your current position?
3	What is your role in your company?
4	What type of projects do you work on?
5	Do you refer to the building code in your current job?
6	Can you tell me more about the building code components that you use?
7	Can you walk me through a building code scenario that you encounter?
8	What do you like about work experience related to building code?
9	What did your employer like about the building code work experience?
10	What is frustrating about building code work experience for you?
11	What is frustrating about building code work experience for your employer?
12	Have you ever thought of looking up existing building code apps?
13	Have you ever messed up building code calculations at a late stage in the design process? If yes, can you describe that experience to me?
14	How much would you/or your employer pay to make this problem go away?
15	What other features would you like to see incorporated into the BCC app?

(version NVivo 15.1.0) to generate codes. Afterward, these codes were analyzed to identify themes. These themes were organized into Tables 3 and 4. The quantitative data gathered from the instructor's survey responses were analyzed using descriptive analysis and a one-sample Wilcoxon test in the Statistical Package for the Social Sciences (SPSS Statistics 29), with a hypothesis median value set at 3 and a significance level (p -value) of 0.05.

3. Results

The interview questions for the industry professionals explored the frequency of code usage, project type, design stage, and types of code used. Findings indicated that the project type largely determined which codes professionals needed to consult. Many participants reported using international code standards such as the International Building Codes, the International Fire Codes, and the International Residential Codes, as well as national and local codes. In addition, the interviews revealed the workflow of collaborations among design team members and their responsibilities. Participants were unaware of mobile apps that could help them with codes, relying on online web

resources, creating Excel sheets, and using the physical code book as available resources. However, many expressed frustrations with existing resources, such as difficulties in finding information and understanding the language of the physical code book. Designers also experienced code miscalculations due to misinterpretations, leading to time-consuming revisions. When asked about how much they were willing to pay to resolve these issues, participants considered the app's value and suggested pricing models such as group licenses, subscriptions, free versus premium versions, and discounted prices for organization members. Other feedback included requests to incorporate additional resources and features into the app, expand code content, add a region selection feature, and implement marketing strategies.

Architects, architectural engineers, and interior design academic instructors, along with department heads and program directors, were also interviewed to understand how building codes are introduced and taught in academic programs. Students are introduced to building codes in their 2nd year and continue to apply them throughout subsequent lectures and studio courses. The codes taught include fire safety, occupancy load, plumbing, structural, and energy conservation codes. Based on their learning experience, students can embrace the rules, gain confidence, and develop reference resources. However, feelings of inexperience, intimidation by code complexity, and difficulty in memorizing and relating them to real-world experiences lead to frustration. The organization of the textbook further contributes to their frustration. Students also tend to miscalculate egress, corridors, floor openings, and compliance with the Americans with Disabilities Act guidelines. While these mistakes are part of the learning process, fixing them is time-consuming, and students are often reluctant to make changes.

Instructors reported appreciating the presence of concrete rules that challenge creativity. They enjoy teaching code through hands-on activities, helping students understand their relevance, and seeing them apply this knowledge in design projects. However, instructors also experience frustration due to the complexity and intimidation of codes, students' lack of interest or feelings of being overwhelmed, and the cost of the required codebook. Instructors are aware of online resources, plugins for Building Information Modeling software, physical code books, and instructional videos. One participant mentioned a Steel Code app, but no instructor was aware of the existence of BCC apps. Regarding the cost of the app, instructors suggested making the app free, offering a student discount, possibly through a subscription, or paid for by the department. Additional feedback includes adding other helpful app features and including more code content.

Table 3. Themes emerging from the industry professionals’ responses to the interview

Parameters/ questions	Themes	Codes	Example
Positions	Design	Architect	“Architect.”
		Interior design	“My title is interior designer.”
	Human resources		“Hiring and retaining talent”
	Business development		“Technology commercialization.”
	Public safety		“University fire marshal.”
	Sales and financing		“Materials sales rep.”
Project type	Commercial design	Healthcare	“But my current role is within the healthcare market.”
		Multifamily	“We did a lot of homes and a lot of multifamilies that were contracted out through firms throughout the United States.”
		Hospitality	“We did a lot of hotels.”
	Residential design	Single family	“Custom homes in the Park City area, where there’s a lot of money in the ski resort.”
Reference building code	Frequency		“I would probably say multiple times a week.”
	Stage		“During the design development phase.”
Building code components	International code standards	IBC	“Local codes, IBC, and IRC.”
		IRC	“Local codes, IBC, and IRC.”
		IFC	“The state of...is an I code state we use, IBC, IFC, IEBC.”
		IEBC	“The state of...is an I code state we use, IBC, IFC, IEBC.”
		ISO	“ISO is the international body for a global standard.”
		IMC	“Then we would move on to, and then it was sent to mechanical and plumbing, and electrical, we would go through those codes.”
		IPC	“Then we would move on to, and then it was sent to mechanical and plumbing, and electrical, we would go through those codes.”
	National and local standards	NFPA	“I also reference NFPA.”
		ADA	“They’ll come back with things to fix so it has occupancy load, ADA access, and things like that.”
		Local codes	“Local codes, IBC, and IRC.”
Furniture	BIFMA	“BIFMA standards are voluntary and are for commercial furniture.”	
Building code scenarios	Design stages	Client meeting	“Usually, we would meet with the client, and they would let us know what we wanted.”
		Preliminary design	“Then we would go back and give them a preliminary design.”
		Approval	“They would okay it.”
	Design team roles	Architects	“We would work with the architects for plumbing like count to make sure that everything was right.”
		Interior design	“We did all the public areas, so the lobbies, the gyms, the swimming areas, so, like, if there was a swimming pool, indoor or outdoor, we would do the courtyards, we would do any of the like the club rooms, and then we would also design the units.”
		Mechanical, plumbing, and electrical	“Then we would move on to, and then it was sent to mechanical, plumbing, and electrical.”
	New projects		“So, when we get a new project, . that’s when I would bring out the codebook and look that up.”
	Renovations		“So, we usually see the drawings before we even, you know, approve the renovation or change that’s going on.”
	Frequency		“So, I reference code very frequently to make sure I’m complying with what’s required.”

(Cont’d...)

Table 3. (Continued)

Parameters/ questions	Themes	Codes	Example	
	Swimming pools		“A couple of our projects had rooftop swimming pools, so we had to do codes concerning the three-foot depth and the construction.”	
	Ada restrooms		“I would go to the ADA guidelines and double check a restroom, for example, what are the requirements for grab bars in a shower? How many? What’s the height, for placement, what are the length requirements? And go through those types of details.”	
	Universities	Review and permits	“So, any project on campus, when it comes to us for building review and stuff like that, we’re the one that issues the actual building permit.”	
		Jurisdiction	“Yeah, the way the university works is the university has its own authority having jurisdiction.”	
	Permits		“When they submit the permit, they have to submit drawings with it.”	
	Occupancy load		“A lot of times they like to play with the numbers, because if they can get the occupant load down, for some reason, that changes the bathroom count.”	
Work experience related to building code	Satisfaction	Enjoyment	“I enjoy finding answers right away when I can.”	
		Accomplishment	“From the moment you start building and then you go through and check it, and your codes are correct, it was just like, there was that sense of, like, I did it right.”	
Employer building code experience	Physical code book	Tangibility	“My employer likes to physically touch the code book.”	
		Efficiency	“Just because sometimes it’s easier to find things in a physical capacity, as opposed to endlessly searching and scrolling online.”	
	Frustration about building codes			
	Book edition		“The city team, I think they just switched to 28 th ...there’s been some issues with that.”	
	Finding information		“Try to find something and you’re not able to find it right away.”	
	Misleading language		“Sometimes the language of the code is misleading, or it can be interpreted multiple ways, and sometimes that can lead to frustration, too.”	
	Dissatisfaction with resources		“Designers do not want to carry books or check websites.”	
	Fix issues		“The frustration also kicked in when there was something that came up, and you’re like, oh, like, I have to fix that in one of the projects.”	
	Looking up building code apps	Apps	Unaware	“Honestly have not, but I wasn’t necessarily familiar that something like that would be out there, so I guess I didn’t know to search for it.”
			Opportunities	“But if there was an opportunity to use one, it’s not something I would turn away from.”
Advantages			“I think I would look into it and see what the advantages of using it would be.”	
Existing resources		Physical code book	“I didn’t access anything other than the physical book.”	
		Online	“Maybe references from online that kind of clarified what needed to be exact in these codes.”	
		Excel sheets	“Some designers created Excel sheets that are not currently updated.”	
Manual calculations			“Most of our occupancy determinations, especially for classrooms and renovations like that, you’re probably somewhere 15–20 min of going through the book, verifying the number, and then doing all the calculations.”	
Miscalculated building codes	Misinterpretation of codes		“The way that the city interpreted it was different than how my boss was interpreting, and it could, honestly, it could have gone either way.”	
	Occupancy load		“He also called again a couple times about the group rooms, where, again, the occupancy load was just too high, so we had to rearrange the design to make sure that they met those codes.”	
	Modifications	Adjustments	“It was about 600 plus units... and it was three buildings... but yeah, so we had to rearrange all three buildings to match that same height.”	

(Cont’d...)

Table 3. (Continued)

Parameters/ questions	Themes	Codes	Example	
How much would you pay for the problem to go away?		Timeframe	“Even though we were working with the architects, it took about three weeks to really re-alter the size of this multifamily.”	
	Employer versus employee		“I might spend less than maybe what an employer might invest if he could get more than one.”	
		Employer investment	Employer subscription	“I think definitely my employers, the four architects who are the presidents, they would have definitely used it and offered it to the employees.”
			Group license	“Group license about \$500”
	Value of the app	Help beginners		“She didn’t know codes, and I think something like this could have been very helpful in those beginning stages.”
			Save money and time	“Feels that a firm would be willing to pay for this app if it could save time and money in the long run.”
			NCIDQ prep	“Certain firms require NCIDQ certification.”
	Subscriptions	Monthly		“So, I guess if you are paying for your Adobe prescription personally, and you just tacked on another, say, \$10, then I could see where monthly would be a benefit, because then you can just kind of keep track of all those expenses at the same time.”
				“If I can just pay one time for the year, then and not have to think about it again for another year, I think that would be preferred, as opposed to having to keep up with it monthly.”
		Trial	“I’d want to test out the app and understand the frequency of use and, like, its accuracy and whatnot, before I would pay a lot of money for it up front, like basically test it out, see if it’s worth it before investing.”	
		Free version	“Have a free downloadable version with limited capabilities.”	
		Premium version	“Charge for popular features.”	
	Organization discounts		“Can be offered through ASID with a discount for members.”	
	Code book price		“Refer to the code book for pricing.”	
	Other features	Graphics		“Add more clarification to the buttons.”
App features		Search bar	“If there was, like, a better way to find the keywords or really direct you to what you’re looking for, I definitely think people would resort to whatever saves them the most amount of time.”	
		Links	“Link to BIFMA or level as additional things to consider.”	
		Tutorials	“Add a tutorial page.”	
		Help menu	“Add a help menu.”	
		Chat box	“Maybe add a chat box to the building permit counselor.”	
		Output files	“Suggested an output file to share with the code official.”	
		Plugins		
Content		Fire rating	“I remember there were a lot of codes concerning fire ratings on textiles, and that can help interior designers within architecture firms.”	
		Acoustics	“Acoustical concerns for materials.”	
Regions			“There needs to be a version for each municipality to account for different ordinances.”	
Marketing		Platforms	“YouTube for marketing and advertisement.”	
		Audience	“Consider different age ranges when providing resources.”	
	Updates	“Collect data to learn who is using the app to help make decisions related to updates.”		

Abbreviations: ADA: Americans with Disabilities Act; ASID: American Society of Interior Designers; BIFMA: Business and Institutional Furniture Manufacturers Association; IBC: International Building Codes; IEBC: International Existing Building Code; IFC: International Fire Code; IMC: International Mechanical Code; IPC: International Plumbing Code; IRC: International Residential Code; ISO: International Organization for Standards; NCIDQ: National Council for Interior Design Qualification; NFPA: National Fire Protection Association.

Table 4. Themes emerging from the instructors’ responses to the interview questions

Parameters/questions	Themes	Codes	Example
Positions	Professors	Architecture	“Professor at the School of Architecture.”
		Architectural engineer	“I’m an Assistant Professor of architectural engineering.”
		Interior design	“Interior design professor.”
	Administration	Department head	“I know you are the department head.”
		Program director	“Program director, yeah.”
Teach or conduct research	Teach		“I just teach. I teach two different classes.”
	Both		“Mostly teach, but I do both.”
Classes and levels	Classes	Architecture studio	“I teach fourth-year studio, which is a studio that prepares students for the comprehensive design, which encompasses all phases of architecture.”
		History & theory in architecture	“I also teach history and theory of East Asia and architecture specifically.”
		Environmental control	“I teach the environmental control courses.”
		Sustainable design	“One elective on sustainable design.”
		Comprehensive design	“I teach in the comprehensive design studio, which is like the capstone studio.”
		Study abroad	“I also teach study abroad in Asia.”
		Capstone studio	“I teach the senior capstone studios.”
		Graphics I	“I teach graphics.”
		Graphics II	“I have taught graphics II, which is the first year.”
		Heritage of interior design	“Then I also teach heritage, which is a lecture class.”
		Lighting	“Lighting class for juniors.”
		Facility management	“I teach Facility management and design, and diversity and facility management and design.”
		Great plains	“I teach two great plains idea courses.”
		Thesis	“I teach our graduate thesis”
		Levels	First/Freshman year
Second year	“Second year interior design studio.”		
Third year	“I primarily teach third year.”		
Fourth/Senior year	“I teach senior level.”		
Graduate	“I teach graduate-level courses.”		
Teaching codes	Yes		“So, in the past, I’ve taught building codes.”
	No		“No, I do not.”
Building code component	Year introduced to the codes	Second	“In the second part of the second year, they take a course where they go deeper into that.”
		Third	“Building codes are mainly covered in the third-year class.”
		Fourth	“Then, in the fourth year, we actually start making it more evident that the code has a lot of guidance on their shapes, on their forms.”
	Courses	Methods & materials	“I used to, a very long time ago, teach the methods and materials course, where we introduced building codes.”
		Studio/Capstone	“So, with the senior capstone project, you know, codes of course are an integral part of the project that the students are working on.”
	Projects	Commercial	“But in undergrad, we went over a lot of different types of building codes for mostly commercial.”

(Cont’d...)

Table 4. (Continued)

Parameters/questions	Themes	Codes	Example
	Design process	Design phase	“Big focus in that class, related to codes, is doing a building code analysis... where the students have already developed their design program and are, you know, getting ready to sort of transition into the design phase of the project.”
		Design development	“Basic code research that will affect the conceptual forms, and then later on in design development, when we ask them to do a wall section.”
	Content	ADA guidelines	“I cover ADA so students can apply the ADA requirement in their project.”
		Concrete codes	“I use ACI 318, which is the concrete design code.”
		Fire codes	“In studio five, we talk about egress fire stairs.”
		Occupancy codes	“We talk about occupancy loads very generally.”
		Plumbing codes	“It’s so much in the beginning plan is more planning concepts about plumbing fixtures.”
		Structural codes	“I use AISC 360 15 th Edition, which is the steel design code.”
		Steel design codes	“I use ASCE 7, and that is the Structural Building Code for loads on buildings.”
		Energy conservation codes	“So, we typically use the IECC, the International Energy Conservation Code.”
		Wall sections	“We also look into a little bit on how that wall section, how the code is going to affect the wall section.”
Building code exercise	Introduction to codes	Lectures	“I just give a lecture of about 30 min.”
		Breakdown	“So, I have kind of a markup to kind of pop out the equations that are used from the code, and really. What is the intent of the code?”
		Resources guidance	“Walk them through where to find this information in the concepts...the section in the IRC for this particular project, and I’ll show them where to find that information.”
		Terminology	“We start with just kind of translating some of the terminology, because they might read it, but they might not understand what they’re reading.”
		Overview	“We usually give them a brief because the code could be very daunting. There’s a lot of information.”
	Calculations	Occupancy	“Initially, it’s to get them used to identifying occupancies, occupancy loads, and how that’s calculated.”
		Plumbing fixtures	“I’ll ask them to calculate the plumbing fixtures needed for the size of this facility.”
		Snowdrift	“Then they’ll have a homework assignment that also calculates the snow drift on our roof.”
	Real-world applications	Exercise	“We actually ask them to look at an exit like egress, and just like walk through the building in our own building and understand what the egress components are, and then go back and read on the code.”
		Private client	“But if you were working for a client and it’s a private then you really, really need to have a secondary entry and you need to follow so, you know, you need to follow the code.”
		Government facility	“We’re the government, so sometimes we don’t follow the code to the letter.”
	Design projects	Elderly care	“Program for all-inclusive care for the elderly, which is a program for older adults that includes social services, a medical clinic, physical therapy, and occupational therapy.”
		Institutional kitchens	“Kitchen appliances and the kinds of things that would be put in, institutional kitchen that would be required by the fire Marshall, as well as the kind of doors that can open and close in case of a fire in the kitchen.”
		Hospitality	“Third year. they do a full-scale hospitality, restaurant hotel project in which they apply a lot of these codes, life safety and access issues, or access codes.”

(Cont’d...)

Table 4. (Continued)

Parameters/questions	Themes	Codes	Example
		Museum	“Student last spring was designing a museum... and she wanted to, she wanted to know whether her exits were far enough apart.”
		Row houses	“One project that we commonly start looking at code is a row house.”
	Applying codes to design	Fire codes	“Taking things into consideration like evacuation and fire safety plans.”
		ADA	“Wheelchair accessibility, making sure that doors are wide enough, there’s enough room, and around furniture to maneuver around it safely and sit comfortably.”
		Egress	“One project where we start to look at this type of egress component for the code.”
		Lighting allowance	“So make sure that after they design the electric lighting system, they don’t exceed the allowance for the load and do the same thing in a comprehensive way.”
	Comprehension		“Come back with some sketches that show they understand corridor dimensions, for example, and basic egress components.”
	Code checklist		“The students go through all those checklists and complete all the checklists as they pertain to the project.”
	Design critiques		“Every week when we’re doing design critiques, looking at how their design is meeting different building codes.”
	Documenting		“Go out and actually document and build sort of a little library of all of the backup code documents that pertain to the information that they’re pulling out in the code checklist.”
	Progress		“So, we started them off fairly small scale, little problems in their second year, just to get their brain around, determining occupancy.”
Code teaching experience	Rules		“I really love having rules that guide the design.”
	Challenging creativity		“Okay, these are the parameters, and now how can I be creative and inventive within those parameters?”
	Research driven		“Very research driven, that the students have to really, you know, understand their project, and they really have to research the codes that are applicable to their project type.”
	Subjective versus objective		“So, it’s much more concrete, and, you know, definitive, and not as subjective as a lot of other things that the students are considering when developing their design projects.”
	Understanding codes	Hands-on teaching	“I asked students to go to the bathroom and... ask them to check the accessible one, and I asked students to bring a tape measure, and ask them to measure the actual dimensions, because they cannot visualize.”
		Connections with real-world applications	“Kind of connecting that idea of social behavior to practical applications through what the code outlines.”
		Assistance	“Helping them understand feels kind of rewarding to me because then they can take that and kind of grow with that.”
		Relevance	“I think it’s nice when they realize that the point is to make people safe, and you feel good when they finally realize that that’s something worth doing.”
		Applying knowledge	“Enjoy making them learn about it and see them apply what they know.”
Students learning experience	Embrace rules		“Then they start getting more responsible and really embracing the rules, because they become liable, but that liability is not apparent to them at the beginning.”
	Reference Resources		“They spend a lot of time and gather a lot of information, and then they have that information to reference.”
	Confidence	Code competence	“I think that sense of knowing and competence is the reward for them.”
		Future career	“I hope they find some usefulness in it, and they gain confidence in their ability to design structures and understand what their job in the future is going to be.”

(Cont’d...)

Table 4. (Continued)

Parameters/questions	Themes	Codes	Example
	Functional Spaces		“There’s not necessarily specific codes, but there are sort of strategies and space planning operations that work better, and they function better.”
	User-centered design		“How do people use them on a day-to-day basis, so sort of like user-centered or human-centered design?”
	Site Visit		“They visit the site, so they walk into the doors of the building that they’re going to be doing the renovation on.”
	Feedback		“Invite professionals to come and, like, give feedback to the students.”
Frustrating teaching experience	Teaching methods	Need for guidance	“We incrementally, sort of spoon feed them, in some ways, the code that they’re learning and the code that is applicable to the project types that we set up for them.”
		Relatable learning	“When you teach it as a way to keep people safe, and you connect it in ways that they’ll remember to what it is you’re trying to accomplish, then they see purpose in it.”
	Challenges	Complicated	“It is kind of a complicated document, especially since the concrete code is written in a way that it’s not easy to navigate... I think it’s a very complicated code.”
		Cost	“The expense of the codes that you know I require for these classes, and they are expensive documents.”
		Intimidating	“The International Building Code is a very intimidating document.”
	Lack of interest	“Students think it’s kind of boring, they don’t know how important it is, and all the clearance and all the numbers, they are not interested. So, I think it’s really important to make them, make them interested in these issues.”	
		Overwhelming	“Helping the students overcome that sense of feeling overwhelmed., something that I found to be frustrating.”
Frustrating students’ learning experience	Inexperience		“I think that the maturity of the architect comes into play; this is very frustrating for them, because they don’t have either the maturity or they don’t have the years of practice that help them navigate that gray area.”
	Intimidating		“It’s intimidating, it’s a lot, and to learn how to teach them what’s important for them to know without overwhelming them.”
	Complexity		“I think that sometimes they don’t know exactly where to start, and you have to kind of give them a roadmap to help them break it down into, you know, some incremental categories and pieces to make it more manageable for them.”
	Memorization		“So, the frustrating part, I guess, is when they only think of it as rules that they have to memorize, and they don’t want to memorize any rules.”
	Textbook	Organization	“They have expressed the same frustration with the concrete code that I have and its organization.”
	Difficulty relating to real-world situations		“They don’t realize how big the space is, how that clearance will work for the wheelchair users, because they don’t have that kind of disability, they do not have any experience.
Looked up building code apps	Code app unfamiliarity		“I have not looked up anything. I don’t have any familiarity with any sort of apps that might be available, if there are any.”
	Online websites		“I always just end up going back to the building code websites.”
	Plugins		“I know for BIM, there have been some attempts to do like once you design a building, to have these applications, like these plugins that will tell you when a corridor is too long or a dead-end corridor.”
	Videos		“I found a few things on YouTube that I kind of like, so I actually have a little cheat sheet of my favorite YouTube places.”
	Code book		“We also had kind of like a code guidebook or a code to reference book.”
	Steel code app		“I do have one app on my phone for the steel code.”

(Cont’d...)

Table 4. (Continued)

Parameters/questions	Themes	Codes	Example	
	Feedback from professionals		“During the studio, we invite the code reviewers... to come and give feedback to the students.”	
Students miscalculating building codes	Egress		“At least for interior designers, that’s always been a challenge to try and get them to understand what a common path to travel means.”	
	ADA		“You know, there are all sorts of ADA and, you know, access things that they miss because there’s so much to know about it.”	
	Corridors		“The dead-end corridor issue is always a big one.”	
	Floor openings		“They really do not understand floor-to-floor openings.”	
	Hand drafting		“Then if you get that far in and have to fix it, then you have to erase your table and your chairs and all the wood grain that you did and all the shading and then redraw it.”	
	Prevention measures	Early feedback		“So, it would have saved me a lot of time if I were able to double-check that before going through all the rendering stages.”
		Grading		“We actually try to grade codes pretty early as a preliminary submission, so that we catch that stuff.”
		Design progress updates		“Get set up with the information that they need so that they don’t have to keep going back and fixing and changing and changing.”
	Errors	Time-consuming		“I mean that can set them back like 10 or 20 h or something, just way, way time-consuming.”
		Reluctant to fix		“The hard part is they’re reluctant to make the changes they need to make it right.”
Time management			“If they mess it up, it’s mostly just because they were in a hurry because they didn’t put in the time.”	
Learning process			“I was teaching sophomore-level studio when, you know, messing up was really part of the learning process for them.”	
How much would students pay for the problem to go away?	References	Software	“I think our students pay for other software, like Rhino. And I think there are, there are a few other ones that they pay.”	
		Code book	“I think it can be, if it’s comparable to the price of a book, it might be affordable.”	
	Free		“I think if it’s free, obviously it’s better.”	
	Student discount		“I don’t know if students would be willing to, or maybe if they got some sort of student discount.”	
		Monthly versus yearly	“I think if I were going to have to pay for it, being able to choose either monthly or yearly, having both of those would be nice.”	
	Subscription	Trial	“Okay, I’ll pay \$4.99 this month to see if I like it, and then if I like it and use it a lot, then I’ll pay the \$60.00 for a year.”	
		University	Tuition	“Maybe paid for by the university. So, it’s like a service provided to the students as part of that tuition.”
			Department license	“I think if our department purchased a subscription to an app-type service that we can then share with the students. Probably they would be more likely to engage with that.”
	One-time payment		“I would think probably a one-time payment would be better for students.”	
	Reasons for purchase	Cheaper	“If there were an alternative to that that allowed them to access the same information for a cheaper price, they would be interested in that.”	
Helpful		“I think this would be something that would be really helpful for faculty. I think the students would be very receptive toward it.”		
Class requirement		“Faculty could also, you know, incorporate it into the resource requirements for a class, if it was something the faculty wanted to require the students to all have.”		

(Cont’d...)

Table 4. (Continued)

Parameters/questions	Themes	Codes	Example
		Books versus apps	"If there were an electronic app version of a textbook that helped them understand these things and by plugging in information, I think they'd be willing to pay for it."
Other features	App features	User animations	"If the app can show how people with disability actually use the space... if some kind of animation shows how the space is used depending on size, then students can realize why they need to provide this much space."
		Project folders	"Save different portions to a folder, maybe almost like Pinterest or something."
		Code book references	"If there's some way that relates back to the actual IBC numbers, so if they get lost or need to go check on something... they can reference back to the code book."
		Highlight extra space	"It would be nice to see how much extra space you have if you want to put like a changing table or a spot to set your bags."
	Materials	Finishes	"What about finishes for interior designers?"
		Construction materials	"So, are there construction materials? You know what kind of structural steel you needed to use or if you could use glulam and those kinds of things."
	Fire codes	Allowable height	"Calculate things like allowable height and area."
		Exit widths	"Is it going to count also the desired width of the exit?"
		Glazing	"What kind of glazing does it have to be, you know, like this kind of stuff?"
	Occupancy classifications		"I think before you get into the occupant load, I think sometimes you need a little bit of a reminder of those occupancy classifications that you might be selecting."
Focus on specific codes		"Everything covered by code it's going to be too much. Maybe tailored to certain courses."	

Abbreviations: ADA: Americans with Disabilities Act; AISC: American Institute of Steel Construction; ASCE: American Society of Civil Engineers; IECC: International Energy Conservation Code; IRC: International Residential Code.

As for the quantitative data, the survey revealed that 85% of the instructors strongly agree/agree that the BCC app would help them accomplish their tasks and teaching goals more quickly, as shown in Figure 6. Figure 7 demonstrates that 92% strongly agreed that the app fits into their working style, with only one participant disagreeing with this statement.

Figure 8 shows that 60% strongly agree/agree that people who used BCC apps had high profiles, while the other 40% responded neutral. Figure 9 reveals that all respondents believe that the app is easy to use.

About 85% of participants strongly agree/agree that the results of using the app were apparent to them. Meanwhile, one participant indicated that the results were not apparent, as seen in Figure 10. Figure 11 demonstrates that 73% strongly agree/agree that there is no visibility for the BCC app in the interior design field.

Figure 12 shows that 92% strongly agree/agree that they had enough time to try the app and see its abilities. In addition, 83% strongly agree/agree that they will use the app in the future, as shown in Figure 13.

The results of the one-sample Wilcoxon test, presented in Tables 5 and 6, revealed that Questions 1–8 had a

p -value less than 0.05, indicating that the observed median significantly differs from the hypothesized median value of 3.

4. Discussion

Based on the interviews conducted, both industry professionals and instructors rely on traditional methods for calculating building codes. However, these methods often cause confusion and frustration among industry professionals, instructors, and students. The misinterpretation of codes also leads to miscalculations, requiring revisions that are time-consuming. Overall, participants are dissatisfied with the current available resources but are unaware of mobile apps that could help them with code calculations. Both professions and educators recognize the value the app could bring to the industry and student education. They believe the app would help save time and money, help prepare for the National Council for Interior Design Qualification examination, and enhance student learning. Furthermore, interviewees expressed satisfaction when they could find answers rapidly and when their calculations were correct. Therefore, this app would help them calculate building codes more efficiently and accurately.

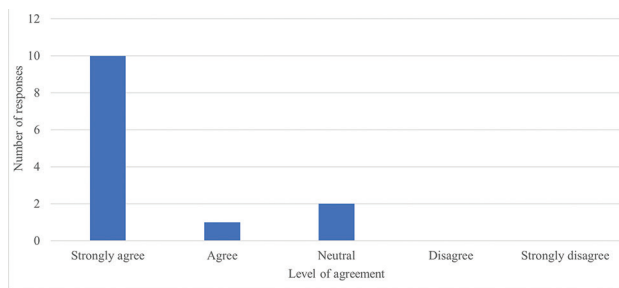


Figure 6. Participants’ responses indicating agreement that the Building Code Calculator app would help them accomplish tasks or teaching goals more efficiently

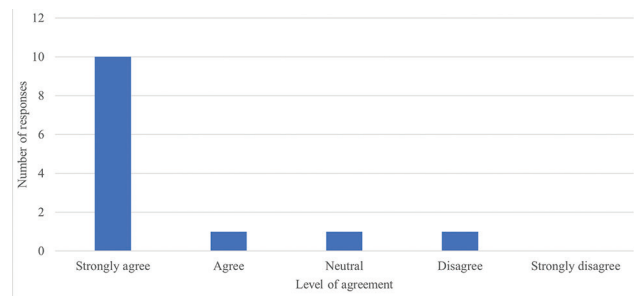


Figure 10. Participants’ agreement indicating the extent to which the results of using the Building Code Calculator app were apparent to them

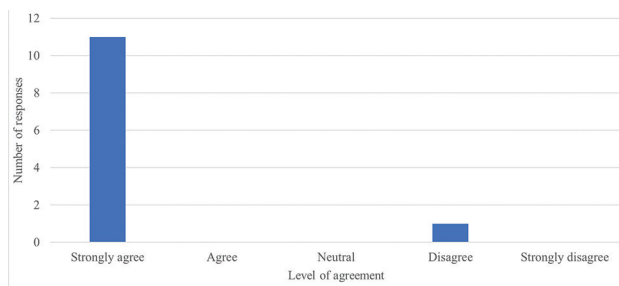


Figure 7. Participants’ responses indicating agreement that the Building Code Calculator app aligns with their work or teaching style

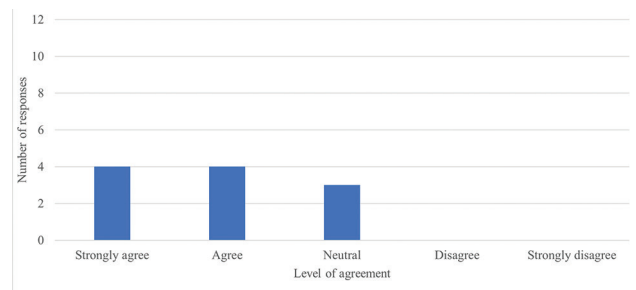


Figure 11. Participants’ agreement regarding the perceived visibility of the Building Code Calculator app within their field

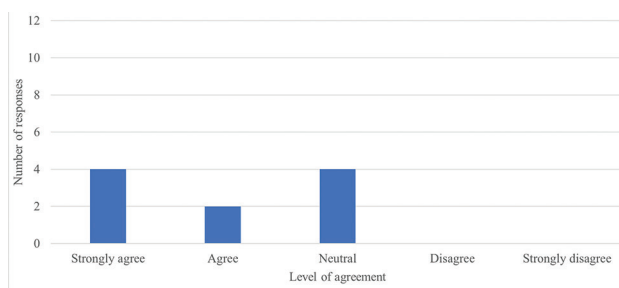


Figure 8. Participants’ agreement reflecting perceptions of the professional image associated with using the Building Code Calculator app in their field

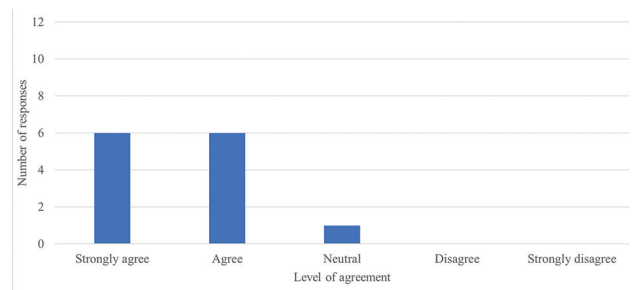


Figure 12. Participants’ agreement about having sufficient opportunity to trial the Building Code Calculator app and explore its capabilities

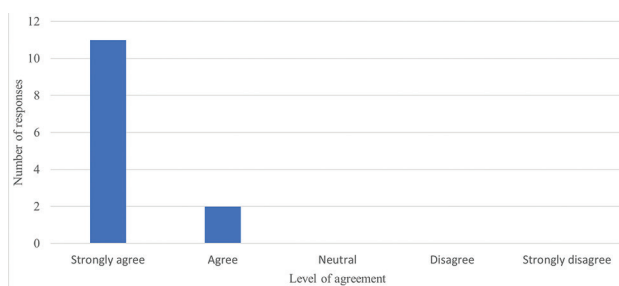


Figure 9. Participants’ agreement regarding the perceived ease of use of the Building Code Calculator app

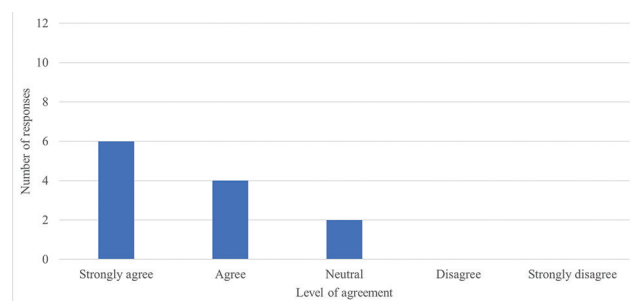


Figure 13. Participants’ agreement indicating their intention to use the Building Code Calculator app in the future

Factors such as relative advantage, compatibility, image, ease of use, result demonstrability, visibility,

and trialability are essential for the adoption of new technology.¹⁷ The majority of participants strongly agreed/agreed that the BCC app would help them accomplish

Table 5. Instructors’ survey responses based on the one-sample Wilcoxon rank hypothesis test

Question	Null hypothesis	Significance
1	The median for the statement, “using the Building Code Calculator App enables me to accomplish my tasks more quickly,” equals 3	0.001
2	The median for the statement, “Using the Building Code Calculator App fits into my work/teaching,” style equals 3	0.001
3	The median for the statement, “People in my field who use the Building Code Calculator App have a high profile,” is 3	0.023
4	The median for the statement, “Overall, I believe that the Building Code Calculator App is easy to use,” equals 3	<0.001
5	The median for the statement, “The results of using the Building Code Calculator App are apparent to me,” equals 3	0.002
6	The median for the statement, “The Building Code Calculator App is not very visible in my field,” equals 3	0.010
7	The median for the statement, “I was permitted to use the Building Code Calculator App on a trial basis long enough to see what it can do,” equals 3	0.002
8	The median for the statement, “I plan to use the Building Code Calculator App in the future,” equals 3	0.004

Note: Significance level at $p=0.05$.

Table 6. Instructors’ survey responses based on the one-sample Wilcoxon signed rank test

Question	Total (N)	Test statistics	Standard error	Standardized test statistic	Asymptotic significance (2-sided test)
1	13	66.000	10.290	3.207	0.001
2	12	77.000	11.619	3.271	0.001
3	10	21.000	4.623	2.271	0.023
4	13	91.000	13.309	3.419	<0.001
5	13	76.500	11.906	3.150	0.002
6	11	36.000	6.964	2.585	0.010
7	13	78.000	12.400	3.145	0.002
8	12	55.000	9.520	2.889	0.004

Note: Significance level at $p=0.05$.

their tasks or teaching goals faster. This finding suggests that professionals perceived the app as having a relative advantage over the manual calculation method, likely due to its efficiency. Furthermore, the majority of respondents indicated that the app was compatible with their working/teaching style. Question number 3 assessed the app’s image and its potential to enhance one’s status. More than half of the respondents strongly agreed/agreed, while the others remained neutral. A total of 40% of participants who responded neutral may not have encountered apps like BCC in their field, which explains their neutrality.

All participants strongly agreed/agreed that the app was user-friendly. Similarly, for Question number 4, the majority strongly agreed/agreed that the app’s results were apparent to them. Recognizing the benefits of innovation is important for its adoption.¹⁷ Furthermore, the results for visibility suggest that apps like BCC are not common in the field of interior design. Participants also agreed that they had enough time to test the app and understand its functions. Based on respondents’ agreement with each

adoption attribute, almost all participants agreed that they would use and adopt the app in the future.

There are no studies using the innovation diffusion model for interior design apps. However, Gharaibeh *et al.*¹⁸ and Emani *et al.*¹⁹ also used the theory and both found that relative advantages, ease of use, trialability, and observability influenced the adoption of mobile health apps among elderly adults and electronic personal health records. Although the context differs, this study’s findings, along with previous research, demonstrate that these adoption attributes influence technology adoption across different fields.

The results of the one-sample Wilcoxon test indicate that there is a significant difference between the observed median and the hypothesized median for all questions, indicating that the participants either agreed or disagreed with the survey questions, deviating from neutrality. The study also highlights some of the practical challenges and support needs for long-term integration of the BCC app.

4.1. Diverse geographic locations and jurisdictional differences

Design professionals and students work across different regions, and each location may have unique building code requirements and local regulations. This geographic diversity presents challenges in ensuring that the BCC app remains relevant and useful across various jurisdictions. These challenges can be addressed through the following strategies:

- (i) Localized code variability: Different states, countries, or municipalities may have specific building codes, standards, and zoning laws that must be considered. The app would need to be adaptable to these local variations. One solution could be to provide customizable modules within the app that allow users to input local regulations, creating a more flexible system for various regions.

- (ii) Continuous updates for code changes: Building codes are subject to periodic revisions, and the BCC app would require frequent updates to stay in line with evolving codes. This can be addressed through a subscription-based model or regular automatic updates that ensure users always have access to the latest regulations.
- (iii) Geographic-specific customer support: Designers in different regions may face unique challenges in using the app due to their local building code structures. Offering region-specific customer support, such as through a help desk or localized online resources, would be essential in ensuring the app's long-term effectiveness.

4.2. Different types of designers with varying needs

The needs of design professionals can vary widely depending on their role, design discipline, and the scale of the projects they work on. The BCC app should be able to address these differing needs in the following ways:

- (i) Small firms versus large firms: Smaller design firms, which may have limited resources, will require an app that is easy to integrate and does not require extensive training or support. For these firms, a more streamlined, user-friendly version of the BCC app with simple features may be the most effective approach. In contrast, larger firms may need more advanced capabilities, such as bulk compliance checks for multiple projects or the ability to integrate the app with other project management tools.
- (ii) Architects versus engineers: Different types of designers have different requirements. Architects may prioritize creative flexibility and visualization tools, while engineers may require more detailed technical features such as load-bearing calculations or mechanical compliance checks. Customizing the app's features to cater to these needs, as offering different versions for different design professionals, would ensure the BCC app's long-term adoption.

4.3. The need for more features

While the BCC app provides valuable services, additional features would make it even more indispensable in everyday design workflows. Some of the features that would benefit the app and its users include:

- (i) Collaboration tools: Designers often work in teams or collaborate with other professionals, such as engineers, contractors, and consultants. Integrating real-time collaboration features (similar to Google Docs or Slack) would allow multiple users to access and edit the same compliance checks, track changes, and leave comments for more efficient teamwork.
- (ii) Customizable reporting: While the app generates PDF reports with calculations, a feature to customize report layouts and include or exclude specific data could help

designers tailor the reports for different clients or projects. For example, adding client-specific branding or highlighting key compliance issues could make the reports more useful for presentations.

4.4. More testing for the app

To ensure that the app can seamlessly integrate into the workflows of busy professionals, more extensive testing is necessary, particularly in the following areas:

- (i) User testing across various regions: Conducting thorough testing in diverse geographic locations to ensure the app performs well with local building codes and regulations is crucial. This will help identify any gaps or issues in the app's ability to meet the specific needs of different regions.
- (ii) Feedback from different design disciplines: Testing the app across different design disciplines—such as architecture, civil engineering, and mechanical engineering—will ensure that the app's features meet the specialized needs of each profession. Engaging a variety of users in testing phases can provide critical insights into feature performance and usability.
- (iii) Scalability for large projects: The app needs to be tested in larger-scale projects with complex compliance requirements. Ensuring that the app can handle a large number of compliance checks, multiple inputs, and cross-jurisdictional code applications is essential for its adoption by larger design firms.

4.5. Marketing strategy for educators and professionals

To ensure that the BCC app reaches both professionals and educators, a robust marketing strategy needs to be developed. This should focus on:

- (i) Outreach to educational institutions: Partnering with universities and design and architecture schools to introduce the app as a teaching tool is critical. Offering free trials for educators and students can encourage adoption in academic settings. Furthermore, creating educational resources, such as webinars, workshops, and tutorials, can help integrate the app into curricula seamlessly.
- (ii) Professional associations and networks: Building relationships with professional associations, such as the American Institute of Architects or the American Society of Interior Designers, could help spread awareness of the app to established professionals. Offering special promotions or certifications for professionals who use the app could drive widespread adoption.
- (iii) Social media and online presence: Promoting the app through digital channels such as social media, industry blogs, and professional forums would help engage a wider audience. Content marketing that

highlights the app's unique features, case studies, and testimonials from users would be effective in attracting both students and professionals.

5. Conclusion

Building codes ensure the safety of buildings for occupants. Hence, designers are required to understand and calculate them accurately. Conventionally, this process has been performed manually, making it time-consuming, error-prone, and costly. With technological advancements, interior designers are encouraged to stay updated and explore new tools that can accomplish design tasks more efficiently. While attempts have been made to automate building code checking systems, they typically require programming skills that many designers do not possess. Therefore, the BCC app was designed to help calculate codes and improve efficiency. The interviews revealed that professionals and students experience frustration with the current available resources and traditional calculation methods. They also recognize the potential value of the BCC app in improving efficiency, reducing errors, and enhancing students' learning. Moreover, the results for relative advantage, compatibility, image, ease of use, result demonstrability, visibility, and trialability demonstrate that professionals are willing to adopt the app. Overall, the BCC app is an effective tool that can be used in the industry to help interior designers calculate complex codes and can be integrated into design courses to help students learn how to calculate codes. For the BCC app to become a permanent and valuable tool in the long-term workflows of busy design professionals and academic curricula, addressing geographic and jurisdictional diversity, expanding features, conducting more extensive testing, and executing a targeted marketing strategy are essential. With the right support and adaptations, the app can establish itself as an indispensable resource for building code compliance across a wide range of disciplines and locations.

While the study's findings are valuable within the specific regions of the study, it is important to recognize that variations in building codes, regional industry practices, and educational frameworks could lead to different outcomes in other geographic areas. Future studies that include a wider range of regions with differing codes and industry standards will be crucial for confirming whether these findings hold across diverse settings.

In addition, while the instructors provided valuable insights into potential educational applications and challenges, we recognize that industry professionals may have different concerns, such as the app's practicality in real-world projects or its compatibility with existing

workflows. For instance, an industry professional might place more weight on the app's ability to streamline daily code compliance tasks, while an instructor might be more concerned with its use as an educational tool in the classroom. These differences highlight the need for further research that directly surveys industry professionals to better understand how they perceive the app's relative advantage, compatibility with current practices, complexity, trialability, and observability, all of which are key attributes of the innovation diffusion theory.

While the study's qualitative component provided valuable insights into the challenges and perceptions regarding building codes and the BCC app, it is important to recognize a limitation in the data collection process. Specifically, nearly half of the qualitative data were captured through field notes, which, while effective for noting overarching themes and key points, may lack the depth and detail found in full interview transcripts. Future research should aim to transcribe all interviews in full to provide a richer and more nuanced understanding of participants' experiences. In addition, incorporating other methods such as member checking or follow-up interviews could further enrich the data and help ensure a more comprehensive analysis. Despite this limitation, the study offers an important foundation for understanding how building codes and the BCC app are perceived by design educators and industry professionals. While the BCC app currently handles samples of complex calculations, we acknowledge that there are additional features that could be developed to enhance its usefulness and applicability across various code systems. For example, we plan to incorporate additional features such as plumbing fixtures calculations and means of egress sizing. These future improvements will help address even more specific code-related challenges. We also plan to enhance the app's ability to support multi-jurisdictional code compliance, which will allow users to automatically adjust for local building codes when designing projects in different geographic regions. This would significantly improve the app's flexibility and value for both educators and professionals working in diverse geographic areas with varying requirements.

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Ethics approval and consent to participate

This study was approved by the Oklahoma State University Institutional Review Board (IRB) under the application number IRB-25-7. The IRB granted approval on January 3, 2025, and processed the application as expedited. Human subjects were involved in this study, and verbal consent was obtained from all participants, ensuring their informed participation.

Consent for publication

Participation in this research study was entirely voluntary, and informed consent was obtained from all human subjects before their involvement. No personally identifiable information was shared, and the findings are presented solely in aggregate form.

Availability of data

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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