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Learning Human Factors/Ergonomics (HFE) in Architectural Education: A Study of Studio Approach in Bangladesh

Sudipti Biswas*, Gourab Kundu and Chowdhury Ali Imam

Department of Architecture, Military Institute of Science and Technology (MIST), Dhaka-1216, Bangladesh

*sudipti.biswas@arch.mist.ac.bd (Corresponding Author)

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ABSTRACT

All the human activities take place in the built environment and therefore human factors/ergonomics (HFE) is an essential design consideration for the built environment designing process. Surprisingly, there have been limited studies on integrating HFE in the design process as well as in the education of architecture. Teaching HFE in architecture is different from teaching HFE in the disciplines that focuses on precise ergonomic application. Architectural education primarily deals with accommodating human activities in the built environment; and therefore, teaching HFE focuses on anthropometry, space standards, and an in-depth understanding of space requirements for relevant human activities. In architectural education, HFE can be taught as theory courses and/or in the design studio courses. This article focuses on the studio approach with an overview of several studio courses and a meticulous study of a studio course that teaches HFE principles. The study follows desktop research, participant observation, and a questionnaire survey. It is observed that the studio approach provides an opportunity for a deeper understanding of the HFE principles and their application in space design. Specifically, the practice of learning within the studio setup, group work and peer critique, assessment and feedback with critique sessions before the evaluation, etc. have a profound impact on the students to internalize HFE in their thought process. A survey among the students also indicates the effectiveness of the studio approach for learning HFE.

1. Introduction

Human Factors/Ergonomics (HFE) considers human well-being and overall system performance and is vital for sustainable development, as it contributes to the social and economic dimensions of sustainability (Radjiyev, Qiu, Xiong & Nam, 2015). The International Ergonomics Association considers ergonomics as the 'scientific discipline' concerned with the understanding of the interactions among humans and other elements of a system, and a profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance. Therefore, HFE is of utmost importance when the built environment is considered as the 'system'. There is some room for debate when it comes to the built environment's role in ensuring sustainable development (Attaianese, 2014; Attaianese & Duca, 2012). However, in this regard ergonomic approaches for building design are scarce (Attaianese & Duca, 2012), except for some studies in the field of healthcare architecture (Villeneuve, 2000). HFE is widely studied and applied in disciplines concerning products and workplaces related to human activities. Surprisingly, even such studies consider the built environment as a simple surrounding or minor element (Attaianese & Duca, 2012).

Although there is a lack of focus in the HFE enclave to consider built environment design as the focal point, the necessity of integrating HFE into architecture is widely recognized (Attaianese, 2012, 2014; Attaianese & Duca, 2012; Garneau & Parkinson, 2016; Olguntürk & Demirkan, 2009). Scholars argue that teaching HFE principles in design schools are proven successful in improving performance, productivity, safety, and health in the built environment (Attaianese, 2012; Garneau & Parkinson, 2016; Olguntürk & Demirkan, 2009).

In the architectural education, HFE is taught as separate lecture courses and/or within the studio courses. Design studios are the core of architectural education where the basic philosophy is learning by doing and solving complex open-ended problems

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(Belluigi, 2016; Kuhn, 2001; Ledewitz, 1985; Schön, 1983). This studio approach is designed to support the students to learn, adapt and apply design principles and relevant course objectives in their design exercises which would eventually nourish their competence in the professional field.

This article studies the studio approach of teaching and learning HFE in architectural education with studio courses in 7 architecture schools in Bangladesh including a detailed investigation of one studio course in the Department of Architecture, Military Institute of Science and Technology (MIST). This detailed study covers the Design Studio III course in level 2 which is considered as the first studio that initiates the designing process of the built environment. Naturally, this is the course that fits best for learning HFE. Along with the study of studio teaching of HFE, this article also attempts to relate the students' feedback based on the learning of HFE and its implementation in their design development process.

2. Architectural Education and HFE

Architectural education is primarily a studio-based education program. Design studios are the core of this discipline. Not only architecture but also other disciplines of art and design, studio-based learning programs are widely recognized for creating an active learning environment for the learners (de La Harpe et al., 2009; Olweny, 2019; Schön, 1983). Studio-based education was introduced in the education of art and architecture in the 1890s at the Ecole Nationale et Speciale des Beaux-Arts in Paris during the educational reform led by the French revolution (Alagbe et al., 2017; Chafee, 1983). The core ideology of the Ecole Nationale et Speciale des Beaux-Arts-based studio program was learning by doing. Modern-day design studio practice was familiarized and spread by the Bauhaus School, established by Walter Gropius in 1919 which was based on the same ideology of learning by doing (Alagbe et al., 2017; Bailey, 2005) Contemporary architectural education around the world adopted the Bauhaus principles of studio-based learning (Bailey, 2005; Lackney, 1999; Salama & El-Attar, 2010).

This studio-based learning is a constituent of problem-based learning and it deals with problems that the students are likely to encounter in their professional lives (Burroughs, Brocato, & Franz, 2009; Moody, 2011). Studio courses' learning by doing philosophy focuses on dealing with open-ended challenges that enable students to engage in innovative and efficient design exercises through a process of discovery that leads to a better knowledge of underlying concepts. Studio approaches are widely diversified and incorporate a lot of complicated and interrelated issues along with the teaching of the architectural designing process. Ledewitz (1985) and Bamford (2002) have identified a studio model, known as the analysis-synthesis model, which is widely followed and can be adapted according to the context of different institutions. In this model, the studio exercises are divided into four stages.

- Briefing: assigned studio project that contains necessary information such as program, design data, site, etc.
- Analysis: breaking the problem into pieces, formulation of performance specifications, identification of constraints, etc.
- Synthesis: generating ideas, putting all the pieces together in different ways, and developing design solutions.
- Evaluation: check against performance specifications and constraints, identify the consequences of putting the new arrangements into practice, etc.

Design studio courses primarily deal with design problems. Naturally, when HFE is the subject of the design problem, they are exercised differently than disciplines that teach HFE as the conventional lecture course. Providing several examples, Moody (2011) has argued in favor of the studio approach for teaching HFE and even for some introductory engineering courses in different disciplines other than architecture. With a particular focus on HFE, Moody (2011) mentions that the studio environment and the interaction between the students and teachers with formal and informal critiques are the core attributes that make the studio learning fruitful.

Although the application of HFE in architecture is not a well-studied academic field, yet scholars agree that HFE plays a major role in the issues of functional efficiency, comfort, workability, financial efficiency, etc. in the design of the built environment and interior architecture (Attaianese & Duca, 2012; Charytonowicz, 2000; Olguntürk & Demirkan, 2009; Remijn, 2006). A significant contribution of HFE is that it can generate a rigorous analysis of the human occupants and their working or living environment (Villeneuve,

2000). Therefore, architectural education focuses more on the human activities and space required for comfortable accommodation of the activities that lies in the field of HFE. The studio courses that integrate HFE principles thus majorly focus on the development of a comprehensive understanding of human activities and relevant space standards according to the studio project. This understanding of human activities covers a wide range of attributes such as body dimensions, flexibility, working procedure, equipment, furniture and fixture, behavioral, sensory, and environmental considerations, etc. Studio courses thus emphasize on conducting rigorous study of human activities and available space standards to develop an in-depth understanding of HFE among the learners and then consider the application of this understanding in their design problems. The study of human activities and space standards for any given type of architectural design is the first step of design exercise for all the design studio courses in architectural education. Therefore, the studio exercise of HFE also helps the students to improve their learning capabilities and train them in analyzing human activities and space requirements for any type of design problem which they might face in other studios or in their professional careers.

3. Methodology

This research is conducted on two levels. The broader level includes a qualitative study of six architecture schools in Bangladesh to get an overview of how HFE is integrated and taught in the studio courses. The in-depth level includes a meticulous investigation of one studio course in a mixed method. Therefore a total of 7 architecture schools are studied for this research.

The broader study is qualitative and conducted with documents and informal interviews. Information about the course was collected through a study of the course outline available in the curriculum, project handouts, and informal discussions with the course instructors. Course outlines include an overview of the course contents and course objectives. Project handouts are prepared by the studio instructors and they contain details of the projects, instructions for study, design exercise and references to relevant literature. Such handouts are useful in determining how effectively HFE concerns are integrated into courses and how well students are able to comprehend them. Lastly, informal interviews with the course instructors were conducted to get a better understanding of the learning objective, process, and outcome of the courses. Such discussions were very useful to understand the educators' perspective of teaching HFE as well as to grasp the students' level of learning.

Detail study of one studio course is done in two phases and using a mixed-method approach. The first phase was based on students' observations during the HFE design studio courses. This phase was conducted following the norms of qualitative field research (Denzin & Lincoln, 2003; Douglas, 1976). The second phase includes the students' feedback about their learning from the studio course which was conducted through a questionnaire survey following the norms of the social research method (Gregar, 1994; Saris & Gallhofer, 2014)

The first phase includes details of a design studio course which is taught in the second level of the five-year-long academic program. As the authors were involved in this course as studio instructors, it was convenient to conduct participant observation in minute detail. Observation topics include HFE principles, teaching-learning method, students' understanding of the HFE issues, students' way of executing the studio exercises, etc. Along with conducting the studio exercises, discussion with the students also provided information in this phase. Observation data was collected as field notes, discussion protocols, diagrams, etc., and analyzed qualitatively.

The second phase aims to know what the students have learned and if the course has helped them in the design process. This phase involves an online questionnaire survey. The questionnaire is designed as structured close-ended questions and the options are prepared as Likert items with five levels. Most of the questions are placed in the form of a statement explaining the topic in a way that the students can easily understand, the options to answer; Strongly Agree, Agree, Undecided, Disagree, and Strongly Disagree. The questionnaire asks about the students' concerns on HFE issues from different perspectives of space designing, level of knowledge before and after the course, their concern of critical dimensions, ability to determine space requirement, etc. The online survey was conducted using Google Forms. The questionnaire was provided to the online platform of students' groups and they were asked to fill it anonymously. The studio

course, under discussion, was placed in the first term of level 2 and the survey was conducted after the students completed the second term of level 2. Therefore, there was enough time for the students to comprehend the learning and internalize the HFE issues in the design thinking process. A total of 25 students participated in the concerned design studio course and 21 of them responded to the survey questionnaire, therefore the response rate is 84%. Survey responses are analyzed both qualitatively and quantitatively with the specific context. Mostly descriptive statistics are applied to interpret the survey results and inferential statistics are not applicable for this dataset. This dataset also incurs a few constraints such as limitation of the questionnaire, non-participation, honesty of opinion, difficulties of analyzing qualitative data, difficulties of analyzing Likert items, etc.

The study has some limitations. It is based on the context of architectural education in Bangladesh, and therefore the generalizability might be compromised. However, the studio approach of integrating HFE issues into the learning process offers a better scope of generalization while the anthropometric study might be limited. Furthermore, this research covers a few architecture schools, and one of them is explored in depth. A similar study incorporating more schools would produce a wider understanding, and identify the areas that improve the students' learning. The ability of students to utilize HFE issues in design is the most significant factor in architectural education. This is covered in the detailed analysis, but it was not possible to do so for the other six schools. Teaching HFE in Architectural Education, Bangladesh Perspective

Formal education of architecture was introduced in Bangladesh only in the early 1960s at the Bangladesh University of Engineering and Technology (BUET). A five-year bachelor program was developed and run with the cooperation of Texas A&M University, USA. Later, several other public and private universities in the country introduced architectural education. The other schools have mostly adopted, more or less, the curriculum developed by BUET.

Therefore, the architecture schools in Bangladesh do not differ drastically in the alignment of the curriculum. The issues of HFE are usually taught as a studio course in Bangladesh and the course in offered in the second year.

This research has studied 7 studio courses, from 7 different architecture schools, which incorporated HFE. The schools include Bangladesh University of Engineering and Technology (BUET), Ahsanullah University of Science and Technology (AUST), State University Bangladesh (SUB), Primeasia University, North-South University (NSU), Pabna University of Science and Technology (PUST), and Military Institute of Science and Technology (MIST). Amongst these 7 courses, the MIST course is studied in detail, while the other 6 courses are studied as a part of developing a wider understanding of the academic approach to teaching HFE in architectural education.

Studies of these schools show a common pattern of teaching HFE issues. The objective of the HFE studio course is to develop an understanding of ergonomics, as the course is constructed in such a way that learners are required to design spaces or objects that must integrate ergonomic considerations. The studio exercises include the study of human body measurements, space standards, human activities and finally designing a simple architectural space or furniture; however, not all schools follow the processes in the same order or place the same emphasis on them.

Usually, the studio exercise starts with a study of human figures and activity analysis. In most cases, this study of human figures involves following the templates mentioned in the literature. The most common literature is Time Saver-Standards for Building Types and Neuferet Architects Data. Not all the schools go for taking body dimensions of a group of people, in many cases, it is found that dimensions are taken within the class in different ways. Sometimes, the students find someone in the class who resembles the 'standard' figure illustrated in the literature and take all the dimensions from that student; or students take dimensions of certain body parts of a few students who 'look like the average of the class. It is also observed that the Time-Saver Standards are followed without taking into account the dimensions of any body. For studying the human activities, mostly the Time-Saver Standards are followed, often blindly. This study usually includes human activities in space and necessary furniture arrangements for simple functions such as basic residential functions. After the study phase, it is to design a simple space, such as mono functional space, pavilion, kiosk, etc., or an object, such as a professional's workstation, different varieties

of chair, integrated study module, etc. The design phase consists of drawings and a scale model of the design space or object; the model scale usually ranges between 1:1-1:25 so that the young learners can comprehend the HFE considerations in the design. Sometimes, as a part of the studio exercise, the students make a life-size model of the designed space.

In the overview of these courses, a void is observed to address the anthropometric difference and socio-cultural practice of the local population from those mentioned in the Time-Saver Standards and similar reference books. Such differences are neither explored nor considered significant for design consideration, except the MIST course which is studied in detail. Moreover, from the course outline or projects handout, it is not possible to render the actual learning of the students. The course design appears to develop an understanding of HFE considerations, which is also mentioned by the studio instructors, although without students' feedback this cannot be ascertained.

4. Detailed Study of a Studio Course Integrating HFE Principles

The Department of Architecture, MIST, has adopted the conventional five-year-long academic program with ten successive design studio courses as the core of learning process. The first 2 design studios are targeted to introduce the students to the wide realm of design and design principles. ARCH 2101: Design Studio III, which is taught at the beginning of the second year, as the introductory course that initiates the academic exercise of architectural design projects. This is the course where HFE principles are taught to the students. Although HFE is not the only subject covered in this studio, it is an important aspect of the curriculum.

The Design Studio III course is targeted to familiarize the HFE principles to the learners along with introducing the basic understanding of built forms, functional arrangement, and the context. The course objectives pertinent to HFE include an introduction to the concept of HFE, a basic understanding of human activities in architectural space, and an analysis of function and program. The intended application of HFE taught in this course, as specified in the learning outcomes, includes

- Ability to understand and analyses human activities based on ergonomics
- Ability to determine space requirements based on ergonomics
- Ability to design object or space for specific function and ergonomics

Usually in this course, along with HFE, some built structures with simple functions such as small office, family residence, etc. are exercised as studio projects. The course is structured in such a way that students can learn about HFE and apply it to design. The course duration is 14 weeks with 12 hours of studio class per week. This article focuses on the first 7 weeks of the course. In this period, HFE learning was designed with three projects planned for step-by-step learning. The projects were aimed to develop an understanding of anthropometric dimensions relevant to architectural space design, human activities in space for selective functions, and designing an architectural space based on the previous learning.

4.1. Understanding the Anthropometric Dimensions for Space Requirements

Learning of HFE starts with the understanding of the human body. For architectural space design, it is the first task to know what body dimensions are to be considered for the activities performed in that space. In the studio, the first project was designed to get the students a clear understanding of anthropometric dimensions for different postures and different activities related to residential functions. In this phase, students were divided into teams. There were in total 5 teams, each team including 5 students. Relevant postures and activities were selected based on architectural space standards mentioned in different books that are considered as a textbook for such standards. This section was primarily taught as lecture courses following relevant literature and then demonstrated in the studio. The books that were consulted for this project are as follows.

1. Time-Saver Standards for Building Types: 3rd Edition, Joseph De Chiara and John Callender, Eds., McGraw-Hill, New. York,1990
2. Human Dimension and Interior Space: Revised Edition, Julius Panero, and Martin Zelnik, Whitney Library of Design, 1979.
3. Neuferet Architects Data: Fourth Edition, Ernst and Peter Neufert, Wiley-Blackwell, 2012.

Following these books and discussions, students identified 40 dimensions of the human body at different postures for different activities. Students measured the body dimensions of their classmates in the studio and subsequently collected dimensions of other people for different age groups. For clarification of any queries, demonstrations were conducted in the studio. Students worked in groups and collected dimensions for 125 adult for different postures. They were encouraged to identify the difference between the international standards mentioned in the books and derived standards for the local people. The body dimensions that were collected are presented in Figure 1. The outcome of this anthropometric study was a dataset containing 40 body dimensions at different postures for the local population and the deviation from the dimensions mentioned in the reference books. For the next stage, this dataset was to be followed as a reference.

4.2. Understanding the Human Activities in Space and Spatial Dimensions

The next step in the learning process is to study human activities for selective functions. Understanding of body dimensions is applied in this phase. Study of human activity and sequence, body dimension for the relevant posture, dimensions of the relevant furniture, the relationship between the human body and furniture, required clearance between the human body and furniture and/or wall surface, clearance required for the movement of the human body to perform the activity, etc. are covered in this step. The studio project regarding this topic was dedicated to conduct a detailed study of basic residential functional spaces that included toilet, kitchen, living room, and bedroom. Students studied a range of human activities and functional requirements in these functional spaces and developed spatial understanding in relation to furniture, fixture, and surroundings.

Students studied activities in space in two stages. Initially, they identified the specific activity with basic dimensions and space requirements, and then they studied the spatial relation by surveying a total of 12 residences of which only 6 were designed by architects. In this phase students also studied space standards mentioned in the books. After surveying the residences, they also identified deviations from the reference standards in relation with the derived standard for the local people, and made suggestions for improvement. Students' final demonstrations on this study are presented in the following figure.

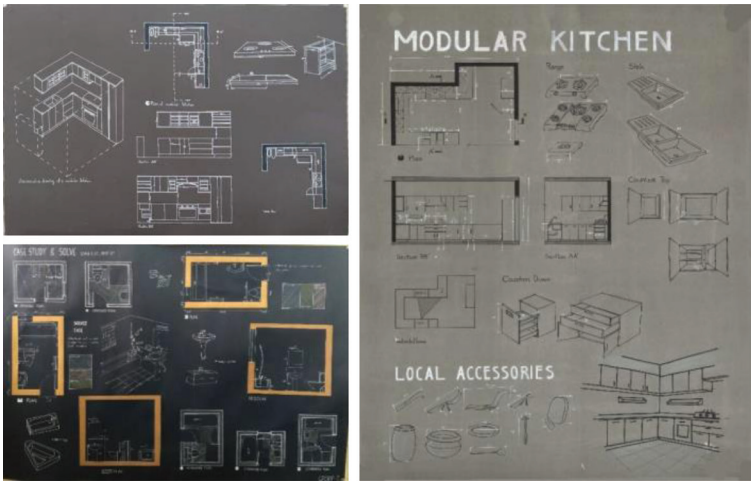

Figure 1: Study on toilet and kitchen.

The core idea of this exercise was to make the students aware and capable to comprehend the HFE issues in human activities that take place in the built environment. Students made this study in groups; different groups were assigned different functions. In the course of the exercise, all the groups presented their findings and shared their knowledge with others. They also shared their challenges which helped the others to overcome similar difficulties.

This exercise was designed with the expectation that the students would be able to comprehend and study any kind of given activity and derive the optimum space required for that activity.

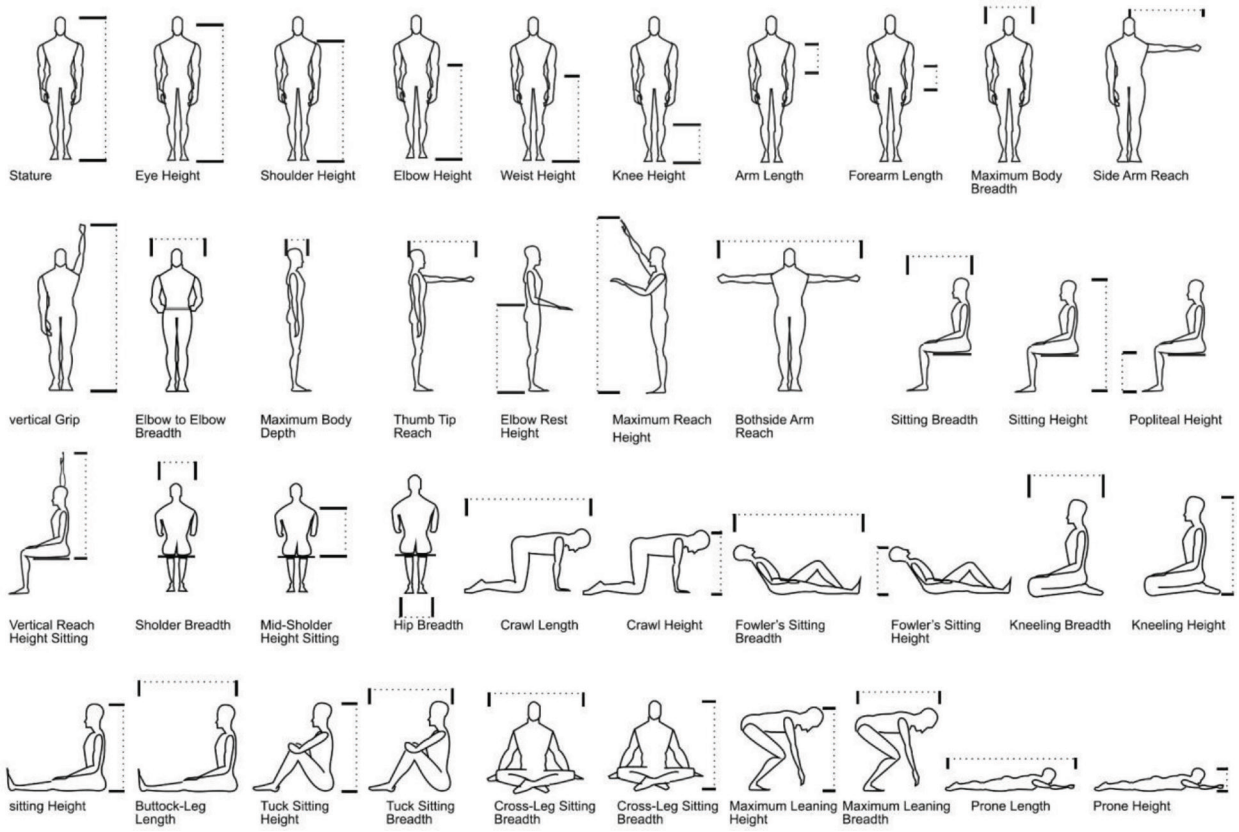

Figure 2: Anthropometric dimensions measured in the studio course.

4.3. Designing a Space Considering HFE

After learning the body dimensions and human activities, the next step is to design a space that can efficiently accommodate the given human activities. To accomplish this, students were assigned to design a living module for a single person. This time, it was an individual task that required each student to accommodate all the basic functions that are required for a person to live in a container size of space.

The project was perceived to make the students work in several stages. It started with identification and analysis of required human activities, furniture and fixture, clearance, local standards, and then generate the space requirement which is termed as an architectural program. This program was generated with a detailed study of different layouts with human posture and furniture arrangement so that the space requirement could be efficient and reduce waste of space. After the program was derived, the students started to design the space to accommodate all the basic functions of living. In this design stage, considerations for local climate and cultural practices were introduced. Therefore, the living module had to fulfill all the following requirements.

- All the basic living functions must be accommodated, such as sleeping, cooking and dining, toilet, dressing, seating, working/study area, etc.
- Space must not be wasted, but the comfort of working/movement cannot be sacrificed.
- Basic climatic considerations should be accommodated such as natural lighting and ventilation, protection from glare and rain, etc.
- Some cultural practices need to be considered such as privacy, entertainment, the orientation of some furniture/fixture, etc.
- Customized and innovative design of furniture to save space and increase efficiency is highly appreciated.

Students developed their designs and presented them for discussion several times before the final evaluation. The assessment took place as interactive critique sessions with both studio instructors and fellow students. Finally, students submitted their designs in the form of models and drawings. Some of the models are presented in Figure 3.

Figure 3: Models of single person living module.

This project provided the scope to examine if all the intended learning outcomes of the studio course that are relevant to HFE have been attained or not.

4.4. Strength of Studio Work

The studio approach of teaching is well recognized for problem-based learning and is considered very effective in many disciplines outside the design studies, while studios form the core of the architectural education. The studio approach of teaching-learning is the strength in architectural education as it allows the students to internalize the learning which eventually enables them to flourish and thrive in the professional field in the 5-year program, students get the opportunity to exercise basic types of architectural projects, but with this knowledge, they can continue to design any type of project. The program is designed to make the students learn how to learn, along with basic design knowledge. This is the core strength of the studio approach, which has made architecture education fundamentally an outcome-based education (OBE) programme from the outset, while other disciplines have just recently begun to incorporate OBE. Moreover, in architecture, the studio is not only a way of teaching, but also a culture that is always carefully nourished.

In the studio course under discussion, the main target was to make the students recognize that HFE is an essential part of space designing. Instead of conventional lecture-based teaching, studio teaching emphasizes learning the topic with empirical work and problem-solving exercises. Students were first given literature information about the relevance of HFE in the architectural design process and anthropometry. Then, there was a discussion in the class about selecting the body postures and their relevance to space usage. Afterwards, students physically measured the anthropometric dimensions of a large number of people. During taking dimensions, and there was some confusion about the correct posture and there were again discussions and demonstrations of the human posture to understand the relation with space use and comfortable posture. This helped to get a clear understanding of taking measurements. In the study of human activities, the students made a dummy of the study space in the studio for demonstration and discussion with the studio instructors and peers. Although different groups were assigned different topics, all of the students had to participate in the discussion-demonstration sessions for inclusive learning. Similarly, intermediate assessments were open for all to participate. The third project was to check what the students have learned and how they can integrate HFE issues in space designing. At first, all the previous studies were shared for the benefit of all the students. In the design development phase, again demonstrations were made in the studio and students helped each other. Scale models were helpful in this project for demonstration. The final output showed that the students were able to consider HFE issues in their design solutions.

In each step of the three studio projects, there were several rounds of discussion, demonstration, and feedback for continuing the exercise. Intermediate assessments were usually informal critiques with the participation of the whole class and thus students received feedback from the instructors and peers. This informal feedback played a supportive role to improve the design and build confidence for the final evaluation as well as their design thinking process. The studio space was available for the students beyond the class hours and this was generally recognized to strengthen lateral learning. Peer critique and lateral learning in the studio environment are widely considered as benefits of studio culture.

5. Students Feedback

In the Design Studio III course that teaches HFE issues, which is offered at the beginning of the second level, students showed a level of understanding and capability of integrating HFE. Now, the question is if they get it in their design thinking and can apply it in their design projects. To know this, a survey was conducted after the completion of second level. The responses depicted a bright image, which is discussed in the following sections.

The studio projects were designed for step-by-step learning progress and with the target of implanting HFE considerations into their design thinking process. When the students were asked if this structured program and the studio mode of learning were useful for them, they responded positively. Almost 90% of the respondents agreed that the course design offered well-structured education and almost 95% agreed that the structured way was useful for them. All of the participants agreed that the course was a good platform for lateral learning and this was helpful for them. Their responses are presented in Figure 4.

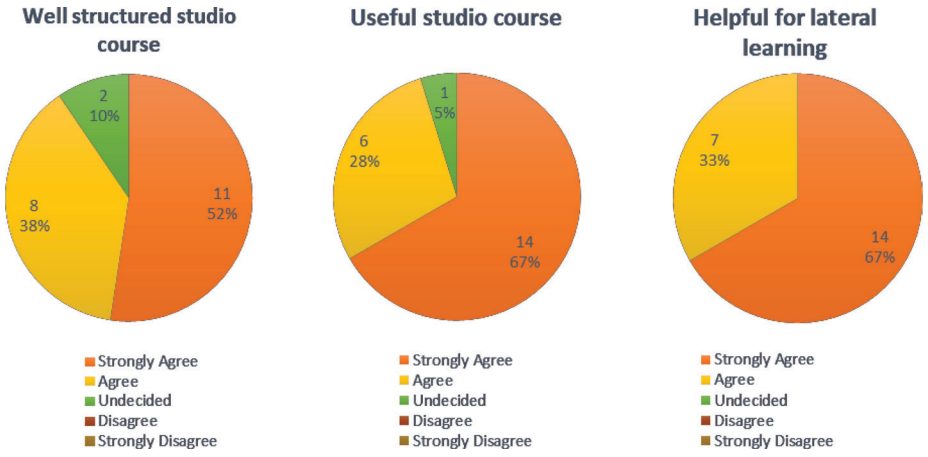

Figure 4: Students' responses about the structure of the studio course (left), the usefulness of the structured program (middle), and lateral learning (right).

The survey was intended to know what the students learned from the course. The respondents generally agreed that they realized that HFE issues must be considered for design, as they developed an understanding of critical dimensions as well as space requirements and acquired the ability to generate space requirements or architectural programs. The responses are shown in the following figure.

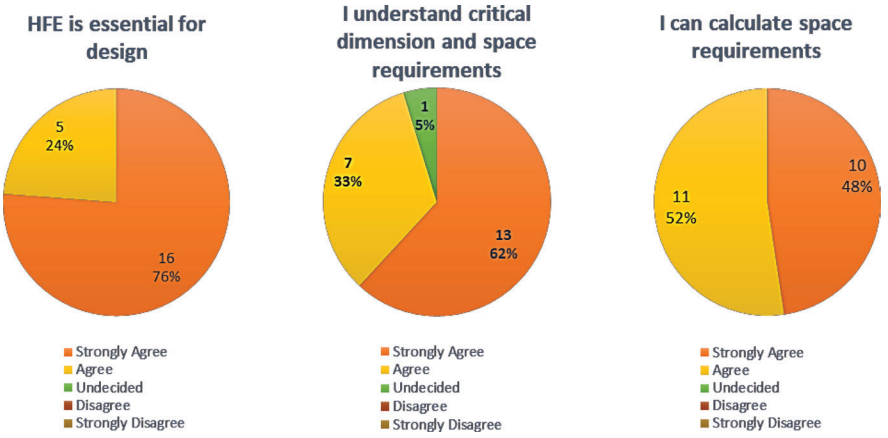

Figure 5: Students' response about learning from the course: consideration of HFE in design (left), critical dimension and space requirements (middle), and preparing space requirements (right).

The survey also asked if the course outcomes helped them in the design process for the next studio exercises, as the survey was conducted after the completion of the term. Here, only one participant (which counts about 5%) was not sure, but the rest approved that the course helped them in the designing process, which was the prime target of the course. However, when asked if the course had taught them enough and if they no longer needed to review HFE topics, the results were varied nearly 80% of the participants appeared to have a good understanding of the HFE difficulties, but the remaining did not.

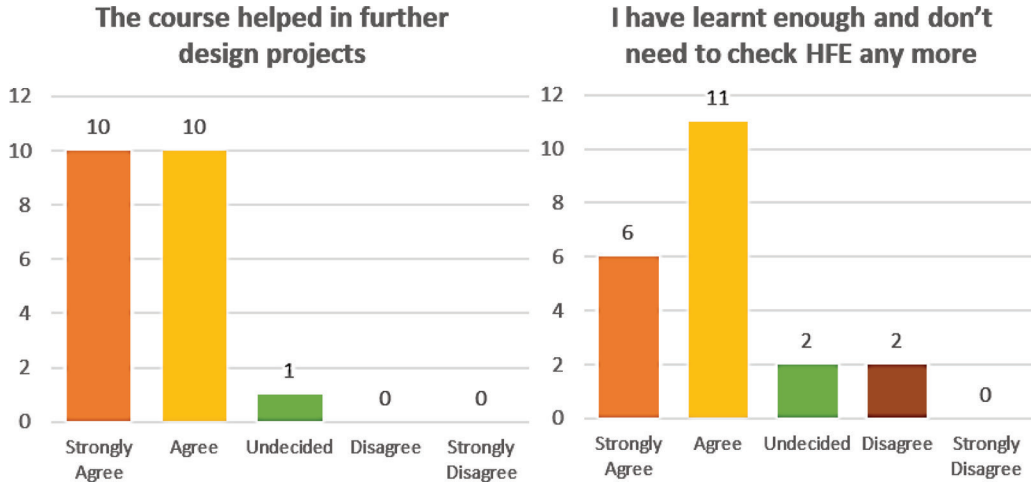

Figure 6: Students' response about the usefulness of the course in the design process (left) and the level of learning HFE issues from the course (right).

The survey asked about the level of knowledge on HFE before the course and the level of acquired knowledge and ability to integrate HFE issues into spatial design. The answers show that the students had a varying extent of information about HFE beforehand. After the course, along with their experience of further design studio projects, they had acquired enough knowledge, and the majority (about 76%) of them could well integrate ergonomics in the design while the rest (about 24%) were able to integrate partially, as shown in the following figure.

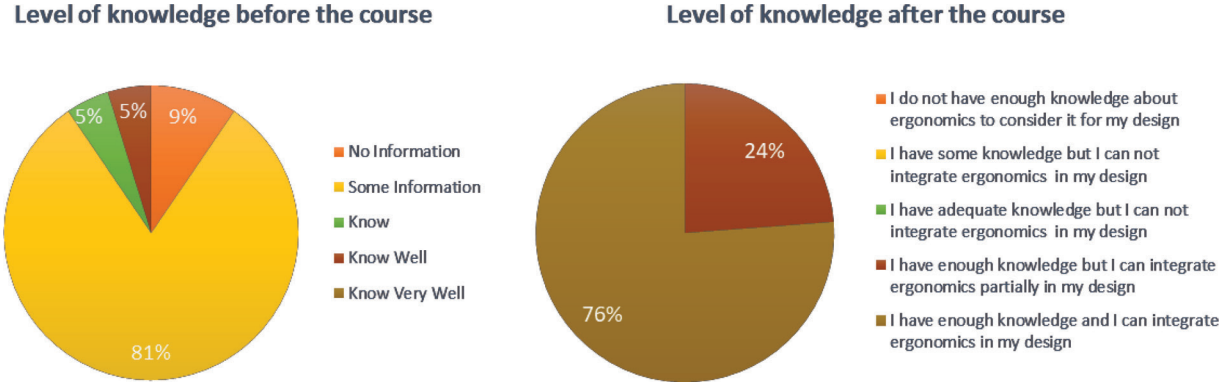

Figure 7: Students' response about the level of knowledge before the course (left) and the acquired knowledge and ability after the course (right).

All the questions mentioned above were asked directly in the questionnaire. Therefore, there is a possibility that the responses may not depict the actual picture. Hence, the questionnaire also contains some indirect questions which revealed the actual understanding of the students. In the survey, it was asked if they thought

about critical dimensions and space requirements while engaging in a new activity. The responses showed a positive direction. Only two of the participants (which counts about 10%) were not sure, but the rest of the participants agreed. There was another question that asked if the students thought about the appropriateness of the dimensions for the users of any furniture/fixture or space they use. In response, all of the participants agreed without any hesitation. Figure 8 illustrates the responses.

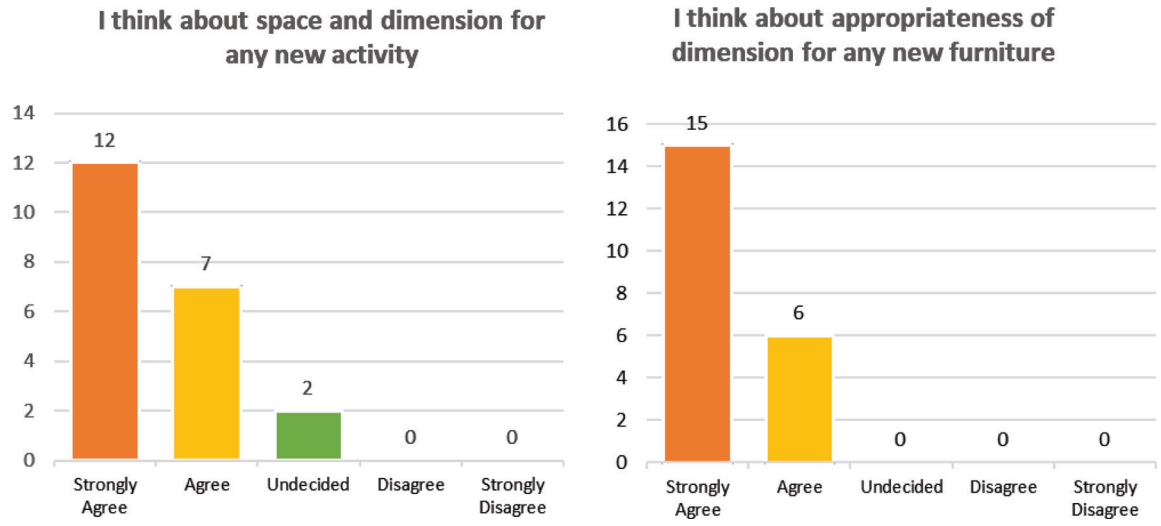

Figure 8: Students' response about concern for appropriate dimension and space requirements for newly experienced activity (left) and furniture/fixture or space (right).

According to the survey results, the studio approach of teaching HFE was beneficial to the students, and they acquired the expected level of awareness and capacity to integrate HFE issues in their designs. For the studio guides, the expectation was not only to fulfill the course objectives delineated in the academic program, but also to make the students internalize the fact the HFE has to be considered for any kind of design issues relevant to accommodate human activity in the built environment. It seems the course was successful in this regard.

Conclusion

Though learning HFE is an essential part of architecture education, the process of learning this knowledge in studio-based education lacks studies on it. This study overviewed several examples and documented one example in detail as a structured way of learning HFE and student's feedback upon learning it. Students started to learn from the literature and, their research on anthropometric dimensions of local people and spaces accommodating precise human activities made them realize the relationship between body dimension and relevant posture with the surrounding space and furniture/fixture. Moreover, their study revealed some deviation from the standards mentioned in the literature and made them more conscious about the context sensitivity. This learning is further reinforced through a design project so that students could internalize the learning and apply them in architectural space design. Students' feedback on the course indicated that they were benefited from this course and developed an understanding of integrating HFE in space designing.

This study indicated another important perspective of integrating HFE in architecture education. The commonly consulted literature on space design standards is not necessarily applicable in every context. The studio course identified several mismatches between the reference standards and the local population. This could be an interesting topic for further research which may lead to formulating an anthropometric database relevant for architectural education as well as practice.

This study of the studio approach can be also useful for other architecture schools. The structure of the learning design and the findings can be considered for learning outcomes, studio projects, etc. to help the students internalize HFE as an important design component for the built environment. Furthermore,

the studio teaching method can be applied to other disciplines that require an understanding of ergonomic application and the development of learning techniques.

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Authorship Contribution

The first author has conceptualized the framework of this study and prepared the main body of the text. The other two authors have contributed to the preparation of the dataset, analysis, and processing of all the supplementary materials, questionnaire survey, and enhancement of the text. All the authors were involved in the ARCH 2102: Design Studio III course as studio instructors and conducted the course.

Declaration

The authors declare that no conflicting interest exists and the authors have received no financial support for this study. The authors also declare that, unless otherwise stated, all the illustrations that appeared in this article are duly credited and belong to the authors.

Note

The affiliation of the second author has been changed from Department of Architecture, Military Institute of Science and Technology (MIST), Bangladesh (where the study was conducted) to Department of Architecture, Bangladesh University of Engineering and Technology (BUET), Bangladesh.

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Chitkara University, Saraswati Kendra, SCO 160-161, Sector 9-C, Chandigarh, 160009, India

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