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INTEGRATING HUMAN FACTORS AND ERGONOMICS PRACTICES INTO DESIGN STUDIO COURSES THROUGH ACTION RESEARCH

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Abstract

Industrial design is a discipline in which numerous information contents are synthesized. The success of the design outputs depends on the correct planning and management of the process in which a large amount of information that is the subject of the design is processed. While human factors and ergonomics provide theoretical information that can be input to the design, it possess also applied contents. Theoretical information would be sufficient in some design studies, whereas the applied studies within the framework of human factors and ergonomics are performed in some other studies. Being able to correctly give the relevant formation to the designers depends on the fact that the theoretical and practical content of design education is in a structure where they are synthesized in a certain harmony. In addition, although intuitive design behaviors can generate subjective results, it should be aimed that the objective evaluation processes can achieve tangible results that can be held accountable and that the foresight skills of the designer candidates should be developed in this direction. In the light of this information, experimental studies have been carried out within the action research framework towards the use of objective information sources in the design process. As a result of the studies, while the tangible design outputs that can be evaluated from an objective point of view were reached, it was also determined that the applied methods made contributions in the learning motivation.

İNSAN FAKTÖRLERİ VE ERGONOMİ PRATİKLERİNİN EYLEM ARAŞTIRMASI YOLUYLA TASARIM STÜDYO DERSİNE ENTEGRE EDİLMESİ

Anahtar Kelimeler

İnsan faktörleri ve ergonomi
Endüstriyel tasarım eğitimi
Tasarım süreci
Tasarım stüdyosu
Elektromiyografi

Öz

Endüstriyel tasarım çok sayıda bilgi içeriğinin sentezlenerek tasarımcıların tasarım karakteri vasıtasıyla somut çıktılar sağlandığı bir disiplindir. Tasarım çıktılarının başarısı tasarıma konu olan çok sayıda bilginin işlendiği sürecin doğru planlanmasına ve yönetilmesine bağlıdır. İnsan faktörleri ve ergonomi tasarıma girdi olabilecek teorik bilgileri sağlarken aynı zamanda uygulamalı içeriklere de sahiptir. Kimi tasarım çalışmalarında teorik bilgiler yeterli olurken kimi çalışmalarda insan faktörleri ve ergonomi alanı çerçevesinde uygulamalı çalışmalar gerçekleştirilmektedir. Tasarımcılara ilgili formasyonun doğru bir şekilde verilebilmesi tasarım eğitiminin teorik ve uygulama içeriklerinin belirli bir uyum içerisinde sentezlendiği bir yapıda olmasına bağlıdır. Ayrıca sezgisel tasarım davranışlarının sübjektif sonuçlar doğurabilmesine karşılık objektif değerlendirme süreçleri ile hesap verilebilir somut çıktılara ulaşabilmesi ve tasarımcı adaylarının bu doğrultuda öngörü becerilerinin geliştirilmesi hedeflenmelidir. Bu bilgiler ışığında iki eğitim projesi üzerinden objektif bilgi kaynaklarının tasarım sürecinde kullanımına yönelik eylem araştırması çerçevesinde deneysel çalışmalar yapılmıştır. Çalışmalar sonucunda objektif açıdan değerlendirilebilir somut tasarım çıktılarına ulaşılırken, uygulanan yöntemlerin öğrenme motivasyonu bağlamında katkılar sağladığı tespit edilmiştir.

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1. Introduction

Meyer and Norman (2020) stated that design education began by feeding on the deep-rooted history of craft and has developed itself until the present day. However, they emphasized that design requirements have today gone through a dramatic change and that a collective structuring where different disciplines coexist is needed rather than a "master designer" approach (p.46). Against these dramatic changes, examples of multidisciplinary studies in which the contents of education, research and practice are intertwined have begun to be structured at Tu Delft University (Voûte et al., 2020, p.63). Today, although design education is mainly practice-based, theoretical courses providing input from different disciplines related to design also supported it. However, in a study conducted with design educators in Turkey, some educators considered interdisciplinary work as a basic skill, while some others stated it was difficult to include an interdisciplinary approach into design studios with time constraints (Yenilmez & Bagli, 2020).

The "Human Factors and Ergonomics" discipline supports the design process with both theoretical and applied contents (Karwowski, 2012). When the product-human relations are examined within the "project course" that aims to develop and strengthen design competence within the design education process, it is usually seen that intuitive evaluations are made. The inability to test intuitively planned product-human relations based on theory by objective methods cannot allow the evaluation of human-compatible and/or incompatible relations. Therefore, this situation ensures that the design evaluations are as intuitive as the design decisions made.

In a study conducted in Turkey in 2013, it has been showed that there was a state of dissatisfaction in students because of insufficient practice studies in the ergonomics education given in Industrial Design Departments (Cifter et al., 2013). In another study carried out in England, practical examination of ergonomics principles during the design process was an approach adopted by both students and instructors (Davies & Bingham, 2013). The perceived importance of ergonomics in the design process has been revealed for the design students in Turkey and Romania (Kaya & Romanescu, 2020). However, it is controversial how effectively human factors is used in the design education process in response to this perception of importance. It is expected that bringing students who receive design education in acquiring the awareness of verifying their intuitive predictions with objective methods may allow them to make a difference in the professional design environment with a high competition.

Norman (2010) stated that design education should be supported by scientific methods in line with today's needs and that it should create its own research and experimental approaches and transform itself. In the study, it is planned to achieve this gain through the approach of adapting academic research and discussions to design practice, which emerged as a result of Dorst's (2016) touching on the lack of a connection between design research and practice, and which was defined as the "academic design" (p.3). The aim of the research is to present a hypothetical model with the "academic design" approach regarding how beyond the theoretical content of human factors discipline, research and applied contents belonging to this discipline can be synthesized in the design education.

The effective role of human factors data in the creative thinking process has been seen as important both to contribute to the creative processes and in terms of the objective of the evaluation stages. Through this model, it was foreseen that the content of human factors should be removed from being only theoretically focused and developed in a way to guide the project processes.

2. Design Studio and Pedagogy

In professions learning, there are teaching ways that provide a certain professionalization together with disciplinary thinking, which is expressed as "signature pedagogies" (Shulman, 2005; Tovey, 2015). According to the principle of signature pedagogies, there are various ways teachers provide for acquiring discipline-specific competencies. In design education, there are profession-specific basic components such as project work, professional dialogues, the materiality of activity, critical and contextual project research and studio environment (Tovey, 2015). The knowledge gained in various courses should be used in the design process to find an optimum solution to the design problem in a design studio (Demirbas and Demirkan 2007). In the learning process, the educator guides the students to identify a real design problem. During the design process, students try to understand various methods and techniques to develop their observation and decision-making skills, discover their own abilities, and develop their own methods and design styles (Chen, 2016).

Design studio projects should allow for the use of different learning styles in the design process (Demirbas and Demirkan 2007). Traditionally, art and design teaching has relied on learning by doing, often by simulating a professional situation through a project brief (Tovey, 2015). There is effectively a transformative learning process in teaching design practice (Bull, 2015). Being a successful designer largely depends on the ability to think through design, and specific design skills and knowledge to translate and develop ideas in line with this ability. Its essence is a process that requires practice to integrate both holistic and linear modes of thinking in a dual processing model, which includes design projects, experiential problem solving, and creative experimentation (Tovey, 2015).

According to Norman (2010), designers need experimental techniques that recognize pragmatic, applied goals in line with today's needs, and design needs to develop its own experimental methods and they need to be simple and fast. Experimental learning encourages deep learning in students, and assessments made within this scope motivate students, and this method also provides students to identify the factors that lead to failure in their own designs and correct them on their own. (Bingal, 2022). Measurable and observable creative experimental process designs integrated into the design studio with a holistic approach are notable for their potential to increase both curiosity and motivation, as well as making positive contributions to the development of the foresight skills of the designer candidate.

3. Creative Design Process

Despite the differences in the nature and complexity of the outputs, it is clear enough that there are numerous similarities between the creative thinking process and the design process (Wong and Siu, 2012). Howard et al. (2008) compare the two processes and states that both processes require the analysis and understanding of information at an early stage. Both processes require evaluation at the end of their own process, and generating ideas between analysis and evaluation. Lawson (2006) commented that the control and combination of rational and creative thinking is one of the most important skills of the designer (p.138). Wong and Siu (2012) developed a creative design process model with 3 variations, based on a model proposed by Howard et al. The model comprises analysis, synthesis and evaluation stages, and the creative thinking process can be in different combinations at these stages. Using these different combinations may vary depending on the context in the process (Wong and Siu, 2012). The contents and inputs that determine the process can be diverse and human factors are considered as a basic criterion in the design process. The question of at which stages the creative thinking process will be used in the design studio also brings with it the question of how to include the information resources obtained from human factors.

4. Method

The study adopted the action research approach, which is frequently used in educational research and defined as improving educational practice. Action research involves action, evaluation and reflection activities (Clark et al., 2020). It is a method that continues in cycles until the desired goal is achieved and is suitable for process improvements (Bolis & Sznelwar, 2016). The reason this method is preferred is that the use of knowledge in terms of human factor and the creative thinking process are planned at different stages of the design process. The study was carried out through studio courses of two students from the Industrial Design Department of Yeditepe University. In the courses, the students were first expected to identify the topic within the need areas outlined by the advisors. Afterwards, research, development and prototyping activities were performed sequentially. There are practices and period differences in the project processes of the two practices. After evaluating the process of the first project, some improvements were made in the second one.

4.1 Human Factors Assessment Methods

In "Handbook of Human Factors and Ergonomics" by Stanton et al., (2005a), the methods are appeared to be divided into headings as physical methods, psychophysical methods, behavioral and cognitive methods, team methods, environmental methods and macro-ergonomics methods (p.1-4). For the aim of giving direction to applied studies; the superficial electromyography imaging technique, which does not require a laboratory environment and one of the objective and psychophysical methods that also includes human research in today's new interaction types, as well as the observation technique that enables the evaluations of the product-human relationship during interaction were preferred.

Electromyography (EMG) is a type of assessment method that is frequently used in medicine, aims to measure and determine muscle activities, and has various techniques (e.g., needle electrode or superficial) (Berger et al., 2010). It can be summarized as recording the electrical differences seen in the membrane potential depending on the action potentials formed in the nervous system by placing electrodes on the muscle surface (SEMG) or inside (needle electrode) (Farina et al., 2004). Since superficial electromyography (SEMG) takes measurements over the skin, it is the techniques used by disciplines such as sports sciences, biophysics and ergonomics, which conduct other human research besides the medical sciences. One of the major goals of ergonomics is to prevent musculoskeletal disorders. For this purpose, it is important to develop methods for the measurement of the muscle force, exhaustion, and the involvement of muscle in a work task (Gazzoni et al., 2016). In addition, the observation technique which is included in the study, one of the objective information gathering methods, is performed by examining the information recorded visually and verbally about the interaction, especially under a scenario (Stanton et al. 2005b).

4.2 Equipment

The SEMG system basically consists of the sensor station, sensors, power cable and a tablet on which the sensor settings and measurements are recorded. The software on the tablet gives instantaneous values and graphs and enables quick and instant information to the design process practices of the designer. Wireless sensors and tablet software are advantageous compared to other cable-connected SEMG systems, due to both spatially and because their movements are not restricted during the measurement. Instant data transfer and comparison features of the tablet software make this system more practical in design activities.

5. Experimental Practice 1

The first stage of this study, which was planned within the framework of action research, was revealed as a result of adapting the stages of the studio course in design education to the action research process of Voort and Wood (2016). Human factors assessments are divided into objective and subjective assessments that are distributed across different stages of the process. This process is planned to be carried out during the research stage to ensure that objective evaluations could be an input to the design during the practice process.

The subject of the first practice is the development of a mechanical product for cracking nut shells, in which the force-hand relationship is intense. A roadmap was determined under the basic stages of the design process. A strategic planning was developed towards at which stages of the design process the human factors criteria would be considered. In line with this planning, the design criteria of a need product with an intense force-hand relationship were determined. These are:

- Functional adequacy
- Human factors adequacy
- Aesthetic adequacy

In the research stage, the products developed for this need in the market were examined, and functionality tests were carried out on three different model samples. Afterwards, human factors assessments in two stages were performed. It was first tried to determine which muscle groups worked more in the product use by manual touch and verbal expressions. Then, the activities in the muscle groups detected were measured by the EMG technique having several procedures for measurement accuracy and reliability. However, in the design process, the EMG application with limited procedures was used to obtain fast results and to support verbal expressions with numerical outcomes.

Figure 1 shows the functional evaluations of three different products and EMG measurement results. It turned out that the first cracker made a homogeneous cracking (cracked at various points), but strained the small muscle groups and caused exhaustion.

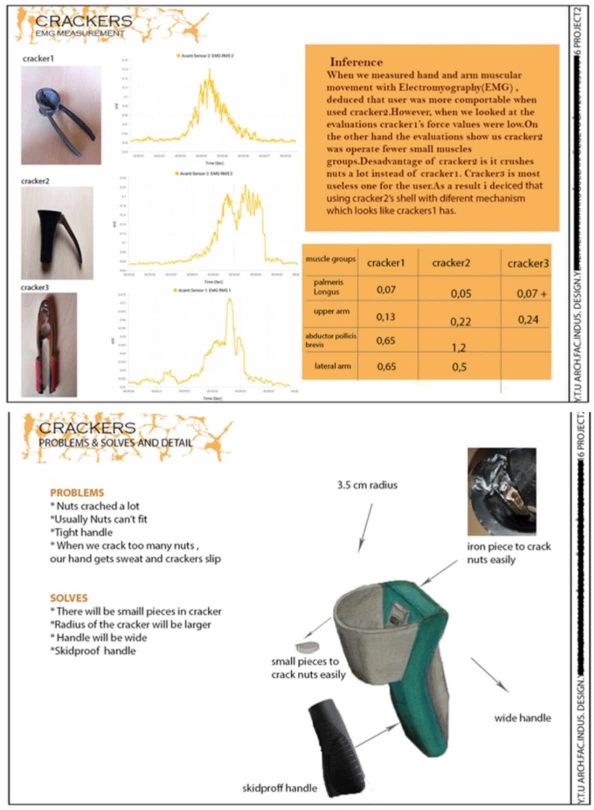

Figure 1. EMG Measurement Results and Functional Evaluation of Three Different Crackers and The Developed Product At The End of The Practice 1

The second cracker was found to have used big muscle groups rather than the small ones, created less exhaustion compared to the other products, but the cracking was not homogeneous. The third product was evaluated to be impractical due to both its weak mechanical advantage and creating muscle exhaustion. As a result of the functional and human factors evaluations made, a conceptual design study towards the improvement of the second product was conducted, and the design was finalized as shown in Figure 1.

The biomechanical principle of the product, which has a mechanical advantage according to the EMG tests, was borrowed, and protrusions that distribute force were planned on the inner surfaces of the breaking chamber to perform the cracking process homogeneously. Its mechanical principal was developed in a unique structure. In addition, shape studies were performed to make the product more graspable.

The prototype of the final product could not be realized due to limitations of the study. The most important of these limitations is that the infrastructure towards producing mechanical parts could not be developed within the course process. It was thought that a model-level product would give misleading results in measuring muscle force. When the effect of the study on the student's course achievements was assessed, in the hand-force relationship, the knowledge about both the correct use of the mechanical advantage arising from muscle strength, and the correct biomechanical grip and wrist angles was transferred practically. In the design process, the student was enabled to experience how the human factors practice impacted the design, and how the design product can be evaluated based on tangible justifications by using applied and objective knowledge production rather than intuitive and theoretical knowledge. The student learned how the input obtained in the analyses affected and directs the type and technique of interaction in the design process. Besides, a practice example of how human factors techniques can be used quickly in the active design process was accomplished. It is thought that the experience gained from this practice would be a guide in environments in which design research is intensive beyond design practice, such as R&D or design centers where real design processes are conducted. However, rapid human factors tests could not be performed since the prototype of the product developed within the study was not realized. Although rapid tests of similar products had been conducted, that ergonomic tests were not applied to the product developed in the study makes the product subjective.

6. Experimental Practice 2

In the second practice, a new process planning was made in accordance with the reflections of the first stage of the action research (Figure 2). In contrast to the first process, intuitive evaluations were made in the research and design process and objective methods were planned over the prototype of the intuitively planned design. This planning would allow the accuracy of the student's intuitive approaches to be evaluated through the final product.

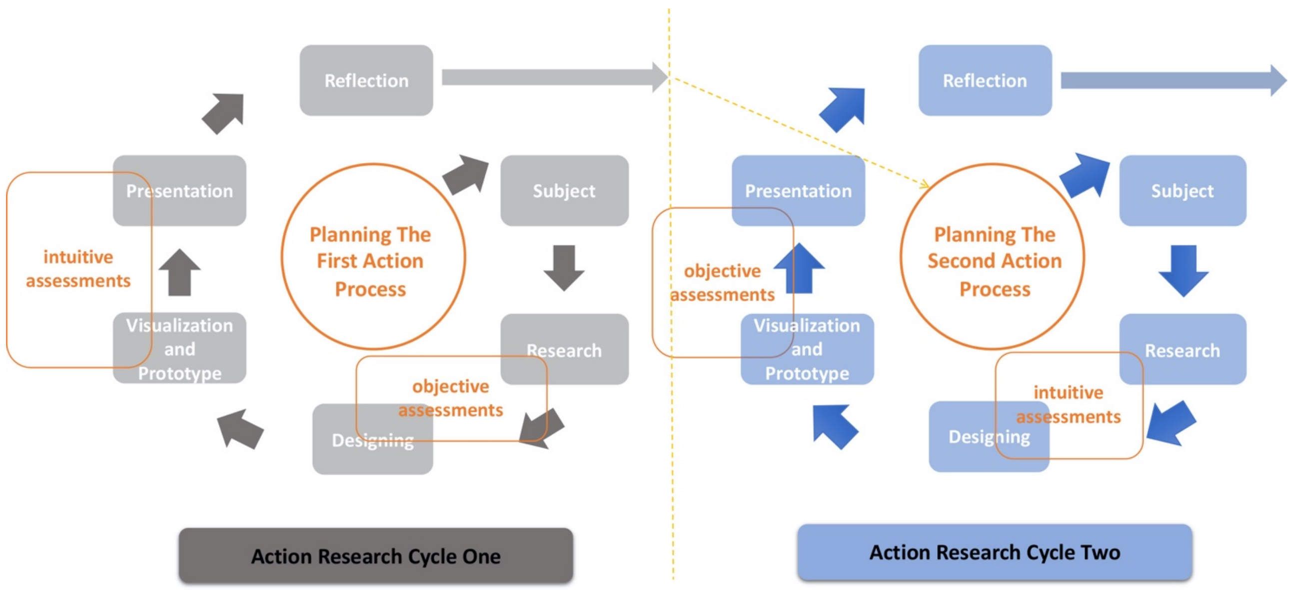

Figure 2. Adapting the Reflections of The Results Obtained in The First Practice To The Second Action Research Cycle

The content of the second practice is to develop a product for the need to grind coffee beans, in which the hand-force relationship is again at the forefront. The stages of this design process are also similar to those made in the previous practice. The students first examined the products with the same functionality in the research process, and then conducted an in-depth research on the coffee experience. As a result of the research, the design strategies were determined based on the finding that the use and performance of home manual grinders is higher than non-professional electric grinders used at home. It was found in the examination of the products with similar functions that their mechanical systems were the same, but they differed in terms of shapes and dimensions. Biomechanically, while the product is gripped with one hand, its turning handle is moved with the other hand. The products usually have a cylindrical main body due to mechanical function. In this case, the diameter of the objects especially held in the air can be an important criterion for the gripping hand. Since the place where the force is obtained is the main body of the product, the grip diameter would affect the loads exerting on the hand. When the grip diameter widens, it is likely to lead to more rapid exhaustions as the force would be distributed to small muscle groups on the hand.

In biomechanical relationships, how the spatial shape of the mechanical turning handle should be also an important factor. The shoulder joint and angle, and the position of the elbow should be planned in the natural movement direction of the body. Where turning movement is parallel to the horizontal plane, rapid exhaustion may occur as the elbow approaches the level of the heart. When the turning movement is perpendicular to the horizontal plane; since one of right or left elbows, surely will move in a horizontal position and approach the heart axis, exhaustion would once again occur rapidly. These assumptions apply when products are used with no support surface. If any support surface is used in the design, equilibrium and momentum forces are also required to be considered. In the light of these evaluations, two market samples were examined. They were determined according to the size of the body section. One represents products having a small diameter body section and the other having a large diameter body section. In terms of the turning handle, the ones that are the most common in the market, and that move parallel to the ground plane was preferred.

Unlike the previous project, the EMG tests of the products with similar functions were not performed before the design in this project. All tests were planned to be carried out with the principal prototype that emerges as a result of the hypothetical realization of human factors tests and the transition to the design. The following design criteria were determined as a consequence of human factors evaluations:

- The optimization of the grip diameter.
- The optimization of spatial location of elbows during turning movement
- The optimization of the turning handle pivot angle.

The essential characteristics of the design to be realized according to the above criteria are as follows;

- If the support surface is not to be used, it should be provided that the grip diameter is small
- In case of using the support surface, the grip diameter should be provided to be large
- During use, the elbows should be kept at a natural angle and away from the level of the heart
- The turning handle pivot angle should be optimized in accordance with the previous criteria.

The functional mechanism of the design was determined as a conical to grind the coffee particles homogeneously in the desired sizes. Then, a design study was conducted according to the determined criteria. To carry out the human factors tests of the product that emerged as a result of the design study, the 3D modeling of the design was first made in the rhino software, as seen in Figure 3. Meanwhile, the design was resized and given its final form.

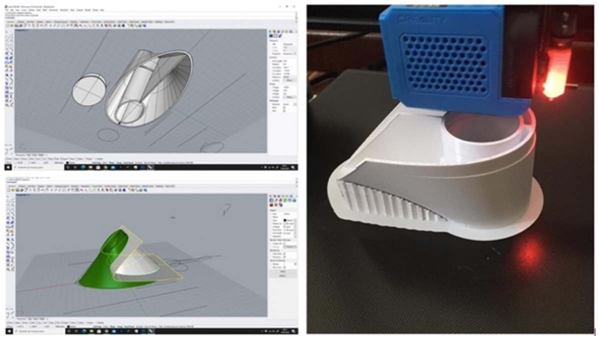

Figure 3. The 3D Modeling and Printing of The Product

After modeling, the body of the designed product was printed on a 3D printer. The mechanism of the prototype was purchased ready-made and used so that human factors comparison towards the product-human interaction can be made objectively.

6.1. Measurement Process In Practice 2

A user research was conducted to verify the human factors evaluations made hypothetically in the light of theoretical information through observation. The observation method provides the collection of instant data on the product-human interaction within the frame of the use time (Stanton et al. 2005). Taking video recordings during the use allowed the observation of the physical activities. In The Practice 2, the thin section product (A1), the thick section product (A2) and the product developed within the study (D) were tested within the framework of the observation procedures, whose stages were revealed by Stanton et al. (2005b).

The market products were subjected to the air and bench-top use tests, and the developed product only to the bench-top use test. This decision was taken because the market products can be used in both ways depending on the user preference. Since the developed product supports only the bench-top use, it was not subjected to the air use test. Video recordings were taken in such a way that the user was to be seen fully en face. The reason for this is to make comparisons of biomechanical behavior during use.

6.1.1. Observation Results

The video footage taken from en face allowed to observe posture, grip angles, axial movements and circular movements during the use. Using the three products in the period of 15-20 seconds was sequentially recorded. The reason for selecting this duration is that the participant stated to have had difficulty in the first two samples. The air use of the A1 coded product is shown in Figure 4. In the figure, the blue line is the level of the heart; the yellow line is the body ax; the red line is the turning mechanism axis of the product; the green area is the turning diameter and the yellow area is the wrist position. The evaluation of the use of the A1 coded product in Figure 4 showed that the right elbow rose above the heart level, the product axis and rotation axis continuously changed angle and location, and the right wrist was bent in certain positions. This can be interpreted as the inability of the product to be fully balanced and the movements made aimed at the force resistance. As the consequence of this resistance, the participant rapidly became exhausted and could not continue the task. The similar problems were observed in the use's evaluation the A2 coded product in the air (Figure 4). However, here, change in the height and related wrist angle deterioration which were seen the other product was not detected. In using of this product, the problem that was not observed in the other is that there was too much activity in the small muscle groups of the left hand that grips the product.

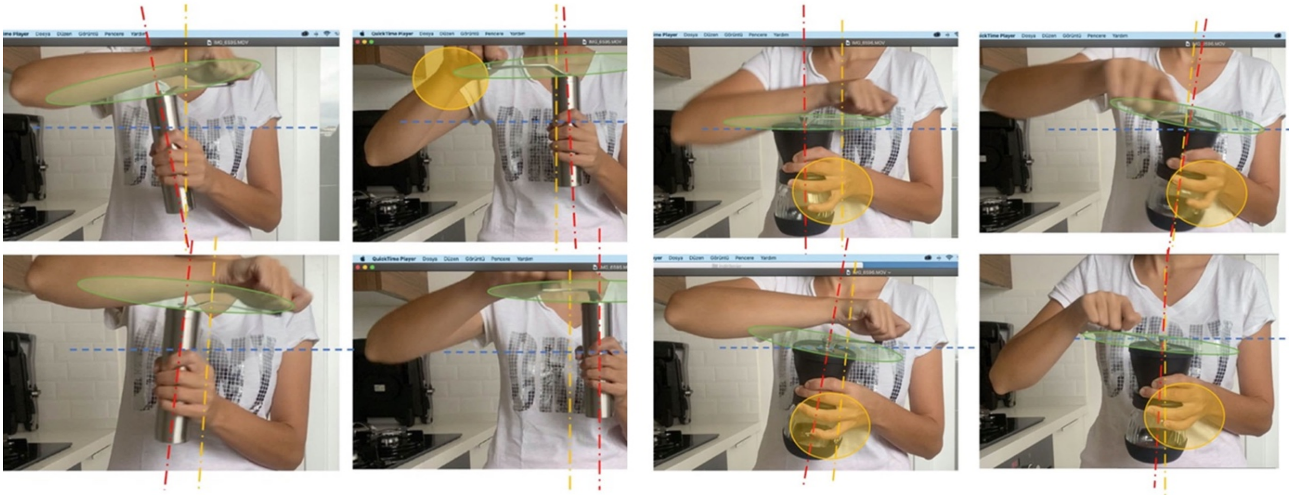

Figure 4. First Stage. The Use Angles of The A1 (Four images on the left) and A2 (Four images on the right) coded products in the air. Wrist angles are shown relative to the axial rotation movement (green). Yellow areas represent strain points. The axis (red line) changes of the products were observed relative to the spine axis (yellow line).

When the bench-top use was examined, the physical and biomechanical behaviors created by the A1 coded product are seen in Figure 5. Since the surface on which the thin-section product comes into contact with the bench was quite narrow, radical shifts emerged in the rotation axis to the right and left relative to the rotation direction. Besides, undesired angles also occurred in the wrist angles. The elbow on the rotating arm working below the heart level can be considered as a positive situation here.

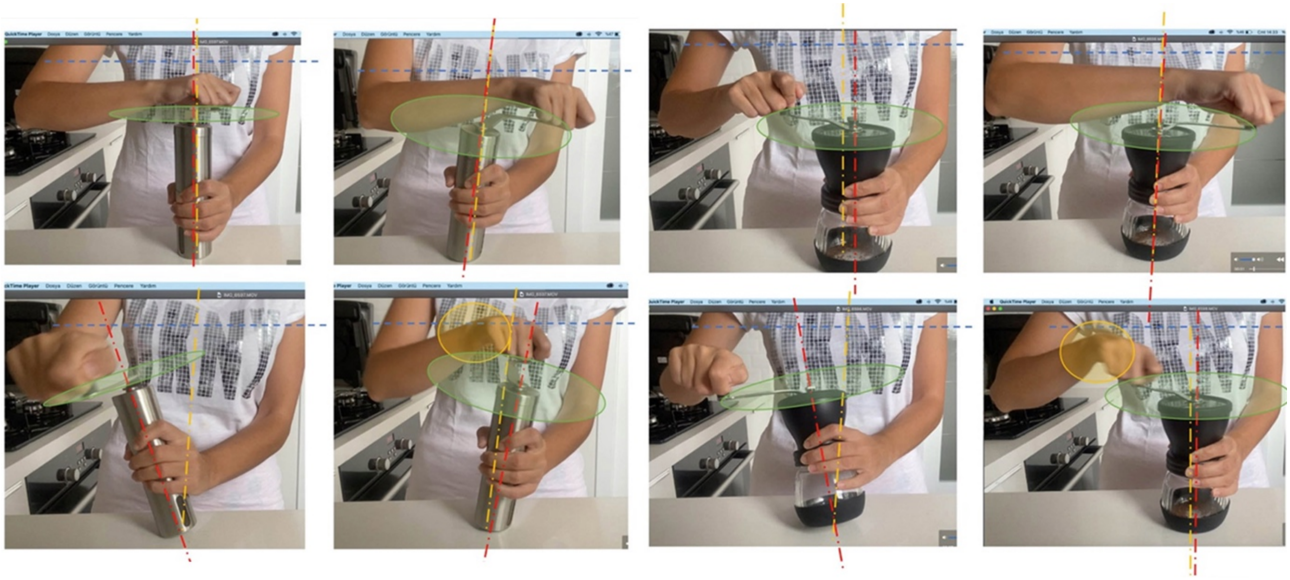

Figure 5. Second Stage. The Use Angles of The A1 (Four images on the left) and A2 (Four images on the right) coded products on the bench-top. Wrist angles are shown relative to the axial rotation movement (green). Yellow areas represent strain points. The axis (red line) changes of the products were observed relative to the spine axis (yellow line).

The examination of bench-top use of the A2 coded product revealed that the angular shifts were less because its floor area was wider, as seen in Figure 5. The arm turning the mechanism remained below the level of the heart. However, as with the other product, wrist angle shifts also occurred in the bench-top use.

Examining the use of the developed product (coded as D) in Figure 6, it was seen that the body axis was fixed, the axis of the product and the axis comprising the center of rotation did not change.

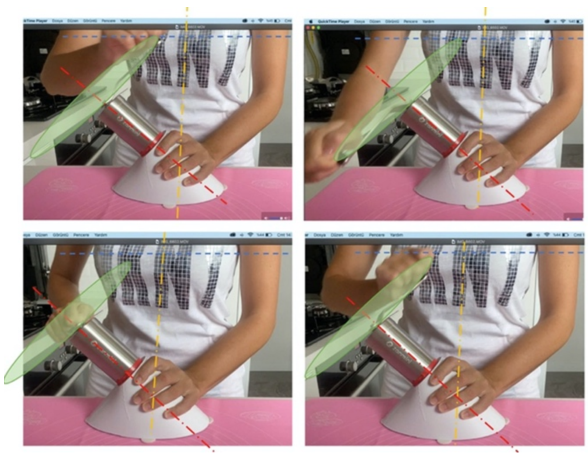

Figure 6. Third Stage. The use angles of the developed product (coded as D) on the bench-top. The rotation axis of the product has been angled and the ground contact surface has been increased. Thus, the product axis is in a fixed position relative to the spine axis. No strains were observed in the wrists.

In addition, it was observed that the elbows and both hands were working below the heart level. The direction of the rotation movement was found to be toward of the natural movement of the shoulder joint, as opposed to the parallel position of the other products to the ground. No bending was observed in the wrist performing the rotational movement.

The muscle group that works intensely is the anterior deltoid (anterior shoulder muscles) when the turning is parallel to the ground, and the biceps and triceps (arm muscles) when it is performed in the natural direction of the shoulder joint. Considering the daily life activities, since arm muscles are used more actively, they would become exhausted later than the anterior shoulder muscle group. The anterior shoulder muscle group is most active when movements and tasks are performed above the level of the heart, which speeds up the exhaustion.

In the design of products that require mechanical force, the mechanical advantage should correspond to human biomechanical characteristics. The user can make various adaptations towards providing mechanical advantage. For example, the first two products can be used in different ways, as either in the air or on the bench-top, according to the user's preference. However, various problems have been determined to be experienced in both these uses as well. The observation study performed revealed that the product developed in the light of the theoretical information and hypothetical criteria related to human factors content was more advantageous in terms of postural and force directions. The three products were evaluated by the Pugh matrix analysis within the framework of ergonomics criteria. This method allows the products to be evaluated through a table in line with the criteria desired to be in the design. For this purpose, the products are placed to the columns and the criteria to the rows of the table. If a design provides an advantage in accordance with the criterion, 1 is given if it does not provide 0, and -1 is given if it provides a disadvantage; then the most successful design is determined by summing up these values (Pugh, 1991; Cervone, 2009). The results obtained in the Pugh analysis indicated that the newly developed product was more advantageous than the A1 and A2 coded products (Table 1).

Table 1. The Evaluation of The Three Products By The Pugh Matrix Analysis.

	A1 coded Product (air use)	A2 coded Product (air use)	A1 coded Product (bench-top use)	A2 coded Product (bench-top use)	Developed Product (bench-top use)
The body axis is constant during the task	-1	-1	-1	-1	1
The product's axis is constant	-1	-1	1	1	1
Turning axis is constant	-1	-1	-1	-1	1
The location of the product is constant	-1	-1	1	1	1
The task is conducted below the level of the heart	-1	-1	1	1	1
The angle of the wrist turning the handle is constant	-1	-1	-1	-1	1
Total score	**-6**	**-6**	**0**	**0**	**6**

6.1.2. Semg Results

This method, where muscle activities are measured, since there are multiple muscle groups working together, first, the muscle group where exhaustion was felt was determined (Figure 7).

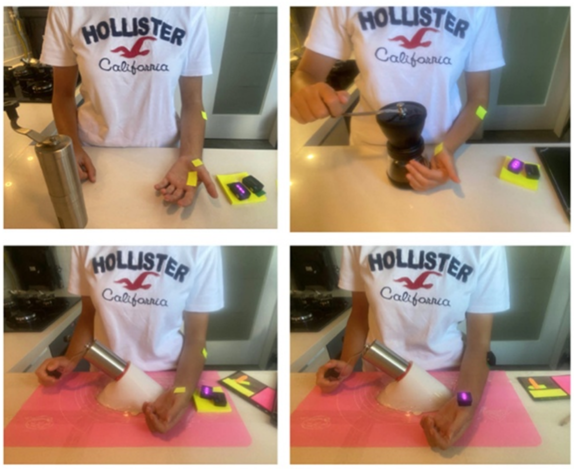

Figure 7. Determination of the Most Intensely Working Muscle Groups During The Use of The Products. Afterwards, emg measurement pods were attached to the muscles and measurements were made.

For this, the muscle groups were determined from the verbal expressions and by the researcher's groping during the test use. This procedure was conducted separately for each product, since different muscle groups can work during the use of the products. As the system included only two EMG measurement probes, the two most intensely working muscle groups were selected during use. These are the extensor digitorum and abductor pollicis brevis muscles.

The tests were video recorded, and the application times were left to the participant. This is because the participant in the observation test stated that the first two products were challenging. The measurement tests of the three products were performed at the same time every other day, on a full stomach. The test duration that was based on the task is the grinding of coffee beans necessary for a cup of coffee. For a cup of coffee, 15-25 g of coffee is needed to be ground depending on the cup size. In this study, 20 g of coffee beans were placed in each grinder. However, since coffee grinding is a process based on muscle force, it is not realistic to grind the coffee in the determined amount in one go. For this reason, the test duration was determined as the interval from the start of the test until the participant felt the need to give a rest because of exhaustion. In this method, which is called whole record, the beginning and the end of the recording are arranged in such a way that the entire record is calculated as a period (Konrad, 2005).

As in the observation study, the use of two market products in the air and on the bench-top was measured separately. Since the developed product was designed for bench-top use only, a single measurement was made in this product. The study was conducted with a single woman due to the need for contact and the pandemic limitations. Because the purpose of the study is to reveal how a method can be used in educational focus, including numerous participants would not contribute critically to this purpose. Following the measurements, an evaluation interview was conducted with the participant about the products. The participant expressed the opinions about the products in this stage.

The measurement results of the A1 coded product:

The interval between the start and the first rest period was found to be 46 seconds in the air. The participant stated not to continue after this point. In response to this use, 3.5 g of coffee beans were ground. In the bench-top use of the same product, a resting period was reached after 48 seconds and once again 3.5 grams of coffee beans were found to be ground. During the use of the product in the air; it was measured that the mean value was 0.12 mV and the peak value 1.21 mV for the extensor digitorum muscle, while the mean value was 0.39 mV and the peak value was 1.83 mV for the abductor pollicis brevis muscle. In the bench-top use of the same product, it was found that the mean value was 0.09 mV and the peak value was 0.62 mV for the extensor digitorum muscle, the mean value was 0.44 and the peak value was 1.71 for the abductor pollicis brevis muscle.

The measurement results of the A2 coded product:

The results obtained during the use of the thick-section product in the air showed that the interval between the start and the first rest period was 42.5 seconds. The participant stated not to continue after this point. In response to this use, 4 g of coffee beans were found to be ground. In the bench-top use of the same product, a resting period was reached after 48 seconds and 4.5 grams of coffee beans were ground. During the use of the product in the air; it was measured that the mean value was 0.11 mV and the peak value 0.28 mV for the extensor digitorum muscle, while the mean value was 0.37 mV and the peak value was 0.94 mV for the abductor pollicis brevis muscle. In the bench-top use of the same product; while the mean value was 0.07 mV and the peak value was 0.13 mV for the extensor digitorum muscle, the mean value was 0.19 and the peak value was 0.86 for the abductor pollicis brevis muscle.

The measurement results of the developed product (coded as D):

The interval at which the participant enters the initial and first rest period was 97 seconds. The participant stated not to continue after this point. In response to this use, 8 g of coffee beans were found to be ground. During the use of the developed product; it was measured that the mean value was 0.05 mV and the peak value 0.34 mV for the extensor digitorum muscle, and the mean value was 0.24 mV and the peak value was 1.1 mV for the abductor pollicis brevis muscle.

6.1.3. Evaluation of the Results

The existence of various parameters that can affect muscle activities in the use of the product makes it difficult to evaluate the results. After finishing the test of each product, interviews were conducted with the participant about the products. The positive and negative opinions were tried to be determined in these interviews. In Table 2, the EMG measurement values of the three products and the results of other measurement parameters are seen together.

Table 2. The Emg Values in Different Ways of Use, The Interval Between The Start of The Test and The First Rest Period and The Amounts of Ground Coffee Beans in The Three Products.

	extensor digitorum				abductor pollicis brevis				Time/s		Ground amount/gr	
	air use (mV)		bench-top use (mV)		air use (mV)		bench-top use (mV)		air use	bench-top use	air use	bench-top use
	peak	mean	peak	mean	peak	mean	peak	mean				
A1 coded product	1,21	0,12	0,62	0,09	1,83	0,39	1,71	0,44	46	48	3,5	3,5
A2 coded product	0,28	0,11	0,13	0,07	0,94	0,37	0,86	0,19	42,5	47	4	4,5
Developed product	_	_	0,34	0,05	_	_	1,1	0,24	_	97	_	8

It was seen that less power was consumed in the bench-top use than in the air use in terms of the mean values of the extensor digitorum muscle for the A1 coded product. However, the comparison of mean values of abductor pollicis brevis muscle revealed that this time less power was consumed in the air use than in the bench-top use. The reason for this would be due to facts that the surface area of the product in contact with the bench was small and the movements of balancing the product that occurred consequently. The peak values show the force values that occurred against the hard beans. Since there is not any support advantage in the use in the air, the peak force was seen to be in higher values in both muscle groups compared to the bench-top use. However, when the peak values were evaluated in terms of the extensor digitorum muscle, it is seen that there is a radical difference. It turns out that the extensor digitorum muscle plays a more active role in use in the air compared to the bench-top use and decreases the activity of the abductor pollicis brevis muscle.

In the examination of the muscle measurement values of the A2 coded product, a radical decrease was observed in the peak force values compared to the first product. This could be considered as a mechanical advantage created by the mechanism of the product. When the comparison was made according to the different ways of uses of the product, the activities in both muscle groups were observed to be less in the bench-top use than in the air use. It was found that the mean value of abductor pollicis brevis muscle in the use on the bench-top was less than the value of half of the use in the air. This result can be interpreted as the product weight providing an advantage on the bench. Since the developed product is solely suitable for the bench-top use, and its measurements were performed in this positioning, its results were compared to only the bench-top use values of the other products. When the EMG measurements of the developed product were examined, the mean value of the extensor digitorum muscle was lower than the bench-top use values of the other two market products. The examination of other values revealed the results obtained from this product were between those of the other two products. Although this finding makes the A1 coded product seem to be more advantageous in terms of the extensor digitorum muscle, the evaluation of the product use duration indicated the participant could use the developed product for almost twice as long compared to the other products. The factor that manipulates the results is thought to be the use of the functional mechanism of the A1 coded product as the functional mechanism of the prototype product. Therefore, it could be said that the functional mechanism with less mechanical advantage increased the peak values in hard beans and these values increased the average values.

The participant was asked to provide feedback on the use of the products to verify the findings obtained in both the observation and EMG measurement stages. The opinions on the products are:

Opinions on the A1 coded product,

"There is a difficulty in gripping; its diameter is so small that I have to exert more effort; the slippery nature of the material causes me to exert more effort. A severe pain arises in my thumb and palm… There is no problem with the turning handle, but when used in the air, exhaustion begins after certain time."

Opinions on the A2 coded product,

"The grip is a bit more comfortable, its shape and its material's not being slippery allow a more comfortable grip. However, the problem here is the heaviness of the product. That creates an exhaustion after a while. I also felt a pain in my thumb related to the gripping in this one as well, but not as severe as in the other product… I did not also feel that much in the palm. However, it fits the hand better when used in the air because of its large diameter. Although I do not feel pain in the palm, this time I have difficulty in gripping it because of large diameter and the heaviness of the product."

Opinions on the developed product,

"In fact, the product was usually easy to grip; I was able to easily grip the product... I feel I can use it comfortably, however since the product moved when the hard beans came across, I mostly spent my power to keep it balanced. However, I could turn it easily, when no hard bean came across. Both my left and right arms were comfortable. Unlike other products, in this product, instead of the exhaustion of my palm and thumb, I only felt difficulty in the upper muscles of my left arm throughout the process towards the end. If it is fully fixed on the bench, it will be very easy and comfortable to use it. Its shape suits my hand very well."

According to the evaluations made from the participant's statements, it was found that the A1 coded product had a small grip diameter and caused a pain in the palm and thumb, the A2 coded product caused a slight pain in the thumb and the product was heavy, and the developed product moved when it coincided to the hard beans and the force was spent to balance it, and the exhaustion occurred in the upper arm muscles. The use position and biomechanical directions of the developed product were seen to create the desired postural orientation, while its figural characteristics turned out to have provided ease of gripping. In this practice, the student was given a more in-depth research practice experience than the first. In terms of educational acquires, this technique allowed the student to increase foresight skills by means of verifying the intuitive approaches that can be input to the design development stage with objective methods. In addition, it was observed that being able to objectively evaluate the tangible outputs of the design process increased the student's commitment to education and the project.

7. Discussion

In industrial design education, students should be mentally prepared from general work to specialization and from abstract to concrete ways of working and vice versa (Liem and Sigurjonsson, 2011) Norman (2010) stated that classical industrial design is an art form that requires deep knowledge of forms and materials, drawing and processing skills, but in line with today's needs, scientific-based methods and experimental design processes should be used in design education (Norman, 2010). However, restructuring and transforming the professional formation change in the discipline of industrial design with scientific foundations requires a transitional education structure. Design educators need time and iterative processes to develop their own methods. The field of human factors offers a scientifically based structure in design research and practices. However, considering the time constraints of the design processes, the motivations and opportunities towards including the practices of this field in the process may remain at a limited level.

In this study, it was demonstrated that human factors methods can be able to make intuitive situations more tangible in the design studio process. When the outputs are evaluated, the direct use of human factors tools in the design process was seen to have two contributions. The first one is that, in terms of design education, it offers an experiential education model in which students take a more active role and their intuitive creations could be evaluated tangibly and objectively. This increases the interest of the students in the lecture, at the same time it is also important in terms of the retention of the experiential knowledge obtained similar to the findings in Bingal's (2022) study. The second one is that, in case this experiential education model (As Norman suggested, 2010) is adopted as the designer behavior and creative thinking process, it provides a basis towards being able to provide more experimental design practices to emerge in the design processes after theoretical education.

The practices are divided into two different uses of the method in the design studio course. The first experimental practice is in a way of realizing that products with similar functions are tested during the design research process and a new design is carried out in line with the objective data obtained through their evaluation from a human factors point of view. The measurement tests were performed before making the design. In the second practice example, the design criteria were determined as the consequence of intuitive human factors evaluations in the design research process. Then, the design activity was conducted in the light of this knowledge, and the comparison tests were made between the prototype and the products with similar functions.

Since project management processes and contents may vary depending on the subject, it is unlikely that human factors criteria can be applied practically in every single project. As human factors discipline is a field of expertise, new course opportunities including direct practice content can be provided for students who are interested in this subject. Considering that today's design issues are inclined towards interaction and human centered approaches, the rapid evaluation (as Norman mentioned, 2010) of human interactions (physical, intellectual, psychophysical, etc.) with objective methods can direct the design decisions and increase the success of the project outputs. In addition, prototyping has positive contributions to idea generation, concretization of conceptual content, design research and evaluation processes (Berglund and Leifer, 2013). Figure 8 shows a model conducted within the study, in which theoretical and practical content of human factors that can be used in project course or support courses with practice content were synthesized.

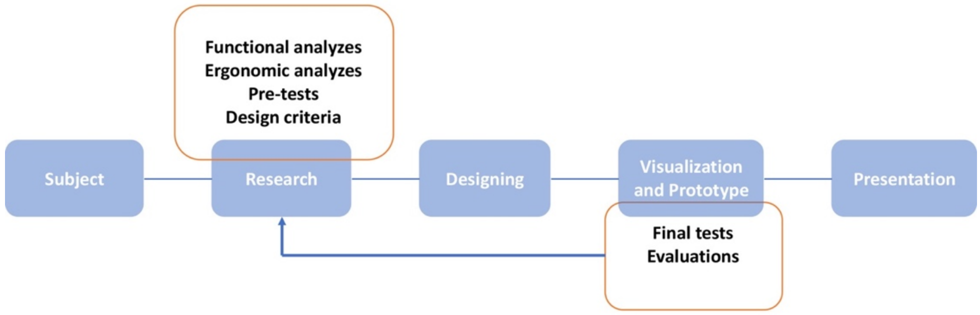

Figure 8. The Model Developed As A Result of The Practices Carried Out Within The Framework of Action Research

In this process model which combines research and practice (Dorst, 2016); different human factors practices can be constructed provided that the methods are specific to the design issues.

The fact that human factors and the other supportive disciplines includes various methods makes it impossible to lecture all these contents within one or two courses. However, it is thought that the knowledge needed by the student would be more permanent by associating and expanding these contents with the project course, and that it would create an educational consistency with more intensive teaching of the human factors criteria.

8. Conclusion

In this study, which is an example of the transformation of design education required by today's needs from an artistic basis to a scientific direction (Norman, 2010), an experiment has been made for the simple and rapid use of an objective method in design education. Despite the relative nature of the design, fast and simple methods that produce more concrete information will help this transformation.

In both practices, which were structured through action research, it was revealed that students' participation and interest in the studio course was high, and it was a process that attracted and followed the attention of other students who were not participants. In the first practice, input was provided to the design process by evaluating 3 market examples with an objective method for a specific purpose. Therefore, although the designed product was not tested, the student was able to use this data in the defense of the product before the jury. In the second practice, the product developed through theoretical ergonomics knowledge was compared with market examples and tested with objective methods to reveal the accuracy of the theoretical knowledge. Both human factors practices ensured the results obtained by creative thinking activity have a defensible concrete background. Teaching the ergonomics discipline contents, which are often used theoretically, to the students in practice has contributed positively to the permanence of the knowledge and pedagogically. Deep and intensive learning activities were carried out in different ways regarding the contents. The practices in the study have shown that different ways of accessing information can be tried and diversified according to the content.

The model proposed in the article was developed as a mixture of two ergonomics practices within the scope of the study and it was foreseen that it could be used in design studio lessons. Flexibility can be provided in the model by diversifying test methods according to the content of the subject and the available possibilities. Thus, while introducing various ergonomics practices and contents to the students, it can also contribute to the strengthening of the systematic structure of the design process.

Finally, action research is useful for the repetitive nature of design education and for transforming designer skills in line with changing needs and giving a quick reaction.

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