TPM Vol. 32, No. S2, 2025
ISSN: 1972-6325
https://www.tpmap.org/

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THE EFFECT OF THE MAGNETIC FIELD ON STUDENTS' CONCENTRATION: A DESIGN STUDIO AT IAU AS A CASE STUDY

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Abstract*— There are no design standards related to exposure to magnetic fields or health legislation in Saudi Arabia. The main purpose of this research is to create an architectural perception of educational buildings, according to occupants' physical and psychological status, in terms of their exposure to magnetic fields. This study aimed to evaluate the mental and health condition of a design studio students, in one of the educational institutions through a quantitative aspect. The magnetic fields were measured using an accurate earth magnetometer and a cell phone application. A simple medical device was used to measure the students' heart rate and arterial oxygen saturation. Moreover, a questionnaire was used to assess the students' concentration after their stay inside the design studio for a certain time. The study reveals a significant direct relation between magnetic values and both students' concentration and their arterial oxygen saturation. While is no clear evidence of mediating factors between magnetic values and students' concentration. The findings contribute to a broader understanding of how magnetic fields can interact with students' concentration, and thus in the architectural educational process.

Keywords*— Learning spaces, Magnetic field, Students' concentration, Vital signs.

I. INTRODUCTION

Humans live on Earth within its natural magnetic field that is produced within the Earth's core, as this field can be accurately measured, which ranges between 25,000 - 65,000 Nano Tesla (nT) [1], equivalently 25 – 65 micro Tesla (µT). The average Earth's natural magnetic field is about 50 (µT), as it varies from about 30 to 70 (µT) according to the geographic location [2]. The Earth's magnetic field can be measured using Earth magnetometer devices. Reference [3] and other researchers used smartphone applications to measure the earth's magnetic field, as it became an easy, economical, and effective tool in terms of educational purposes. Where modern smartphones are well suited to analyse the Earth's magnetic field properties, as reference [4] used a smartphone with an "Android" system, to measure the Earth's magnetic field, through the "Physics Toolbox Magnetometer" application.

Some places have disturbances in the earth's electromagnetic field, which is called geopathic stress (GS). This term refers to the earth's natural harmful energies, as the word "geopathic" is derived from two ancient Greek words meaning "earth disease" [5]. Reference [6] define GS as the energy emitted from the earth beneath at certain locations, which affects the normal human body functions. Moreover, areas of GS seem to influence the earth's magnetic field, as well as atmospheric pressure and temperature [7]. The literature survey reveals that some scholars, authors, and practitioners offer explanations about the potential effect of natural magnetic fields on the human body [8]. Since areas of GS can affect humans both physically and psychologically, the physical effects appear as changes in blood pressure and heart rate in addition to fatigue and headaches, while psychological symptoms appear as depression and nervousness [9].

Regarding investigations about both static and alternating magnetic fields, an experimental study was conducted on two groups of "Gypsy moth caterpillars", as they were exposed to a static magnetic field of 235 milli Tesla (mT), and an alternating magnetic field 2 (mT) for three days, to examine their effects on neurosecretory neurons. This study reported changes in medial neurosecretory neurons in caterpillars' brains. It concluded that the influence of the static magnetic field was an intensive synthesis of insulin-like neurosecretory material, while synthesis was decreased after exposure to the alternating magnetic field [10]. It is worth mentioning that the 1 (mT) equals 1000 (μT).

Winfried Schneider the director of the "Institute of Building Biology + Sustainability IBN" wrote that it concerns the study of the holistic relationships between the built environment and its occupants, as it aims to create healthy, natural, sustainable, and beautifully designed living and working environments [11]. The Building Biology Evaluation Guidelines are based on the precautionary principle, which is designed for sleeping areas associated with long-term risks. As it concerns on testing methods that help identify, minimize, and avoid environmental risk factors, including variations in the earth's magnetic field. It considers geological disturbances in Earth's Magnetic Field above 200 Nano Tesla (nT) as a severe anomaly and is not acceptable, as it will have biological effects and human health problems. While values exceeding 1000 Nano Tesla (nT) require a call for immediate and rigorous action, based on international guidelines and recommendations for public exposure [12].

The "International Commission on Non-Ionizing Radiation Protection" (ICNIRP) is a non-profit scientific body, that has strong collaboration ties with several international organizations including the World Health Organization (WHO). It develops and provides science-based advice on protecting people against the negative effects of Non-Ionizing Radiation (NIR), which include magnetic fields. The ICNIRP provides advice, guidelines, and limits of exposure to NIR. While, leaving the responsibility of formulating codes and regulations for international and national authorities and institutions [13].

However, the Saudi Geological Survey (SGS) is concerned with the field of Medical geology, which combines geology, biomedicine, and community health, as it targets the creation of a geomedical map of Saudi Arabia including underground water [14]. Moreover, many geophysical surveys including magnetic and terrestrial gravity surveys were conducted in three provinces in the Kingdom of Saudi Arabia [15]. However, there are no design standards related to exposure to natural magnetic fields in the Kingdom of Saudi Arabia, nor are there any health legislations on this subject yet. Although a systematic review was done by reference [16] to assess the impact of the design of learning spaces on attention and memory from a neuro-architectural approach, the magnetic fields within the space was not included. Where it concluded that no accepted standard approaches nor protocols to determine how the built environments influence the human cognition processes.

Regarding concentration, many articles and books on teaching indicate that students' attention declines after 10 to 15 minutes of the lecture beginning [17]. While, Donald A. Bligh clarified in his book "What's the use of lectures?" that students will maintain attention (concentrate) if the topic is interesting, in addition to some lecturing skills, as well as several cognition breaks [18]. Here, the Architectural Design Studio is supposed to keep students thinking about their design problems. When task difficulty is high, students' attention becomes more stable, as they will gradually raise their concentration to maintain their desired level of performance [19]. The mental concentration is selective attention, as it refers to the ability to selectively attend to a certain stimulus and ignore other sources of information [20].

Where, Bligh was surprised that there are so few laboratory studies of attention during a lecture [18]. He referred to the correlation between heart rate and students' attention, as it is an indicator of arousal, which is one of the attention components. Measuring students' heart rate during lectures seems to be the closest measure of attention during class [17], as variations in heart rate could be considered a promising biomarker of cognitive problems [21]. A systematic review of 12 studies showed a longitudinal relationship between heart rate variation and cognition [22].

Based on previous studies, the heart rate has a relation with both magnetic disturbances and concentration. Thus, this research suggests that heart rate could be a mediator between magnetic disturbances and students' concentration.

Therefore, regarding the possible significance of this newly recognized field, this paper attempts to examine students' physical and psychological conditions during a Design Studio classroom, in terms of their exposure to natural magnetic fields.

II. STUDY OBJECTIVE

As the values of the magnetic fields may differ from one place to another in the same room. The main objective of this research is to study the magnetic fields values in a Design Studio and its impact on the students' vital signs, and their cognitive skills. To achieve that objective students' heart rate (HR) and their arterial oxygen saturation (O2) were measured, along with assessing students' concentration. Through a quantitative evaluation, a relationship can be established between studio magnetic fields, and potential effects on students' both physiological and psychological status during academic activities.

III. MATERIALS AND METHODS

Authors have complied with APA ethical standards in the treatment of this research human sample. After the research was approved by the Institutional Review Board with the number (IRB-2023-19-166), potential Participants were orally informed about the research experiment and the process of measurements, as they are students of the researchers. The participants were informed about their rights, purpose, and process of the research experiment. Participants were asked to read and sign the Informed Consent form, in case they agreed to volunteer and participate in the experiment. Students were previously asked about their medical history, any student with one or more chronic diseases was excluded from participation in the study. Students with less than 75% of attendance in the classes were excluded from the sample by the end of the experiment and before the results were statistically analysed, to maintain reliability.

The study took place in a Design Studio located on the ground floor of one of the university buildings, and it lasted for seven weeks. The students of the "College of Architecture and Planning" are all males and aged between (18-23) years. These students are divided into three groups (20-25) student each, sharing the same Design Studio but at different times. The study took place on a randomly selected group of students. The study utilized various tools and methods to explore the relationship between magnetic values, HR, O2, and student concentration in a Design Studio environment. The magnetic values of the place of every student in the Studio were measured at the beginning of the experiment before the students started taking their regular classes in this Studio.

The study determined the magnetic field values within the Design Studio environment at specific sitting locations. The Earth magnetometer device model "EM2" was used to measure the natural earth magnetic values at ground level. The "Physics Toolbox Magnetometer" application with the "Huawei Mate 10 pro" cell phone was used to measure the magnetic values at chair level (MACH). This combination allowed accurate readings of the studio magnetic fields, as both magnetic values were measured in micro Tesla (μT) units. The assessment of changes in these magnetic measurements was crucial for understanding their potential effect on students' psychological and physiological status.

Regarding vital signs (HR and O2), readings of every student were taken after they chose their sitting places at the beginning of the class, using the non-invasively "Beurer PO 80 pulse oximeter" device. The time for collecting the readings of all students took 15 minutes, as two researchers were working in parallel to ensure optimum data collection time. The measurements were repeated by the end of the class time, enabling a comparative analysis to assess the changes in students' vital signs parameters. This process was repeated weekly, and the average of the readings was statistically evaluated. The average differences between the pre and post-readings took place in the final assessment of the effect of the class environment (magnetic values) on students' HR and O2.

A standardized questionnaire was distributed to participants at the beginning and the end of every class of the study to determine students' concentration. The questionnaire consisted of 16 questions, answered by students using a 5-point Likert scale ranging from "never" to "always". This method allows an accurate understanding of students' concentration levels by capturing their personal experiences in the Design studio. The questionnaire was distributed to the students by the beginning of the class, and they were asked to answer it while collecting their classmates' HR and O2 readings. Students were asked to complete design-related tasks and develop their projects during the design studio class, which lasted for 120 minutes. Students were asked to answer the same questionnaire by the end of class time. This process was repeated weekly, and the average of the answers was statistically evaluated. The variation of students' responses to these 16 questions enabled researchers to determine changes in students' concentration over time, to assess its relation with magnetic values, HR, and O2.

By analyzing the average differences percentage between pre- and post-class responses, the study can provide insights about how the studio environment (magnetic values) affects students' concentration and cognitive status. This systematic approach ensures that the collected data is reliable and relevant, which is essential for drawing accurate conclusions regarding these specific factors. In the case of missing data from the students' HR and O2 readings, both pre and post-evaluations were eliminated for that session. The same action was taken for the questionnaire responses. A statistical analysis was done after gathering all research data, to clarify the correlation between the studio magnetism and the students' HR, O2, and concentration.

IV. STATISTICAL ANALYSIS

This group consists of 21 male students and their ages range between (18-23) years. Data was collected weekly for 7 weeks, both HR and O2 readings along with the concentration questionnaire were done at the beginning and after the class session with two hours of separation time. Data was entered through an "Excel" sheets, and results were statistically analysed using the "SPSS" software. The "SPSS" was used for statistical analysis, while the "Smart PLS4" was used to investigate the probability of mediation effects and correlation between variables. These tools were used to verify consistency, and correlation analyses, as well as facilitate a comprehensive understanding of the relationship between magnetic fields and students' HR, O2, and their concentration inside the Design Studio at their specific sitting locations. Regarding the questionnaire, the data were analysed using a statistical approach to identify trends in students' concentration levels.

V. STUDY DESIGN

According to the literature, this research suggests that variations of magnetic values within the studio could directly affect students' vital signs (HR and O2). Reference [9] Concluded that the earth's energy disturbances exerted different influences on humans physically and psychologically, but no evidence of a direct or indirect relation between humans' concentration and magnetic variations. In case no direct relation is found between magnetic variations and students' concentration, this study hypothesizes a mediation role of HR and O2 in the relationships between earth magnetic values at floor level (EM2) or magnetic values at chair level (MACH) and students' concentration in the Design Studio. The suggested model (Fig. 1) includes the structure model of mediation effects between study variables. To illustrate, the study proposes the following hypothesis:

Hypothesis 1: The O2 mediates competitively the relationship between EM2 and students' concentration in the studio. Hypothesis 2: The O2 mediates competitively the relationship between MACH and students' concentration in the studio. Hypothesis 3: The HR mediates competitively the relationship between EM2 and students' concentration in the studio. Hypothesis 4: The HR mediates competitively the relationship between MACH and students' concentration in the studio. The study follows a quantitative design, given its purposes and hypotheses. The structural model was evaluated using the PLS-SEM. The authors used "Smart PLS 4" to evaluate the mediation effects among factors. Furthermore, the reliability and convergent validity of the reflective measurement models were assessed.

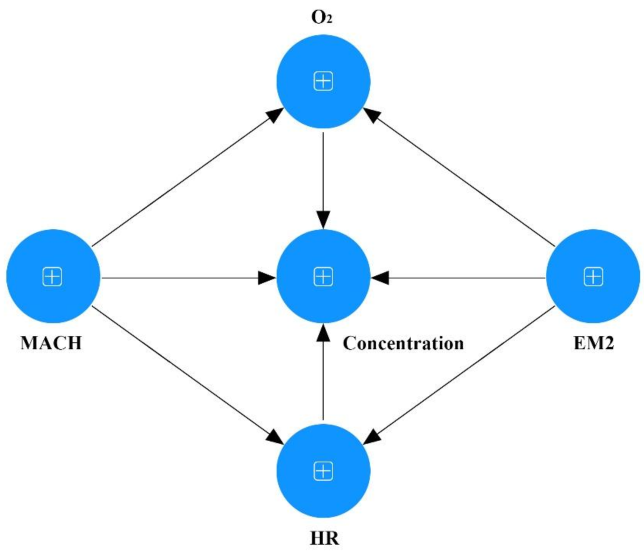

Fig. 1 Structure model and study hypothesis using “SmartPLS 4”

VI. RESULTS

The study is based on a sample of junior university students of the "College of Architecture and Planning" with a total number of 21 participants. The study measured the differences between magnetic values at sitting locations on both (floor and chair) levels. As, (Fig. 2) shows the magnetic values measured by micro Tesla (μT) units, using the "Earth Magnetometer EM2" device at ground level, and the "Physics Toolbox Magnetometer" application at chair level. The results showed compliance between magnetic values at both (ground and chair) levels, as the

MACH values were higher than the EM2 magnetic values of students' sitting locations, except for (4,5, and 6) locations.

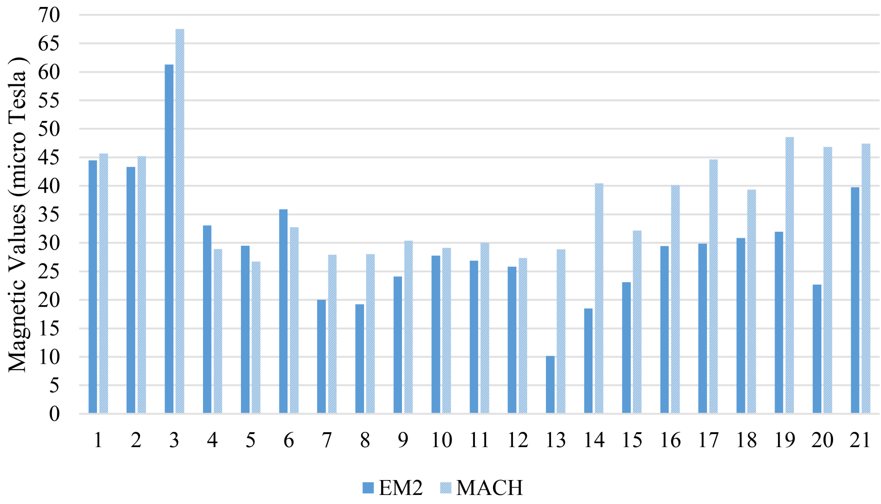

Fig. 2 Magnetic Values were measured by (micro Tesla) for students' sitting locations at both (ground and chair) levels

(Fig. 3) shows the average difference percentage between before and after (HR and O2) measurements of the study sample at sitting locations. The results showed no compliance between (HR and O2) average difference percentages. (Fig. 3) shows almost equal numbers of students in terms of increase and decrease in their heart rate, as eleven of them showed an increase in their HR measurements, with a maximum increase of about 7%, while ten of them showed a maximum decrease of about 8.6%. Unlike HR measurements, thirteen students showed a decrease in their O2 measurements, with a maximum percentage of about -4.3%, while eight of them showed a slight increase of about 1.3% or less. Furthermore, it is worth mentioning that student in location number 18 has the most decreased percentage in both (HR and O2).

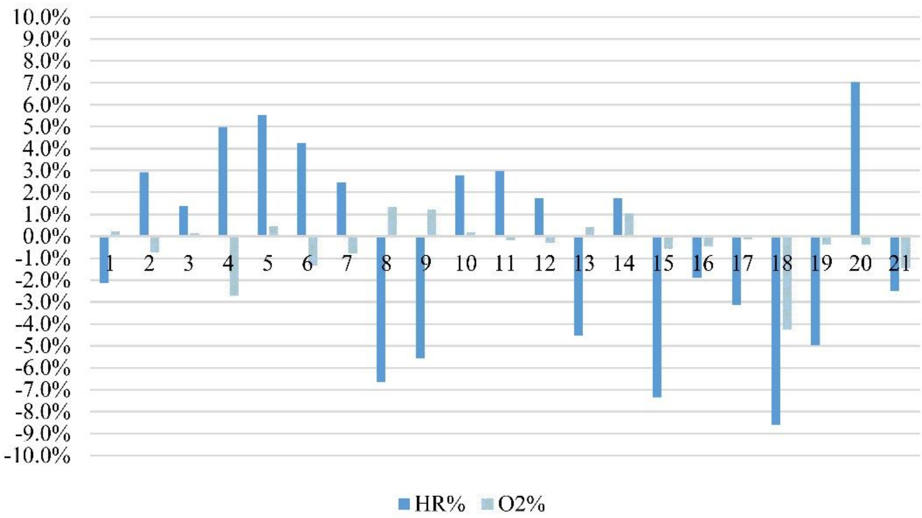

Fig. 3 The average difference percentage between before and after for both (HR and O2) at sitting locations

(Fig.4) shows the average difference percentage between before and after concentration responses of the study sample at sitting locations. The results showed equal numbers of students in terms of increase and decrease in their concentration, as ten of them showed an increase in their concentration, with a maximum increase of about 4.4%, and an equal number of them showed a maximum decrease of about -5.7%. While one of the students showed no change. Furthermore, the student in location number 18 has the most decreased percentage in concentration.

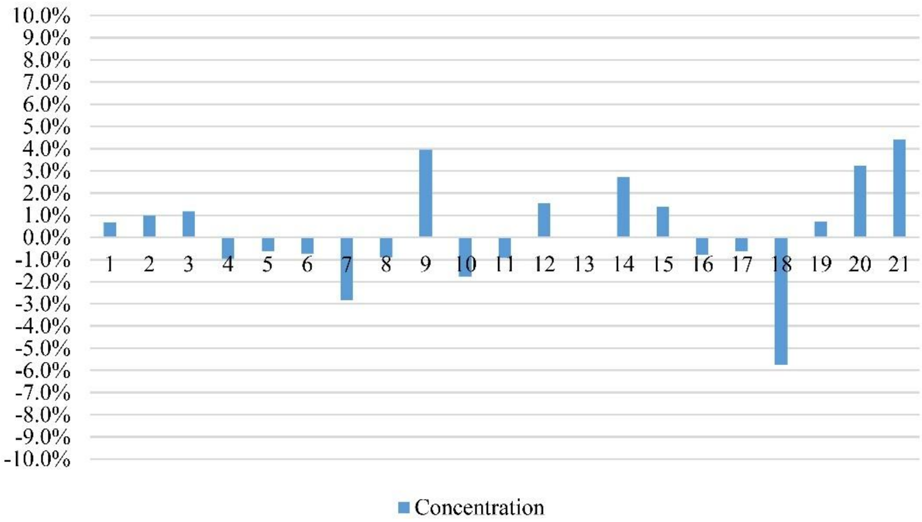

Fig. 4 The difference between before and after Concentration averages at sitting locations

The measurement model was measured to verify the reliability and validity of the constructs. The study considered the outer loadings of the items associated with each construct. Further, composite reliability (CR) and average variance extracted (AVE) were investigated. This study used SPSS version 22, to analyze the collected data, more specifically using internal consistency, descriptive statistics, correlation, and regression analysis of the variables. (Table I) contains all the correlation analysis results of the variables. (Table I) shows, Pearson's Correlation analysis of study variables. It shows a very significant correlation between students' arterial oxygen saturation and their concentration (.559) at a 0.01 significance level. Moreover, it shows a significant correlation between the earth's magnetic values at ground level, and magnetic values at chair level (.492) at a 0.05 significance level. While no significant relation between students' heart rates and any other variable.

TABLE I
THE PEARSON CORRELATION ANALYSIS OF STUDY VARIABLES

		HR	O2	Concentration	EM2	MACH
HR	Pearson Correlation	1	.055	.099	.054	-.045
	Sig. (2-tailed)		.813	.669	.816	.847
	N	21	21	21	21	21
O2	Pearson Correlation	.055	1	**.559****	-.293	.027
	Sig. (2-tailed)	.813		.008	.198	.906
	N	21	21	21	21	21
Concentration	Pearson Correlation	.099	.559**	1	-.090	.290
	Sig. (2-tailed)	.669	.008		.698	.203
	N	21	21	21	21	21
EM2	Pearson Correlation	.054	-.293	-.090	1	**.492***
	Sig. (2-tailed)	.816	.198	.698		.024
	N	21	21	21	21	21
MACH	Pearson Correlation	-.045	.027	.290	.492*	1
	Sig. (2-tailed)	.847	.906	.203	.024	
	N	21	21	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

(Table II) shows, Spearman's rho Correlation analysis of study variables. It shows a significant correlation between arterial oxygen saturation and the earth's magnetic values, as it shows an inverse correlation (-.449) at a 0.05 significance level. Moreover, it shows a significant correlation between students' concentration and magnetic values at chair level (.447) at a 0.05 significance level. Furthermore, it shows a significant correlation between the earth's magnetic values and magnetic values at the chair level. While no significant relation between students' heart rates and any other variable.

TABLE II
THE SPEARMAN'S RHO CORRELATION ANALYSIS OF STUDY VARIABLES

		HR	O2	Concentration	EM2	MACH
HR	Pearson Correlation	1.000	-.112	-.066	.140	-.126
	Sig. (2-tailed)		.630	.777	.546	.587
	N	21	21	21	21	21
O2	Pearson Correlation	-.112	1.000	.341	**-.449***	-.044
	Sig. (2-tailed)	.630		.130	.041	.850
	N	21	21	21	21	21
Concentration	Pearson Correlation	-.066	.341	1.000	-.009	**.447***
	Sig. (2-tailed)	.777	.130		.970	.042
	N	21	21	21	21	21
EM2	Pearson Correlation	.140	-.449*	-.009	1.000	.527*
	Sig. (2-tailed)	.546	.041	.970		.014
	N	21	21	21	21	21
MACH	Pearson Correlation	-.126	-.044	.447*	.527*	1.000
	Sig. (2-tailed)	.587	.850	.042	.014	
	N	21	21	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Mediation analysis was performed to assess the suggested model of the impact of O2 percentage as a mediator on the role of earth's magnetic values or magnetic values at chair level and students' concentration in the studio. The results (Table III) indicated an insignificant total and indirect effect of earth's magnetic values on students' concentration through O2 percentage (β= -0.170, t = 1.560, p > .05), and insignificant total and indirect effect of magnetic values at chair level on students' concentration through O2 percentage (β= 0.230, t = 3.034, p > .05). With the inclusion of O2 and the effect of earth's magnetic values on students' concentration still insignificant (β= 0.081, t= 0.452, p > .05), and the effect of magnetic values at chair level on students' concentration also still insignificant (β= 0.152, t= 0.379, p > .05). This shows no mediating effect of O2 percentage in the relationship between earth's magnetic values or magnetic values at chair level and students' concentration in the studio.

TABLE III
MEDIATION EFFECTS OF O2 PERCENTAGE

Total & Direct effects			Indirect effect				
β	T	p	β	T	p	95% CI Lower	Upper
H1: EM2 →O2 → Concentration							
-0.170	1.560	>.05	0.081	0.452	>.05	-0.275	0.446
H2: MACH →O2 → Concentration							
0.230	3.034	>.05	0.152	0.379	>.05	-0.327	0.419

EM2: Earth's magnetic values at ground level, O2: Arterial oxygen saturation, Concentration: Students' concentration, MACH: Magnetic value at Chair level.

At the level of the second suggested mediating role of the heart rate as a mediator on the roles of earth's magnetic values or magnetic values at chair level and students' concentration in the studio. The results (Table IV) indicated insignificant total and indirect effect of earth's magnetism values on students' concentration through heart rate (β= -0.237, t = 1.083, p > .05), and insignificant total and indirect effect of magnetic values at chair level on students' concentration through heart rate (β= -0.621, t = 2.197, p > .05). With the inclusion of heart rate and the effect of earth's magnetic values on students' concentration still insignificant (β= 0.742, t= 2.231, p > .05), and the effect of magnetic values at chair level on students' concentration also still insignificant (β= 0.081, t= 0.452, p > .05). This shows no mediating effect of heart rate in the relationship between earth's magnetic values or magnetic values at chair level and students' concentration in the Studio.

TABLE IV
MEDIATION EFFECTS OF HEART RATE

Total & Direct effects			Indirect effect				
β	T	p	β	T	p	95% CI Lower	Upper
H3: EM2 →HR → Concentration							
-0.237	1.083	>.05	0.742	2.231	>.05	-0.270	0.754
H4: MACH →HR → Concentration							
-0.621	2.197	>.05	0.081	0.452	>.05	-0.411	0.832

EM2: Earth's magnetic values at ground level, O2: Arterial oxygen saturation, Concentration: Students' concentration, MACH: Magnetic value at Chair level.

VII. DISCUSSION

The researchers discussed the results of the study in light of the complex relationships between one of the class environment factors (magnetic values), students' vital signs, and their concentration levels within the Design Studio. The collected data revealed compliance between the earth's magnetic values at floor level (EM2) and the magnetic values at chair level (MACH). Notably, the results indicated higher magnetic values at chair level for all sitting locations, except for (4, 5, and 6), where EM2 values were higher. Moreover, our findings (Table II) clarify that the magnetic values at chair level, have a direct relation and significant effect on students' concentration, rather than magnetic values at ground level. Regarding students' heart rate, this study showed contrasting measurements among participants, as eleven of them showed an increase in heart rate, while ten students experienced a decrease. Moreover, no direct relation nor mediation role between HR and students' concentration was observed. Thus, no evidence assures the reference [17] suggestion of the correlation between heart rate and students' attention. As this research suggests that variability in students' HR within the Studio magnetic field, may comply with the table of heart rate measurement in reference [9] study.

Although no Geopathic stress zones were defined in this research, it is worth mentioning that the highest and lowest EM2 values were (61.3 and 10.13) micro Tesla at sitting locations of student number (3 and 13) respectively, and their HR differences were (1.4% and -4.5%) respectively. In contrast with reference [9] findings, there is no significant evidence that students' heart rate has a correlation with earth magnetic variations within the Studio. Moreover, there is no consistent trend was evident between HR and O2 regarding magnetic values within the Studio, as this non-compliance clarifies that HR does not necessarily correlate with O2. While, arterial oxygen saturation was significantly inversely affected by magnetic values at ground level as shown in (Table II), and results in (Table I) showed that O2 has a direct and significant relation with students' concentration.

Furthermore, the examination of the mediation effects and the proposed hypotheses regarding HR and O2 as mediators in the relationship between both (EM2 and MACH) and students' concentration, highlighted two main results. First, the competitive mediation of HR and O2 suggests that these vital signs indicators do not affect concentration levels. Secondly, the analysis did not show significant mediation, indicating that the indirect relationships might not be as influential as the initial hypothesis.

The study points to the need for further research to fully understand the relationship between one of the studio's internal environment factors (magnetic values) and students' concentration. The researchers stressed the importance of exploring other potential influencing factors and understanding contextual interactions within the Design Studio environment.

VIII. CONCLUSIONS

Overall, the study indicates a potential interaction between magnetic exposure and students' physiological and psychological status. As the study emphasizes the interaction existing within a Design Studio between one factor of its environment (magnetic values) and some of the students' physiological (vital signs), and psychological (cognitive abilities) parameters. The work is significant, as it highlights the relationship between magnetic values and both (students' concentration and their arterial oxygen saturation). The study found that both (HR and O2) have no mediating effects between magnetic values and students' concentration. While it reveals a significant direct relation between magnetic values and both (students' concentration and their arterial oxygen saturation). The findings contribute to a broader understanding of how magnetic fields can interact with students' concentration, and thus in the architectural educational process. However, individual response differences highlight the importance of a personalized approach when considering the relationship between the Studio environment and students' both (vital signs and cognitive abilities).

ACKNOWLEDGEMENT

The authors would like to extend their gratitude to Dr. Ahmed Khatiry for his valuable support and constructive feedback, which significantly contributed to the development and completion of this research.

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