Erasmus+ KA-2 Project ARCHISTEAM
"Greening the Skills of Architecture Students via STEAM Education".

Project Report

O1 - ASSESMENT OF STEAM SKILLS IN EXISTING CURRICULUM IN ARCHITECTURE SCHOOLS

This Project is granted by the European Commission under the Erasmus+ Programme (Lifelong Learning or Youth Programme), implemented by The Turkish Republic Ministry of European Union and the Center for European Union Education and Youth Programmes (Turkish National Agency/http://www.ua.gov.tr)

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1. INTRODUCTION

Starting with the first founded university in Bologna in 11th Century, higher education has been evolving continuously, yet the pace of this evolution is not as fast as the changes that we observe in practice, bringing in discussions on how university and education should be: is it delivering a degree and a place for research or more? Today, these discussions are not only limited with the content of the curricula and it has even been more focused on the expected skills and competencies. Each and every discipline has been in continuous search of "right" way of formalization of education both content wise and skill and competency-wise. Design education compared with many other disciplines is always a more controversial subject since design process itself does not have a complete and consented definition yet. This project is focused on architectural design education incorporating discussions on the role of STEAM (Science Technology, Engineering, Art and Mathematics). It is proposed that STEAM as a holistic approach provides a valuable structure for curricula of architectural design education and related skills and competencies. It is evident that 21st Century skills and competencies should be much different than the ones delivered in 20th Century due to rapidly developing and spreading new design and information technologies. This project re-position STEAM in architectural design education by contemplating 21st century skills and competencies (a.k.a. survival skills) of design students. In order to identify and define those skills and competencies, it is necessary to understand the discussions on design act and design methods starting from 1940's and to picture the contemporary architectural design education by examining the general curriculum structure of highly acknowledged architecture schools. Hence the first part of the research provides a detailed survey on design act and methods and a concise time line is developed showing how design education is evolving. Moreover, surveys among students and academicians of project partner universities are conducted to further discussions on skills and STEAM understanding. This part is then concluded with the proposal of a set of so called "survival skills and competencies" for architectural design education.

1.1. A GENERAL PERSPECTIVE OF DESIGN EDUCATION

In the quest of definition of the skill and competencies in architectural design education in 21st century, it is important to picture current situation in architecture education in connection with the ongoing discussions on what design is, what is/what should be a design studio, the paradigm shift with new technologies as a mean to design, learn and ultimately to survive in the coming revolution of industry 4.0 and beyond.

Abstraction and rationalisation is a very natural part of the architectural design process for which terms like perception, intuition, conception, emotion, reasoning, creativity and etc. are used in the cycle of the design process. The spiral structure of the design process, swinging between abstract and rational brings the notion of ambiguity not only in the design process but also in the design education. "Who is an architect" is probably a query as old as the architecture leading inevitable questions like what should be taught, what skills should be aimed, what is the role of creativity and how creativity can be promoted.

It has never been so easy to be able to answer these questions as they evolve in time. Yet, abstract or concrete, qualitative or quantitative, tangible or intangible, the complexity of the architectural design problems and the diversity of the subject matters necessitate architects to be capable of synthesising several subjects and be able to solve design problems in a creative way. Thus architectural education in its essence is an amalgam of science, technology, engineering, art and mathematics in the past, now and in future. Education should also foster "creativity" which is a complex function of the human brain. In "How Creativity Happens in Brain" by Arne Dietrich1, creativity is discussed in the realm of neuroscience and psychology referring to a detailed literature. In this book, several different approaches explaining creativity process in brain are explored. The relation between divergent and convergent thinking as creative and non-creative thinking modes are also argued. Dietrich emphasize the

1 Arne Dietrich , "How Creativity Happens in Brain" , Palgrave MacMillan, 2015.

importance of Dennett's "design space" concept in explaining creative process in brain. He defines design space as

> *"We can think of design space as the logical space that contains all possible permutations of information. All creations, every design that has been made and every design that might be made, complex or simple, actual or potential, biological or cultural, alive or artificial, have their proper place somewhere within it. To borrow from Dennett (1995) again: "There is only one design space, and everything actual in it is united with everything else. The concept of design space brings into sharp focus that all fruits of our creative adventures are threads of actuality that emerge from a vastly larger set of possibilities."*

Possibilities in his definition is related with cognition and knowledge. Like Dennett Dietrich and many others use terms like design space, brain topography, brain landscape, brain architecture and starting from 1990's imaging technologies in order to de-code the physical code of the creative process in brain. Although creativity still remains an elusive process and one of the most complex functions of the brain, it is all concluded that creativity is improved by multi-dimensional knowledge/cognition. Hence it can be claimed that education should not be uni-directional and should not only be a giving an academic degree, but skills and competencies to survive in anywhere, anytime and any condition.

H.F. Mallgrave in his book "Architect's Brain" focused on creative process of architectural design providing an important literature on not only in the field of architecture but also in neuroscience[2]. In concluding his book as quoted below, he pointed out the importance of understanding how brain works in design training.

> *"If we want to continue to speak of architecture as a creative process, we have to take responsibility for training creative architects…We now have a better appreciation for how the brain works, how important it is for the brain to draw upon all of its specialized areas and potential strengths to foster creativity. If "coarse semantic coding" and "hyper-connectivity" are now deemed to be two of the linchpins of the creative at, we should be able to find a way to draw out rather than inhibit these two powers. Aspects of architectural education, only a few years ago, did a fairly good job in recognising the complexity of the human brain, and the necessity for design training to develop such resources. Things have changed, to be sure"*

Today, it is evident that design education should not only be a way of conveying a bunch of information, but it should also foster creativity. Art in its broadest meaning (liberal and creative) has been demonstrated to be crucial in developing creative skills and in problem solving capacity. Impact of ICT, computational technologies as well as rapidly changing social, economical and political situations, crisis and turmoils, heavy environmental problems of today force education to find new and more flexible ways as Mallgrave underlined "*things have changed to be sure*".

1.2. DESIGN AND CREATIVITY

Large number of studies available on what design process is and what architecture is does not show only importance of the subjects but also disagreement on them. This lack of consensus also makes it difficult to discuss how architecture should be taught and thus how education should be formalized.

It has been already demonstrated that crises in the fields of art and creativity are contemporary to corresponding strengthening in epistemological foundations of contemporary sciences[3]. While, on one side, sciences specified proper domains and boundaries, on the other, arts and creativity, whose richness has always come from a certain indefiniteness of their borders, were suddenly asked to specify their respective purviews, their methods and proper goals. Before 18th century, a systematic overlap between art and science was condition for a continuous exercise of intuition and for an uninterrupted series of experimentation and discoveries[4].

Contemporary debates on art, architecture and on the role of author, still have their roots in romantic

2 Harry Francis Mallgrave , "Architect's Brain", Taylor and Francis, 2010.

3 Ermanno Migliorini, *Prefazione*, in C. Batteaux, "Le belle arti ricondotte ad un unico principio", Bologna, Il Mulino, 1983, p. 12

4 Paolo Rossi, "La nascita della scienza moderna in Europa", Bari: Laterza, 1997, pp.50-52

understanding of an artist as the kind of creative genius described by Immanuel Kant, that is a man who *"cannot indicate scientifically how it brings about its product, but rather gives the rule as nature. Hence, where an author owes a product to his genius, he does not himself know how the ideas for it have entered into his head, nor has he it in his power to invent the like at pleasure, or methodically, and communicate the same to others in such precepts as would put them in a position to produce similar products..."* [5].

The issue about creativity introduced an ongoing double-debate. In one hand the question regards the awareness of the author respect to the design process; in the other and consequently the problems touches possibility to teach methodologies or strategies to amplify creativity. Thus the era of industrial revolution began unveiling the gnoseological problem, posing the question not only on possibility of knowing, but even on the one of teaching.

The course of modern aesthetic inaugurated then on questioning art's proper object. Architecture was partially repaired from these debates due to its contamination with practical and functional goals which tended to leave it from the realm of fine arts.

It's the second quarter of 20th century which finally promoted a rehabilitation of architecture[6], commencing a reflection not only on architecture's final objects, that is any built environment, but also on the processes of its perception and composition starting from the researches conducted by John Dewey[7] and from the thinking of Karl Popper[8].

Posterior, in 1960s, complexity of the design process in any discipline gave way to so called Design Method Movement (DMM). Bruce Archer, John Chris Jones, Christopher Alexander and Horst Rittel were founders of this movement. The movement was aiming to provide an understanding of different design activities realised in different disciplines through scientific viewpoints. With the scientific optimism of post-world war period, they believed that design process could be improved and tried to explain how this improvement would be possible. Cross pointed out that DMM started out with intentions of making design more 'scientific', but more mature field of design methodology has resulted in clarifying the differences between design and science. DMM still plays a crucial role in understanding design and design education[9].

In 1980s' discussions on definition of design continued with a different perspective. Donald Schön and Herbert Simon are the forerunners of cognitive design theory in an opposing way. Simon defined design *"as a problem solving activity searching for better solutions in a design space of all possible designs*[10]". Whereas Shön described design as *"reflective activity" in which "reflective practice", "reflection-in-action", and "knowing-in-action"* are the determinants[11].

> *"If it is true that there is an irreducible element of art in professional practice, it is also true that gifted engineers, teachers, scientists, architects, and managers sometimes display artistry in their day-to-day practice." [Donald Schön, The Reflective Practitioner, 1983]*

Schön also stated that *"competent practitioners usually know more than they can say*"[12]. Willemien Visser interpreted this as the difference between *"knowing how and knowing that" as a part of classical question of "to know*"[13]

Nigel Cross as quoted below, in 2001, discussed "*design as a discipline versus design as a science"* and provided a very concise review on relationship between design and science[14].

5 Immanuel Kant, Critica del Giudizio, Bari, Laterza, 1997, p. 292-293

6 In Italy particularly by Benedetto Croce, Problemi di Estetica, Bari, 1923; after, in a global scale, by Martin Heidegger, printed in Germany in 1954 and translated into Italian only in 1976

7 John Dewey, Art as Experience, New York, 1934;

8 Karl Popper, Knowledge and the Body-Mind Problem. In defence of interaction, Routledge, 1994. Look also: ESİN KÖMEZ DAĞLIOĞLU, "Karl Popper's architectural legacy: an intertextual reading of Collage city", in METU JFA 2016/1 pp. 107-119; see also Sarah Deyong, "Colin Rowe, Karl Popper and the Discipline of Architecture", in journal of visual culture, Volume: 15 issue: 3, page(s): 372-376; Article first published online: October 4, 2016;Issue published: December 1, 2016; DOI: https://doi.org/10.1177/1470412916665140

9 Nigel Cross, "Science and Design Methodology: A Review", Research in Engineering Design, Springer-Verlag, 1993.

10 Herbert Simon, The Sciences of the Artificial, MIT Press, 1996.

11 Donald Schön, "The reflective practitioner: How professionals think in action", Basic Books, (Reprinted in 1995).

12 ibid 2.

13 Willemien Visser, "Schön: Design as a reflective practice", Art + Design & Psychology, pp. 21-25, 2010.

14 Nigel Cross, "Designerly ways of knowing: design discipline versus design science", Design Issues, 17(3) pp. 49–55,

> *"...Just as the other intellectual cultures in the sciences and the arts concentrate on the underlying forms of knowledge peculiar to the scientist or the artist, so we must concentrate on the 'designerly' ways of knowing, thinking and acting [33, 34]. Following Schön and others, many researchers in the design world have been realising that design practice does indeed have its own strong and appropriate intellectual culture, and that we must avoid swamping our design research with different cultures imported either from the sciences or the arts..."*

Lawson contributed these discussions by describing design as *"highly complex and a sophisticated skill. It is not a mystical ability given only to those with recondite powers but a skill which, for many must be learnt and practised rather like the playing of a sport or musical instrument" and "designing as prescriptive rather than descriptive act*[15]*".*

Willemien Visser in 2009, not only provided a very elaborate review on cognitive design research literature but also proposed cognitively oriented generic-design hypothesis. He emphasised "significant similarities between the design activities implemented in different situations and crucial differences between these and other cognitive activities"[16].

In 2007, Nigel Cross recapped milestones in the discussions of design methods and design research at the 40th anniversary of Design Research Society, clearly indicating how those discussions are still alive and spreading more and more[17].

Two years later than Cross, Meng published a paper by comprehensibly outlining Schön's and Simon's point of view of design and designerly ways of knowing[18]. She refers Cross and declares that *"Design research, as Cross (2007) so nicely points out, was and still is struggling to move away from that kind of linear design thinking, and charting out-as it should-a distinct way of thinking about the design process, in order to establish design as a discipline on its own, with a particular designerly way of knowing.*"

Instances regarding autonomy of the design process are also at the basis of studies attempting to investigate design as a proper recognizable research strategy whose epistemological basis are still arguments of debate[19]. At the very center of these studies, there is an idea that the design process itself could be considered a specific way to reach knowledge[20] even if its methodology is not recognizable as deductive or inductive and it is rather defined by some authors "abductive"[21].

The attempt to reconduct the design process to a scientific activity, similar to ones which can be detected in any step and phase, even if directed to the production of new realities and conditions and not to analysis of existing ones,[22] demonstrates fragility of contemporary aesthetics and of investigations on the creative path. Difficulties to develop a consistent understanding of the analogical way to knowledge, tend to promote a logical reduction of its complexity, that is, in relation to our project, an attempt to absorb "A" (Arts and Architecture) into "STEAM".

It is not so convenient to claim that those discussions would end in a foreseeable future. It is for sure many studies are to be conducted as in the past and academics, education technologists, practitioners and many others will try to shift the concept of design and the act of designing from black box to white box in order to make them much more clear in minds.

Discussions on design are augmented with discussions on the role of cognition and creativity as well as analytical and practical skills to be

2001.

15 Bryan Lawson, "How Designers Think: The Design Process Demystified", Routledge, 2006.

16 Willemien Visser, "Design: one, but in different forms", Design Studies Vol 30 No. 3 May 2009.

17 Nigel Cross, "Forty Years of Design Research", Design Studies 28 (2007)

18 J.C. Soo Meng, "Donald Schön, Herbert Simons and The Sceince of Artificial", Design Studies 30, 2009.

19 L. N. Groat, D. Wang, Architectural Research Methods, New Jersey, Wiley, 2013; M. Fraser, "introduction" in M. Fraser (edited by) "Design research in Architecture: an overview". Farnham, Ashgate, 2013.

20 F. Nilsson, M.U. Hensel (editors), "The changing shape of practice. Integrating Research and Desing in Architecture. New York: Routledge, 2016 look expecially Introduction.

21 T. Faste,H. Faste, "Demystifying "Design Research"; Design is not Research, research is not Design", IDSA Education Symposium, 2012, https://www.academia.edu/3019956/Demystifying_Design_Research_Design_is_Not_Research_Research_is_Design

22 J. Verbeke, "This is research by Design" in M. Fraser (edited by), Design Research in Architecture: An Oevrview", Farnham, Ashgate, 2013, pp. 137 - 159

entailed in design process. These discussions cannot be isolated from the theory of education and learning theories.

Considerations related to creativity are always associated with thinking and cognition. In late 1960s, J.P Guilford segmented thinking as convergent and divergent. Convergent thinking seeks a single and a correct answer/solution, whereas divergent thinking seeks for alternatives, many different ideas to reach solution while he considers these as requirements for creativity[23].

In 1973, Harold Halfin in his dissertation listed essential and universal design cognitive capabilities as "analyzing, communicating, computing, creating, defining a problem, designing, experimenting, interpreting data, managing, measuring, modeling, models/ prototypes, observing, predicting, questions, hypothesis, testing, visualizing"[24].

Studies on cognitive skills are linked with studies on intelligence and learning. At this point, Robert Sternberg's Triarchic Theory of Human Intelligence in 1988 deserves a special attention. Sternberg defined intelligent behaviour as "as a balance between analytical, creative, and practical abilities, which allow students to achieve success within particular sociocultural contexts. Analytical abilities enable students to evaluate, analyze, compare and contrast information. Creative abilities generate invention, discovery, and other creative endeavors. Practical abilities allow students to apply what they have learned in the appropriate setting by bringing analytical and creative abilities together."[25]

Sternberg, in his *Creativity Handbook,* also provides a very concise description of creativity in the following way[26]

> *"1. Creativity involves thinking that is aimed at producing ideas or products that are relatively novel and that are, in some respect, compelling. 2. Creativity is neither wholly domain specific nor wholly domain general. It has both domain-specific and domain-general elements. The potential to be creative may have some domain-general elements, but to gain the knowledge one needs to make creative contributions, one must develop knowledge and skills within a particular domain in which one is to make one's creative contribution. 3. Creativity can be measured, at least in some degree. 4. Creativity can be developed, in at least some degree. 5. Creativity is not as highly rewarded in practice as it is supposed to be in theory."*

It is important to note that Sternberg describes creativity as a skill that can be taught and developed requiring domain specific skills and knowledge hence it is a subject matter of any education, especially in fields related with design.

Ömer Akın points out the role of creativity in design as "progress in design occurs as a result of suddenly emerging ideas that can be described as "eureka events," "ah-ha moments," or "creative leaps."[27] .

Similar to Sternberg, Akın defines creativity as

> *"1. Creativity arises under special conditions. 2. Creativity is manifested either through a product or a process. 3. Creativity spans a considerable range of activities and products, from the sciences to the arts to everyday occurrences. 4. The product of a creative act is novel and unusual in some sense. 5. It is possible to discern some gradation of creativity among these products and processes, for instance, in terms of their social or lasting value."*

Still, there is no clear definition of the term creativity, and it is demonstrated to be contentious. One reason for this variety and flux could be changing factors that affect shaping creativity, such as "person, process, product, and place"[28]. In spite, there is a claim that creativity is learning outcome of all educational programs.

23 J.P. Guilford, "Basic Conceptual Problems of Psychology", Annals_of_the_New_York_Academy_of_Sciences, 1960.
24 Cited in Todd Kelly, Martin Rayala, "The Knowledge and Skills of Creativity and Design", https://www.researchgate.net/profile/Scott_Warner2/publication/275344304_Creativity_and_Design_in_Technology_Engineering_Education
25 Robert Sternberg's "The Triarchic Mind: A New Theory of Human Intelligence", Viking Adult; 1st.Edition edition, 1988.
26 J.Kaufmann and R. Sternberg, "The International Handbook of Creativity", Cambridge University Press 2006
27 Ömer Akin and Cem Akin, "Frames of Reference in Architectural Design: Analysing the Hyperacclamation (a-H-a-!)," *Design Studies* 17:4 (1996)
28 Robert Fisher, "Creative Minds: Building Communities of Learning for the Creative Age Robert Fisher," in *The Teaching*

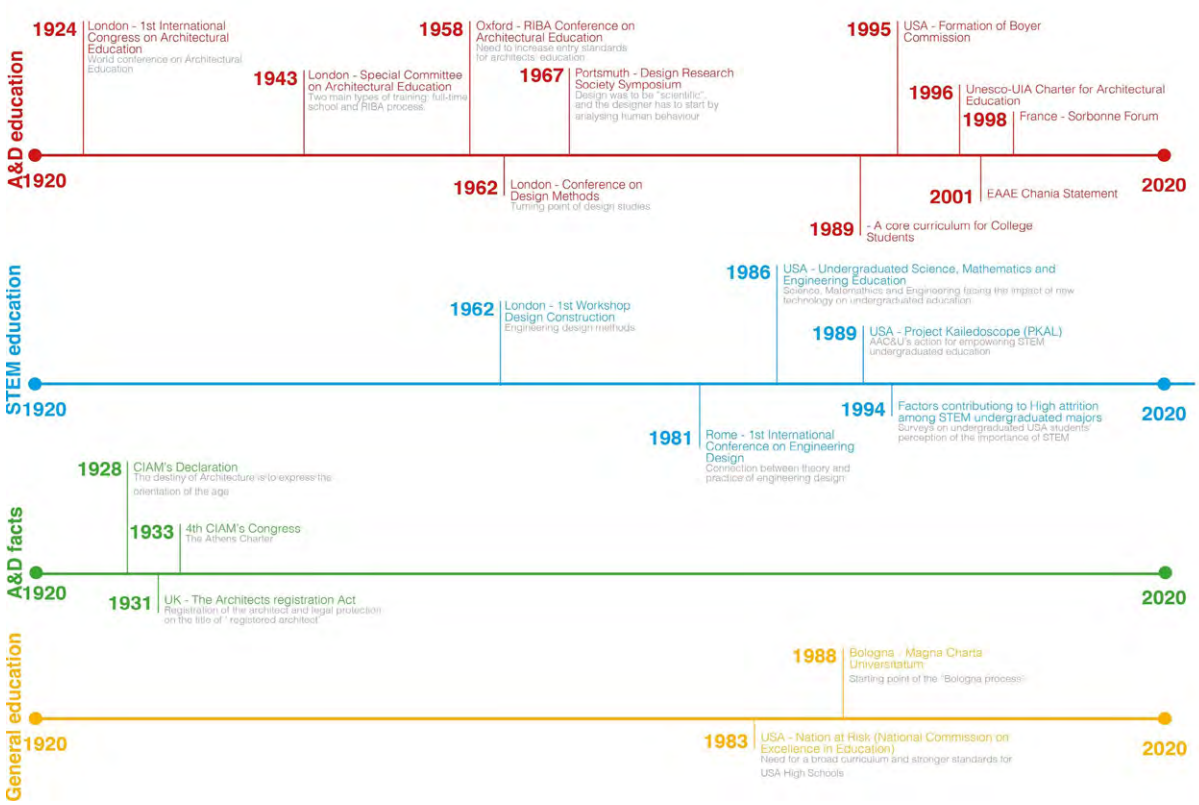
Contemporary revolutions in technologies provide designers and architects a collection of brand new powerful tools with important implications not only to final representation of architectural objects, but also to the design phases. The heavy impact of technology in every field force disciplines to change/modify and adapt their medium of learning/teaching and to incorporate new tools of "doing" and even ways of thinking, creating, and problem solving.

Relation between tools and technologies used in design is another subject matter in design act discussions. While a pencil can be considered as a natural extension of a designer's body[29], the relationship that new design tools establish with an architect's body generates a new range of opportunities and at the same time of boundaries that should be considered carefully in the attempt to investigate new balances between arts and science within the design process.

As pencils are flanked by softwares, in the same way, the most usual matter where the design process was stratified, that is paper, has been placed side by side with files, moving the subject's operativity from the reality to virtuality.

Consequences of this new technological improvement are relevant both in relation to the design process and especially in relation to that "medium matter"[30] where the design process gradually stratifies, and on the relationship between this matter and the designer in one hand, between the design and the realized work in the other. The virtual cloud where more and more the design process takes place, influences the architectural results, but also the skills which an architect is now supposed to match. Technicalities are not only related to building and the ability to solve architectural problems. The use of new technologies and autonomy in the use and comprehension of hardware and software are new technological skills that architects need since the design process uses less primitive tools for its development.

Table 1: Timeline



Qualities Initiative Conference (Hong Kong, 2002)

29 M. Merleau-Ponty, L'occhio e lo spirito, Milano, Studio Editoriale, 1989

30 L. Bartolomei, "From the interactive dialogue between man and matter, to contemporary tools for architectural composition: innovations and consequences on architecture's educational processes". in Proceedings of the international conference EDULEARN2012, Barcelona, 2-4 Luglio 2012, 4th International Conference on Education and New Learning Technologies, pp. 2784-2790

1.3. AN OVERVIEW OF MAJOR EVOLUTIONS IN ARCHITECTURAL EDUCATION

Timeline given below shows some important actions, movements, organisations in education in the last 50 years. Evolution of architectural education cannot be considered by ruling out them. The timeline below aims to summarise benchmarks in the education, some important milestones related to architecture and its education are also illustrated.

When architectural education is concerned, the complexity of design act and rapid growth of technologies force to propose a new understanding in education. Yet, architectural education does not have one and only way. Nicol and Pilling in their paper, contemplate how education should be configured for the future architects as[31]

> *"... Nowadays, not all architecture students go into mainstream architecture when they leave formal study: an increasing number are embarking on careers that only have a marginal connection with the construction industry. And as a result of changes in society, technological advances and the rapid growth in information, those entering a profession are likely to have to update their knowledge and skills many times over a lifetime. All this is calling on architects to become more skilled in the human dimensions of professional practice and more adaptable, flexible and versatile over the span of their professional careers. Architectural education must respond to these changes: it must enable students to develop the skills, strategies and attitudes needed for professional practice and it must lay the foundation for continuous learning throughout life..."*

They also picture architectural education in UK which is conveyed in five main areas of study; architectural design; cultural context of architecture; environmental design, constructional and architectural technologies; communication skills; professional studies and management.

It is obvious that those five areas are almost the same in any school of architecture in the past or now. STEAM which aims to provide a holistic curriculum including science, technology, engineering, art and mathematics serves perfectly to cover these five areas and help education to achieve intended learning outcomes of the 21st century. .

Discussions on architectural education has always been accompanied by discussions on architectural design studios which have special roles in architectural design education both as physical educational settings and as learning environments. Design studios generate their own studio cultures. Student-instructor interactions, yearly changing complexity of the design problems, individual and teamwork projects, not only shape this culture but also learning process Design studios aimed to be melting pot of the design education. However, integration of studio education and materials taught in lectures into design studios is always a challenge of architectural education. There is a massive literature on architectural design studios, on their objectives, pedagogical approaches, methodologies. Although there is no perfect recipe for the formalization of them, it is all consented that profiles of the students and instructors their backgrounds and domain knowledges are the key factors in the studio education. In this regard, studio education should also approach design problems in a holistic way. It is possible to accept studios as the field application of STEAM in design. But in the scope of the present project, considering the uniqueness of design cultures, STEAM discussions in architectural education are carried on without specifically pointing the studio education.

31 D. Nicol and S.Pilling, " Architectural Education and the Profession: Preparing for the Future", published in Changing Architectural Education, Spon Press , 2000.

2. STEAM AND CONTEMPORARY ARCHITECTURAL EDUCATION

2.1. WHAT IS STEAM?

Educational research studies are looking for ways to enhance students' learning and equip students with skills that are helpful to meet 21st century's demands (Retna, 2015). Easy access of information and high availability of technology makes our lives easier; yet, definition of being a successful student and significant factors that are necessary for being successful both in academic and professional life have also changed. A set of skills that are required for success in 21st century's societies and professional life are called as 21st century skills. These skills differ from traditional schools' outcomes in terms of not only being content-based knowledgeable. Critical thinking, creativity, communication and collaboration have been proposed as the Four Cs of 21st century's learning by United States Based Partnership for 21st century skills which is a non-profit organization founded in 2002 (p21.org, 2016).

Educators and academics tried to improve their students' 21st century skills by using different learning approaches. Science, Technology, Engineering, Math, Art (STEAM) education is one praxis of efforts. STEAM education contains skills, knowledge and beliefs that are collaboratively constructed at the intersection of more than one STEAM subject area (Çorlu, Capraro, & Capraro, 2014). Several studies related to different thinking skills such as critical thinking, computational thinking, analytical thinking has been conducted under higher-order thinking skills (HOTs) label to improve learning outcomes and prepare students to era that we live in.

STEAM approach in teaching aims to prepare individuals with high creative and innovative skills who can achieve in high-tech industry. Furnishing students with STEAM skills are considered as the key for sustainable development in the 21st century. Moreover, STEAM provides a learning frame for instructors of different fields to create an innovative and highly creative learning environment for students. It is a catalyst for students to combine their science and art skills to provide innovative solutions to challenging problems of the real world.

Architecture, since from the very beginning, is accepted as the ultimate profession of integration. Considering the diversity of the design problems, social, economical, cultural and aesthetical dimensions of the design problem and architecture, STEAM approach is particularly important in the architectural education both in terms of necessary subjects to be covered and as base to develop further thinking skills.

2.2. PICTURE OF CONTEMPORARY ARCHITECTURAL EDUCATION

In order to understand the presence of STEAM in today's architectural education, different analysis on three components of the architectural education as educational institutions, instructors and students were conducted. Another goal for these analysis is to understand what skills are offered by departments, how these skills are taught and conveyed to students by instructors and finally, how students perceive relevance of STEAM and ICT to architectural education as well as contribution of their former education to those skills. Importance of the results obtained from these surveys arise during the phase where gaps and deficiencies between aforementioned three corners of the triangle are to be diagnosed, identified, and highlighted.

First, curricula of undergraduate level programs of the top ranked educational institutions, universities in the scope of this project, were analyzed to understand the contribution of STEAM content to globally recognized architecture and design education programs.

Following the analysis of the programs, information related to knowledge content of the courses, assignments given throughout, teaching methods and teaching materials employed as well as assessment procedures of the learning outcomes were gathered using a survey distributed to course coordinators of three partnering universities.

Also, an online survey was delivered to undergraduate level architecture and design program students of the participating universities in order to outline profile of the students, examine

Table 2: 50 top ranked universities from QS

Rank	University	Rank	University
1	Massachusetts Institute of Technology (MIT)	26	University of Pennsylvania
2	UCL (University College London)	27	University of British Columbia
3	University of California, Berkeley (UCB)	28	Georgia Institute of Technology
4	Delft University of Technology	29	Pontificia Universidad Católica de Chile (UC)
5	Harvard University	30	Universitat Politècnica de Catalunya
6	University of Cambridge	31	Seoul National University
7	ETH Zurich - Swiss Federal Institute of Technology	32	Princeton University
8	Tsinghua University	33	University of Toronto
9	National University of Singapore (NUS)	34	University of Texas at Austin
10	Manchester School of Architecture	35	Cardiff University
11	The University of Hong Kong	36	RMIT University
12	Columbia University	37	Eindhoven University of Technology
13	The University of Tokyo	38	The University of Sheffield
14	University of California, Los Angeles (UCLA)	39	Universidade de São Paulo
15	Politecnico di Milano	40	Technical University of Munich
16	The Hong Kong Polytechnic University	41	Yale University
17	The University of Sydney	42	Kyoto University
18	The University of Melbourne	43	The University of Queensland
19	The University of New South Wales (UNSW Australia)	44	The University of Auckland
20	Cornell University	45	University of Michigan
21	Ecole Polytechnique Fédérale de Lausanne (EPFL)	46	University of Salford
22	Tongji University	47	Carnegie Mellon University
23	Stanford University	48	The University of Newcastle, Australia (UON)
24	KTH Royal Institute of Technology	49	KU Leuven
25	University of Illinois at Urbana-Champaign	50	Politecnico di Torino

their ICT habits and understand their perception of relevancy of STEAM skills with architecture.

Finally, remarks of all these analyses are put together to present the big picture of current situation in architectural education in terms of stakeholders perspectives. Next sections discuss methodology used, present obtained results and argues the outcomes of these three analysis.

2.2.1. SEMANTIC ANALYSIS OF COURSE TITLES FROM TOP 30 RANKED UNIVERSITY CURRICULA

The aim of the semantic analysis of course titles has been to examine the existence and distribution of STEAM skills in acknowledged architecture programs all over the world. Each program has its own composition of STEAM skills, and the effort here has been focused at creating a general overview.

2.2.1.1. METHODOLOGY

The task of choosing the programs to be part of this survey has initially given rise to two different considerations: a) What are the selection criteria for being included as *an acknowledged school?* and b) *How many architecture programs* should be included?

To accommodate the first consideration about which architecture schools to be included in the examination, a recognised university ranking has been selected as the basis. Various university rankings are available, but *QS World University Rankings for 2016* has been chosen as it offers a thematic ranking of *Top Universities for Architecture & Built Environment*[32].

To accommodate the second consideration about the number of top ranked architecture programs to include in the survey, 30 of the 50 top ranked

32 https://www.topuniversities.com/university-rankings/university-subject-rankings/2016/architecture

schools has been included, taking into account both availability of data and their reputation. The list of the 50 top ranked universities is shown in table X below. For some universities in the list, curriculum data needed has not been available, hence the next university in the list has been chosen. It is noticed that in fact a few well-known and recognized universities seem to organize their website more to communicate the experiences they provide to their students rather than the sequence of courses which constitute the curriculum they offer.

DEFINING AND USING TRIGGER WORDS

The investigation of STEAM skills in curricula of the top ranked universities has been conducted by semantic analysis of course titles with respect to credits per course, and credits to complete a bachelor degree. To do so, indicative words from all course titles have been extracted and distributed into all the categories of STEAM to cover all courses. The occurrence of those "trigger words" fitting into each STEAM category has been counted and evaluated from various perspectives; see examples of trigger words in table XX. To make the survey as precise as possible, *Science* has been divided into Natural Science and Social Science. By introducing the trigger words as the basis for the mode of analysis, a certain level of objectivity has been reached. Looking deeper into each course syllabus and learning goals would also be a viable way to investigate the distribution of STEAM components in the educations, but this approach would have been more sensitive to interpretation as well as considerably more time-consuming.

THE DATA, RIGOR AND VALIDITY

The data for this survey has been collected through a process of screening online material from the selected universities. In order to get a fruitful output of the survey, several other types of information have been obtained for each course apart from the course titles. This additional information includes credit systems, course credits, mandatory/elective status, geographic location, course position in curriculum, etc.

For the survey, a total of more than 940 separate courses distributed across the 30 architecture programs have been registered. While this number of courses is acceptable from a statistical point of view, rigor of the survey is highly dependant on both the categorisation of trigger words mentioned above, but also on the quality of the course titles, which in some cases can be both generic and ambiguous. It may furthermore be argued that the basic premise – a general correlation between course title and course content – may not always be present, and this affects validity of the result of the survey. However, this margin of error is

Table 3: Examples of trigger words extracted from course titles and sorted into the STEAM categories with Science (S) being split Natural and Social Science.

Natural science	Social science	Technology	Engineering	Arts	Math
Anthropocene	activity	3-D model	acoustic	ancient	algebra
biolog	american	3D model	building	art	calculus
climat	asian	advanced	concrete	art	cod
conservation	australia	animat	construct	baroque	geometr
ecolog	buddhist	building information model	dynamics	beyond	math
environment	business	cad	electric	century	paramet
green	chinese	code	energy	cinema	programming
health	citi	comput	engineering	classical	quantitative
heat	city	data	geotechnic	colo	script
hydrolog	civic	digital	hvac	communicat	stereotom
material	client	fabrication	infrastructur	composition	topolog
natur	community	generative	innovation	contemporar	math

considered to be acceptable and error checks have been made to minimize this risk.

2.2.1.2. RESULTS

OVERALL STEAM DISTRIBUTION

An overall STEAM distribution analysis is made across all programs in the study. This analysis is weighted with respect to the number of credits pr. course and the number of credits to complete a bachelor degree. This analysis shows a relatively even distribution of natural science, social science, technology and engineering components respectively, a significantly smaller amount of mathematics components, and a significantly larger amount of arts components respectively (Figure 1).

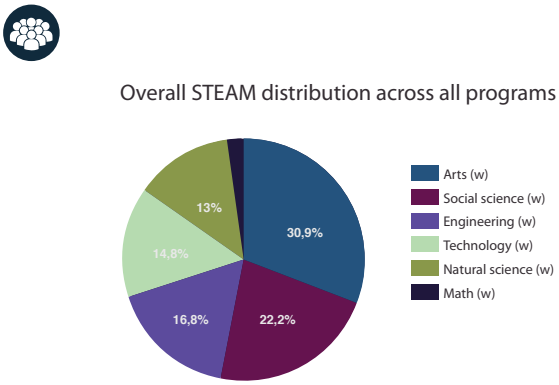


Figure 1: Overall STEAM distribution across all programs, weighted with respect to the number of credits pr. course and the number of credits to complete a BSc degree.

COURSE LEVEL STEAM INTEGRATION

An overall course level STEAM integration analysis is made across all programs in the study. The analysis examined the integration of science, technology, engineering and mathematics (STEM) components respectively with arts components. Among all the courses which contain arts (A) components, more than half of the courses do not integrate any STEM components. The most integrated STEM component is social science (SC), as around 40% of all courses which contain social science components are integrated with arts. Around 20-30% of all courses with technology (T) and engineering (E) components are integrated with arts. The STEM components which are the least integrated with arts are mathematics (M) and natural science (NS), as less than 20% of courses containing these components were integrated (Figure 2).

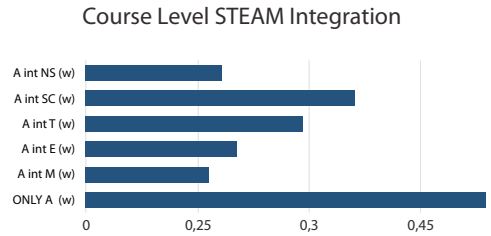


Figure 2: Course level STEAM integration with respect to "A" (NOT weighted)

PROGRAM LEVEL STEAM DISTRIBUTION

In order to understand how STEAM skills distribute among different programs, a program level STEAM distribution analysis has been performed. The results have been presented in a horizontal bar chart, sorted with respect to Arts (Figure 3). Due to lack of data, it was only possible to do this analysis for 18 out of the total 30 programs in the survey.

There is a remarkable difference in the amount of arts components from one end of the scale to the other. At ETH (Swiss Federal Institute of Technology) around of two thirds of the courses had arts components whereas this was only true for around 10% of the courses at TUD (Delft University of Technology). However, most programs have around 25-40% arts components in their courses.

All programs have both arts and engineering components. Three programs do not have any natural science components. One program does not have any social science components. A little less than half of all programs do not have any mathematics components. In this context, one program (ETH) stands out for not having any other components than arts and engineering, while one program (PUC) has only arts, engineering and social science components.

The amount of technology and engineering components do not generally seem to be at the expense of arts components, as these components combined account for roughly 30% in most programs, irrespective of the amount of arts components. Neither does the amount of natural science and mathematics components display a tendency relative to the amount of arts components. Social science components; however, have a tendency to be more present in programs with less arts components.

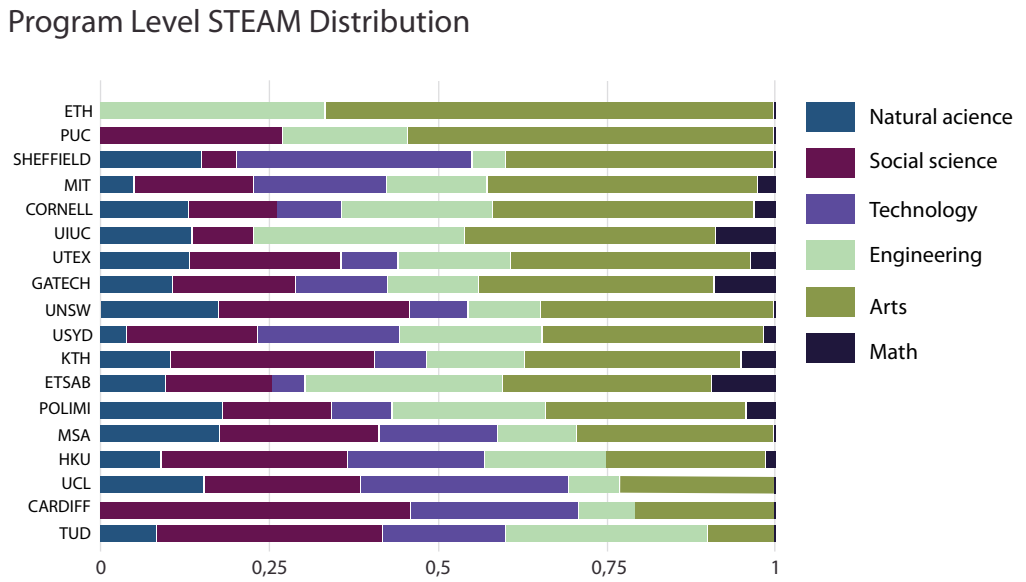


Figure 3: Program level STEAM distribution with respect to Arts

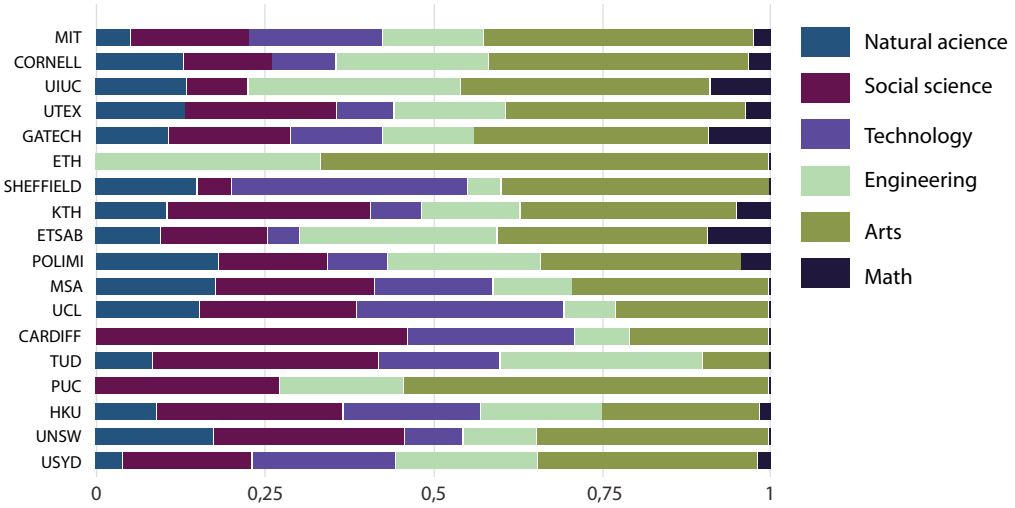


Figure 4: Program level STEAM distribution sorted by region with respect to Arts

In order to understand how STEAM skills distribute among programs in different regions, the program level STEAM distribution analysis was sorted by region with respect to arts (Figure 4). At the top of the chart (MIT-GATECH) is North America. Next (ETH-TUD) is Europe. South America (PUC) and Asia (HKU) are represented by only one university respectively. At the bottom of the chart is Australia (UNSW-USYD).

There is no clear tendency with regard to the distribution of arts components by region, although some British programs (MSA, UCL, CARDIFF) have less arts components than average. All North American programs (MIT-GATECH) have mathematics components, whereas none of the British programs (SHEFFIELD, MSA-CARDIFF) have any mathematics components.

2.2.1.3. DISCUSSION

The overall picture of the STEAM distribution across all programs is not surprising. Arts are more dominant than average, whereas mathematics and natural sciences are less dominant. It may raise some attention that social sciences are relatively dominant. However, this may be due to the fact that many words indicating geography or culture (e.g. american, asian, australia, buddhist, chinese, islam, korean) have been defined as social science trigger words, while in course titles in architecture and design programs, they may simply denominate

architecture in a particular context, even if the course does not treat its sociocultural aspects.

Another set of social science trigger words relate to urban planning (e.g. city, community, neighborhood, urban) which in architecture and design is often tied to architecture, and to urban design in particular. Again, had they been assigned as art trigger words, the picture might have been different. It would therefore be relevant to check to which extent words indicating geography or culture, as well as words indicating urban planning, impact the social science dimension.

Conversely, the arts dimension is generated from words covering both visual art (e.g. draw, figuration, model, paint), architecture (e.g. detail, garden, ornament, villa), history (e.g. ancient, baroque, modern, post-war), and more. While these categories all belong to arts/humanities, they represent quite different aspects of architectural training, as learning how to design (visual art) takes up a position than architectural history and theory. Decomposing the arts category with respect to these differences is therefore likely to provide a deeper understanding of the composition of the different programs.

The course level integration of different STEAM components corresponds roughly to the overall STEAM distribution. The most dominant components are also the most integrated ones. Nonetheless, integration is generally modest, as only typically between 15% and 30% of STEM components (except for social science) are integrated with arts components. Around a third of all courses with social science components are integrated with arts components. This however, may be due to the overlap between architecture and urban planning as discussed above.

Mathematics and natural science are less integrated with arts than the other STEM components. This may be because of less scope for integration. But it may also be because of less tradition to do so. In the scope of the project, it could therefore be interesting to test, whether there are new and unexplored ways of integrating mathematics and natural science components with arts components in architecture and design courses.

Although there is no clear tendency with regard to the distribution of arts components by region, there is a remarkable difference between the relative amount of arts components from the most arts dominated to the least arts dominated program. In this regard, it is important to note however, that naming practices for courses may distort the image. Hence, it is unlikely, for instance, that ETH has no science (natural and social), technology or mathematics components in their program, even though none of their course titles contain trigger words for these components.

The tendency that social science components are dominant at the expense of arts components may be due to the overlap between architecture and urban planning as already discussed. It is remarkable that all North American programs have mathematics components while none of the British programs do. But as with the example above, it may also be due to naming practices. Nonetheless, a more qualitative look at the North American and British programs respectively may shed more light over this question.

2.2.2. INSTRUCTOR SURVEY

Purpose of the instructor survey is to understand, in more detail than what is possible from the semantic course analysis, not just the whats but also the hows of architecture and design courses. In this survey, course coordinators were asked about the form and content of specific courses.

2.2.2.1. METHODOLOGY

The survey has been conducted among course coordinators for all Bachelor level courses (studio, lecture courses, electives such as study tours, etc.) at METU, UNIBO and AAU. The survey has been sent out as an online questionnaire with 9 separate sections of questions. The following central questions were asked:

- Which fields of knowledge are covered in the course?
- How is the course taught?
- Which types of course materials are used in the course?
- Which types of assignments are used in the course?
- How is the course evaluated?

In addition to these central questions, some base questions were asked about the instructor's age, gender and experience, with whom (s)he is teaching the course in question (alone, with colleagues and/or assistants), and more.

The questionnaire has been made in English as a way to minimize variation in questions asked

due to language difference. To accommodate cultural differences and variation in how words and concepts are used across country borders, each of the sections included detailed descriptions of the terms used in the specific question. As an example have the words "topic" and "subject" been thoroughly described as part of the section concerning course content.

2.2.2.2. RESULTS

A selection of results from the survey are presented here. More results could have been presented, but these are the ones which is considered as important at this phase. The charts in this section present the answers across all instructors at both METU, UNIBO and AAU. Thus, they do not reflect potential variations between the three programs. Also, they do not reflect variations between different courses within each program.

At the time of writing, 45 responses were received to the survey, 24 of which were from AAU, 7 were from UNIBO and 14 from METU. Hence, the response rate is quite low, as significantly more courses are taught. The response distribution is also very unequal, with more than 54% of all responses coming from AAU, 15% from UNIBO and 31% METU. The results should therefore be considered as indicative rather than conclusive.

Almost a sixth of all courses are taught individually by one person alone (15.9%), while a eighth of the courses are taught by only one instructor with the aid of teaching assistants. Almost all other courses are taught either with colleagues (67%) or with both colleagues and teaching assistants.

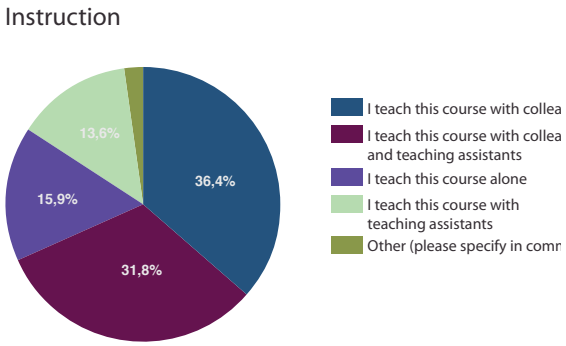


Figure 5: Instruction

More than half of the respondents indicate architecture/design as the field in which they earned their degree at both Bachelors/Masters and PhD level, while almost a quarter of the respondents indicate engineering for the respective degrees. There are more respondents who have a Master degree than a Bachelor degree, indicating that they have a five-year Masters degree with no separate Bachelor degree. Four respondents (9%) indicate that they do not have a doctoral degree, one of which overlaps with the one respondent indicating not to have a Masters degree. One person holds Bachelors and Masters degrees in humanities and two persons hold all three degrees in mathematics.

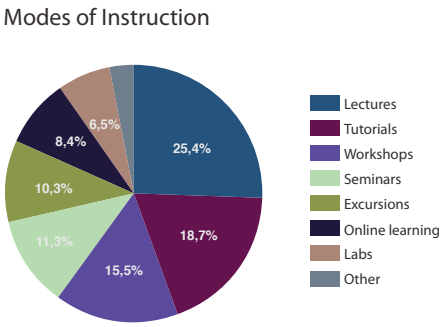


Figure 6: Modes of Instruction: How is the course taught?

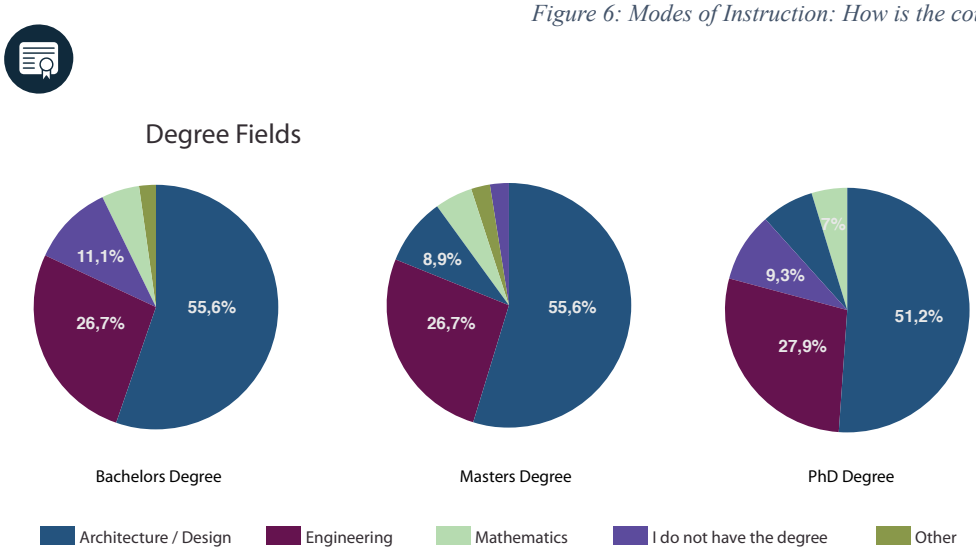


Figure 7: In which field did you earn your Bachelors/Masters/PhD degree?

When it comes to the types of course materials which are used in the courses, textbooks, academic texts, reference texts and software applications are the most widely used course materials (50% all together). As second tier comes news and social media, videos, physical materials and artifacts. Fiction and audios are hardly used by anyone, and no one is using other types of course materials (Figure 8).

Types of Course Materials

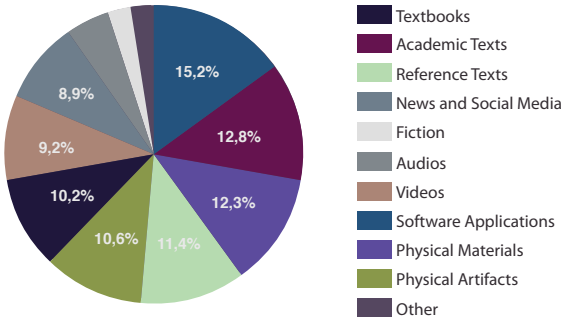


Figure 8: Which types of course materials are used in the course?

The most widely used course evaluation formats are reviews of submitted works and oral exams based on submitted works (41% together). Oral exams and final reviews are used to a lesser extent, while critiques, pin-ups, peer evaluation, self-evaluation and other formats are used less again (Figure 9).

2.2.2.3. DISCUSSION

Course Evaluation

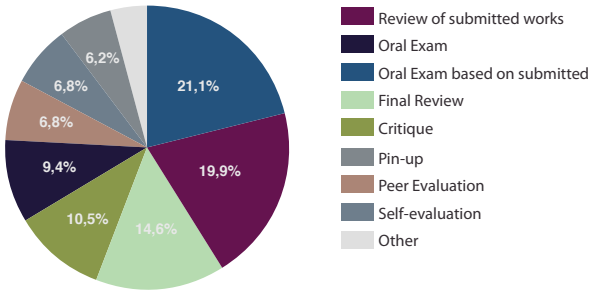


Figure 9: How is the course evaluated?

As the response rate to the survey is low and the response distribution is unequal, it is too early to draw any conclusive insights. However, some trends may be indicative, and worthy of remarks.

Almost a sixth of all courses are given by one academic alone, sometimes with the aid of a teaching assistant. This might indicate that those courses are subject related rather than topic related (integrated) unless this one person is multidisciplinary. In addition, when instructors background is also considered, it is likely that the courses taught with colleagues are given by more than one instructor with architecture/design background.

The fact that most courses are given by instructors with a background in architecture/design or engineering is expected. Considering around 75% of all responses are from AAU, it is remarkable that over half of the respondents indicate that they have a Bachelor degree in architecture/design, as this was not offered up until recently in Denmark. AAU has many instructors who hold engineering degrees in architectural and design engineering. It is therefore likely that they have indicated architecture/design rather than engineering.

The primary modes of instruction seem to be traditional, as lecturing, tutorials and workshops are the dominant modes of instruction. With the strong focus on studio teaching (tutorials) and the widespread conservative understanding of the concept of a (lecture) course in architecture and design education, this comes as no surprise. The fact that lab teaching is limited may be cost-related. The same cannot be said for online teaching, which is also limited. Here, the reason is more likely to be the lack of will, skills and insight on behalf of the instructors.

The fact that the use of teaching materials is also traditional – textbooks, academic texts, reference texts and software applications – is in line with the seemingly conservative understanding of the concept of a (lecture) courses. The fact that fiction and audios are hardly used at all may not present a problem, but may give rise to considerations as to whether it represents an unused potential.

What the course evaluation formats are concerned, there are no surprises either. The formats are traditional – review of submitted works, forms of oral exams, and final reviews – just as it is expected in architecture and design education. These formats are predominantly summative assessment formats, however, although they may contain formative elements inasfar as they include elements of discussion. Critiques and pin-ups seem to be less used. It would be interesting to see if this trend will continue with more responses to the survey, as one might expect those formats to be more prominent. Peer and self-evaluation is not widely used. Therefore, there seems to be a potential for more formative assessment formats.

2.2.3. STUDENT SURVEY

Aim of this questionnaire is to define the profile of the current students enrolled to graduate and undergraduate level architecture programs of the partnering institutes, namely Aalborg University, University of Bologna and Middle East Technical University in terms of how STEAM fields are perceived and usage of ICT tools for their education. By this way, it is aimed to see whether the students are able to adapt themselves and grasp rapidly changing communication and education mediums and how the STEAM disciplines corresponds to the relative components in their education.

2.2.3.1. METHODOLOGY

For this study, students were asked to fill out an online survey presented as a printed version on APPENDIX 1. Questions can be classified into two groups. The first set of questions, which are related to personal profile of the students, were asked to analyze gender, age, current level of study, intention for choosing architecture as a profession of the participants while the second set of questions were asked to analyze the STEAM skills of the participants.

Total of 129 responses as 41 from University of Bologna, 42 from Middle East Technical University and 46 from Aalborg University is collected to have an insight about the perception of the students in terms of both architecture discipline and architecture education. In order to avoid bias caused by dishonest responses and error caused by inattentive responses, the responses which fail at consistency check questions are omitted. As a result, 26 responses are disregarded and results are inspected with respect to 103 responses. The results are analysed both per university in order to inspect the influences of different approaches on education among schools and as total to have an insight on perception of architecture and architectural education from students' point of view.

2.2.3.2. PROFILE OF RESPONDENTS

The levels of respondents vary for each university resulting in approximately 40% from 1st grade, 15% from 2nd and 3rd grades and 30% from 4th grade. The weight of 1st graders for METU and 4th graders for UNIBO has strong influence while responses from AAU is relatively evenly distributed. The age distribution of the respondents varies between 18 and 30 mostly accumulated between range of 19-24.

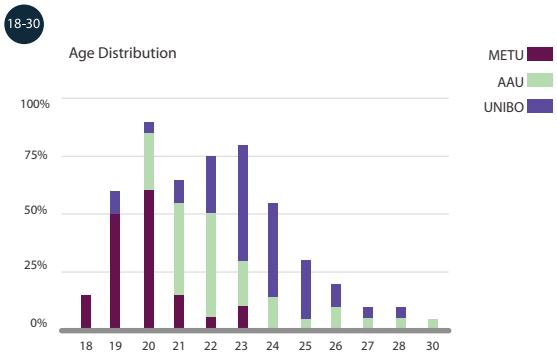


Figure 10: Age Distribution / Profile of Respondents / Student Survey

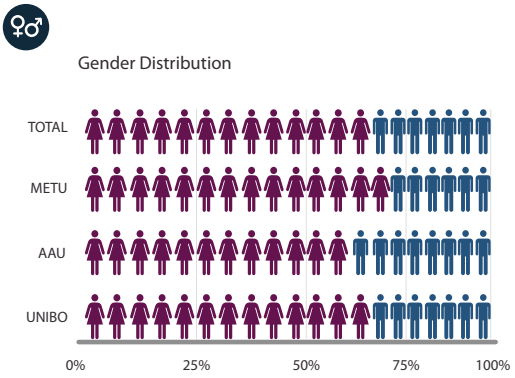


Figure 11: Gender Distribution / Profile of Respondents / Student Survey

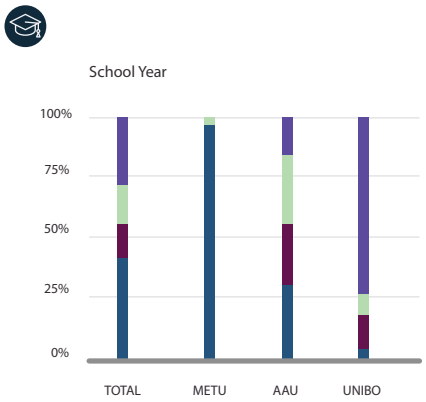


Figure 12: School Year / Pro le of Respondents / Student Survey

Gender distribution among the universities, regardless of their levels are approximately same showing that almost 60% of the students from each of the universities are female.

The primary motivation of students while choosing architecture is identified as the perception of architecture being a medium of design and artwork. The most dominant answer to question "What is the reason for choosing architecture" is "I like design" in total distribution, followed by

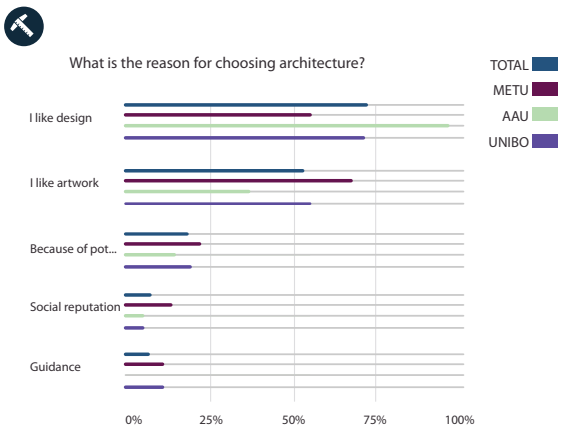


Figure 13: Student's answers to the question of "What is the reason for choosing architecture?"

the second most favourable option "I like artwork" which is more dominant for METU case. "Because of potential profits", "Social reputation" and "Guidance of others" answers are other options respondents chose.

2.2.3.3. QUESTIONS REGARDING SELF-DISCIPLINE

The majority of the students, regardless of their university perceive themselves as self-directed person and they are able to set goals and high degree of initiative. When respondents from universities are inspected individually, responses from METU have a general trend towards agreement with the statements whereas very few UNIBO students answered *"disagree"* for being self-directed person and none of the students from AAU answered *"disagree"* for having high degree of initiative and high motivation to start.

While students are perceiving themselves as self-directed, having high degree of initiative and motivation at start, most of these students also have problem with time management. Majority of the respondents answered *"Neither agree or disagree"* for managing their study time effectively from all universities and being self-disciplined from AAU and METU students. Most of the students from UNIBO recognize themselves as self-disciplined.

2.2.3.3. RELATION OF ARCHITECTURE WITH STEAM

Responses received from the questions regarding the relevance of Mathematics, Design, Arts, Engineering and Science fields to Architecture are processed to obtain a pentagon radar chart to observe the weight of these fields from the perspective of architecture students. The results are analyzed for both total responses and each participating university. Each response is multiplied with the relative weight of the answer and then normalized.

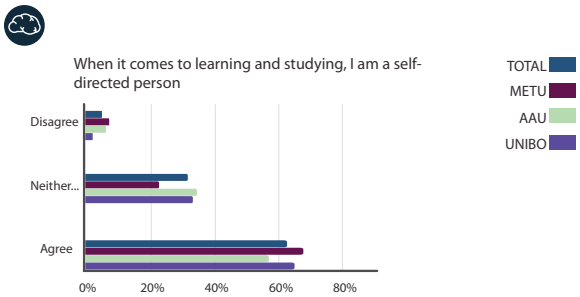


Figure 14: Student's answers to the question of "When it comes to learning and studying, I am a self directed person"

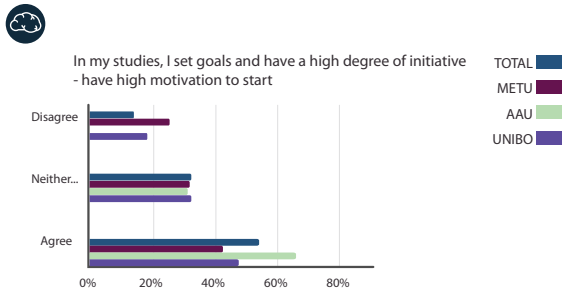


Figure 16: Student's answers to the question of "In my studies, I set goals and have a high degree of initiative - have high motivation of start"

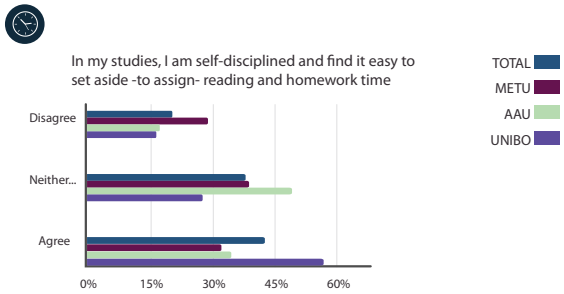


Figure 15: Student's answers to the question of "In my studies, I am self disciplined and find easy to set aside -to assign- reading and homework time"

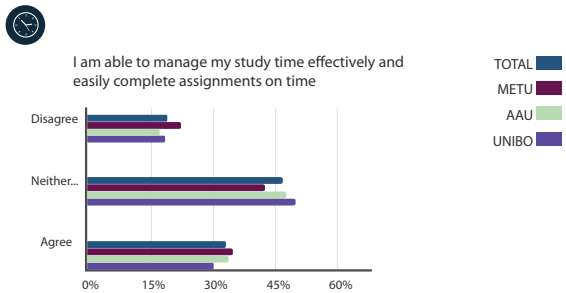


Figure 17: Student's answers to the question of Student's answers to the question of " I am able to manage my study time effectively and easily complete assignments on time. "

Students' Point of View of STEAM

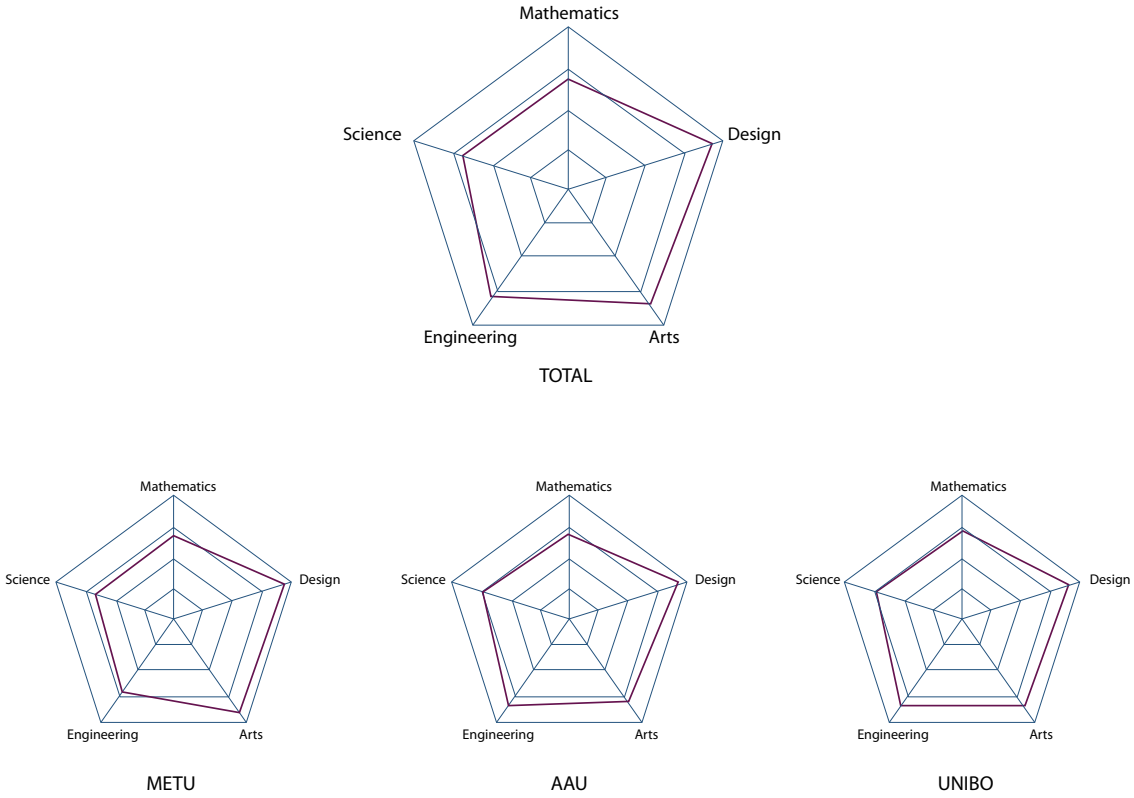


Figure 18: Students point of view regarding the Relation of Architecture with STEAM

The results show that in all cases, the students perceive design as the fundamental part of architecture. It is also observable that students see mathematics and science is noticeably less relevant with architecture whereas the weight of art and engineering differ across universities. The students at METU distinguish that the relevance of arts is more than of engineering, while students at UNIBO perceives the weighting more balanced and students at AAU is more focused on the engineering aspect rather than arts.

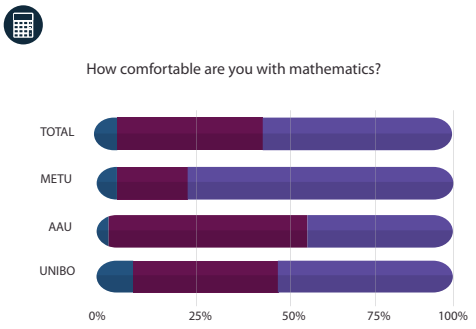


Figure 19: Student's answers to the question of Student's answers to the question of "How comfortable are you with mathematics?"

MATHEMATICS

It is remarkable that almost none of the respondents answered *"not comfortable"* with mathematics. Majority of the students are either comfortable or moderately comfortable but does not perceive mathematics as a fundamental part of architecture.

ARTS

No correlation between previously taken art courses in high school education and perception of relevance of art and architecture is observed. Most of the students from UNIBO took courses related to arts but find arts less related with architecture comparing to METU students. On the contrary, majority of METU students did not take such courses but find arts as a highly related field with architecture while AAU students did not take such courses and perceives arts similar to UNIBO students. However, regardless of the courses taken related to arts and rate of relevance with architecture majority of all respondents use social media accounts, blogs and websites to reach relevant information related to arts.

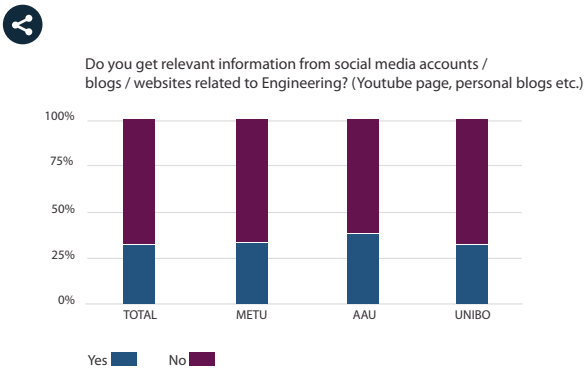


Figure 20: Student's answers to the question of "Do you get relevant information from social media accounts/blogs/ websites related to Arts?"

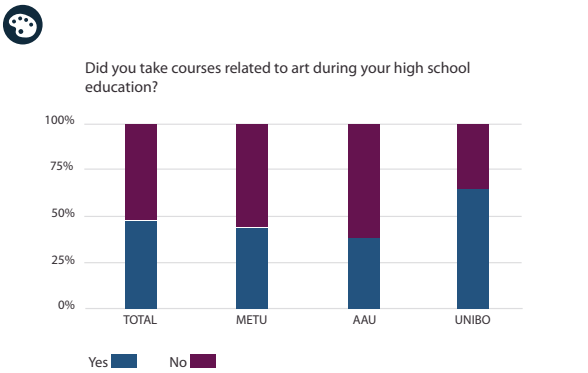


Figure 21: Student's answers to the question of "Did you take courses related to art in your high school education?"

ENGINEERING

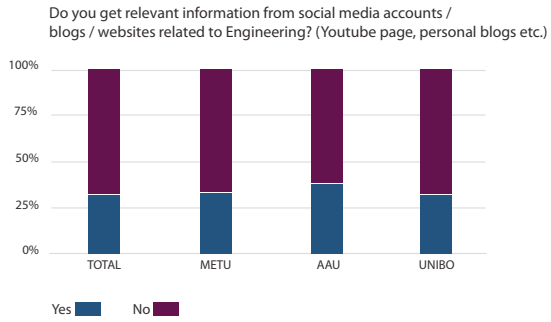


Figure 22: Student's answers to the question of "Do you get relevant information from social media accounts/blogs/ websites related to Engineering?"

Even though respondents from AAU and UNIBO perceive engineering a highly related field with architecture, majority of the respondents regardless of their university does not get relevant information from social media accounts, blogs and websites to reach information associated with engineering.

LIFE SCIENCES

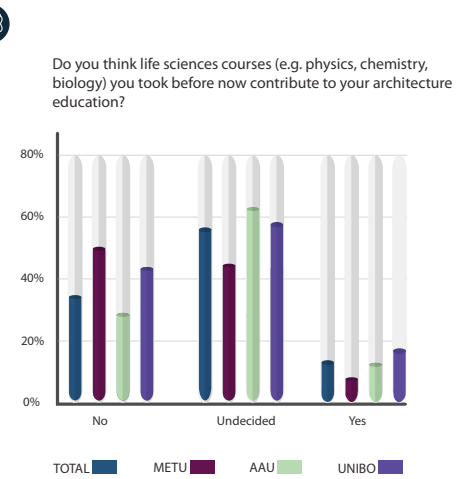


Figure 23: Student's answers to the question of "Do you think life sciences courses you took before are now contributing to your architectural education?"

The majority of the students perceive that the life sciences courses that they took prior to their architecture education are not fully contributing to their current courses. Only approximately 11% of the participants claimed a full contribution while more than half of the participants are undecided on contribution of their former life science courses to their current studies. Nearly 50% of METU students think that former life science education does not have any contribution to their studies related to architecture education.

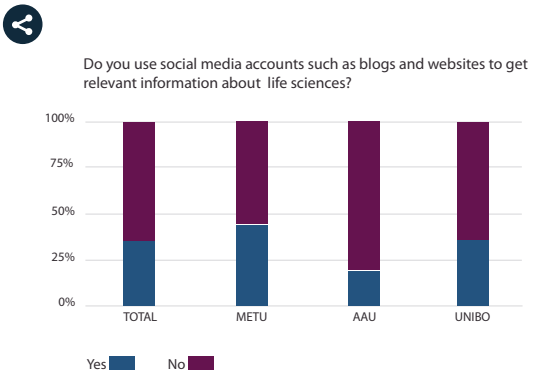


Figure 24: Student's answers to the question of "Do you use sıcial media accounts such as blogs and websites to get relevant information about life sciences?"

Use of social media, blogs and websites for gathering information about life sciences changes among students from different universities while majority of the students does not prefer to use internet for educational activities related to life sciences. Only 17% of the students from AAU, 35% of the students from UNIBO and 45% of the students from METU use online sources to be able find information related to life sciences. It is not surprising to see the relatively low tendency of using social media services and web tools to find information related to life sciences, as students find life sciences less relevant with architecture compared to other fields, which can be seen on the radar charts.

MOBILE LEARNING

The respondents are asked whether they find mobile learning useful for five purposes namely as listed below:

- To access educational content online
- To access educational content offline
- To access supporting educational information (e.g. math concept, examples) via WWW
- To collaborate with other students
- To collaborate with instructors

The majority of the students regardless of their university consider mobile learning useful for accessing educational content online and collaborating both with students and instructors. For accessing educational content offline and accessing supporting educational information via WWW, majority of METU and UNIBO students recognize mobile learning useful while majority of AAU students are neutral to use of mobile learning for these purposes.

It is evident that use of mobile learning tools are grasped by students.

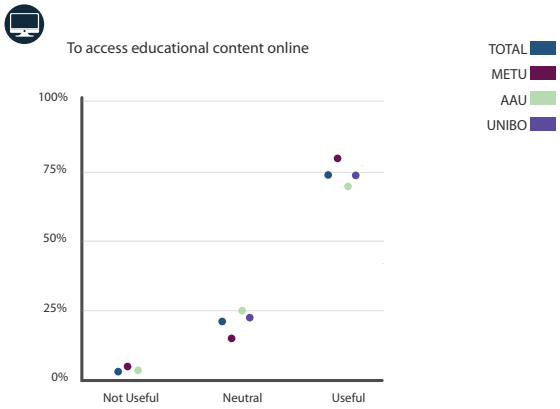


Figure 25: Students answers regarding the usefulness of mobile learning to access educational content online

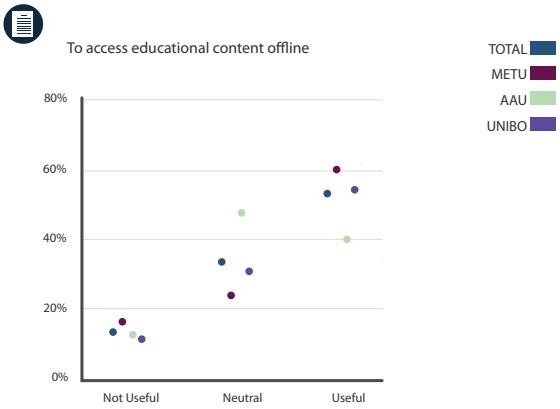


Figure 26: Students answers regarding the usefulness of mobile learning to access educational content offline

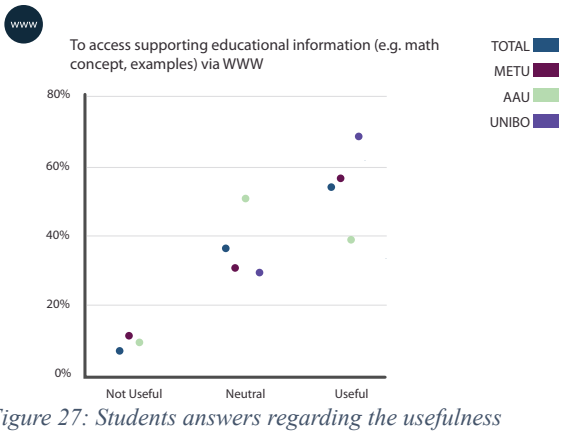


Figure 27: Students answers regarding the usefulness of mobile learning to access supporting educational information via WWW

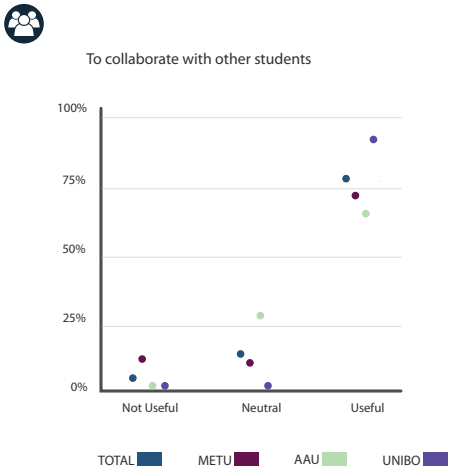


Figure 28: Students answers regarding the usefulness of mobile learning to collaborate with other students

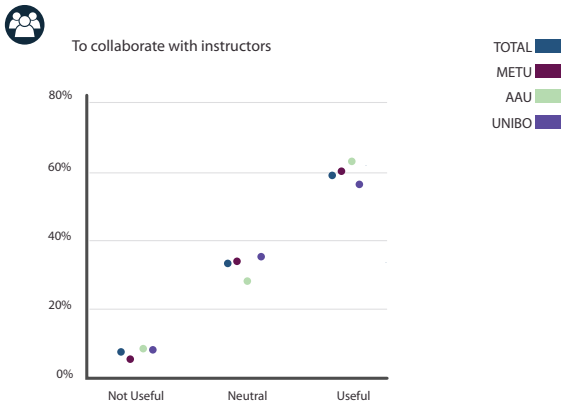


Figure 29: Students answers regarding the usefulness of mobile learning tocollaborate with instructors

Order of action when having a problem with an electronic device:

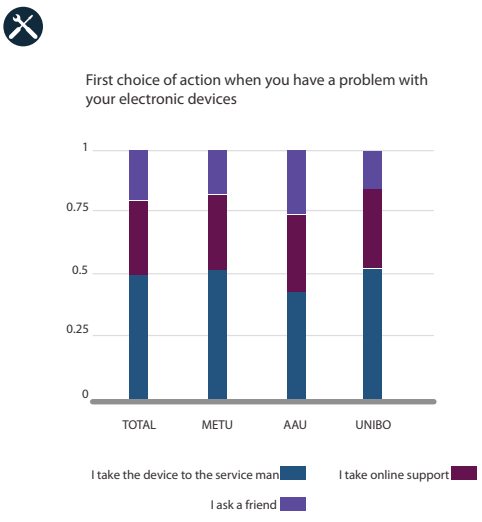


Figure 30: Student's answers to the question of "What is the first choise of action when you have a problem with your electronic devices?"

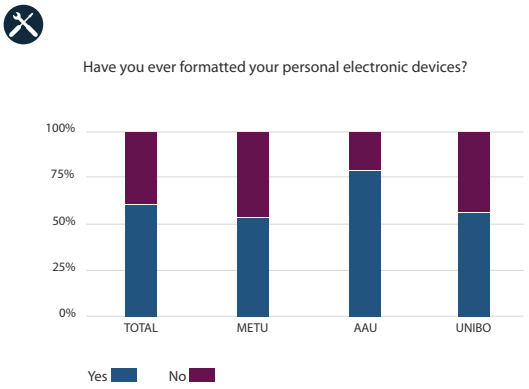


Figure 31: Student's answers to the question of "Have you ever formatted your personal electronic devices?"

Respondents stated that in case of a problem with their electronic devices, 49% of the respondents prefer to take their devices to a serviceman as the first choice while ratio of the respondents who prefer to take online support as first choice remains at 32%. One quarter of the respondents prefer to ask for help of a friend about the problem.

According to figure XX, 38% of architecture students from participating universities have never formatted their personal electronic devices. In detail, 48% of the students from METU, 22% of the students from AAU, 46% of the students from UNIBO have never formatted their personal devices.

These numbers can be perceived as an indicator that the respondents are not comfortable with personal electronic devices when it comes to troubleshooting even though they are comfortable with everyday use.

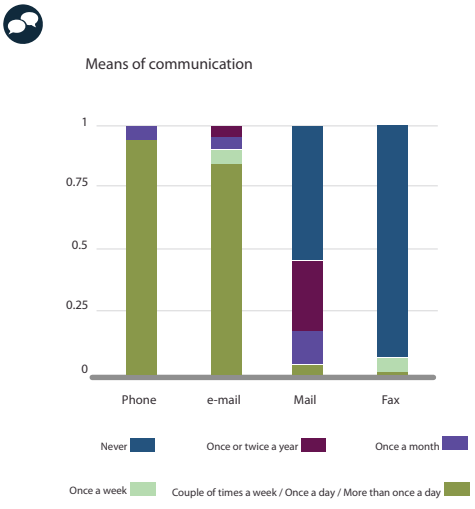


Figure 32: Student's answers to the question of "Please indicate how often you use the following means of communication?"

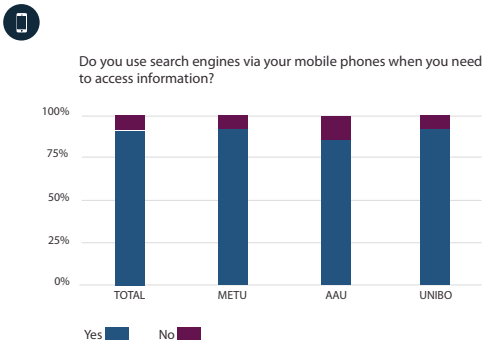


Figure 33: Student's answers to the question of "Dou you use search engines via your mobile phones when you need to access information?"

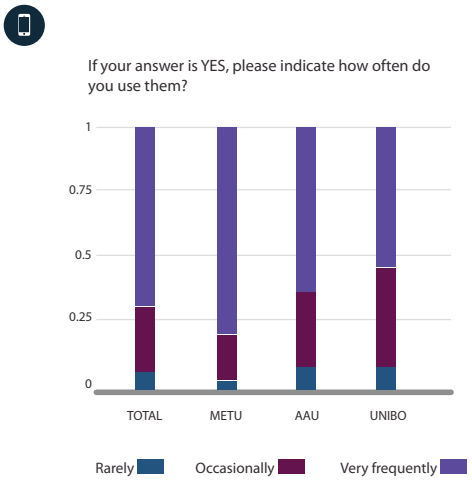


Figure 34: Student's answers to the question of "If your answer is YES, please indicate how often you use them"

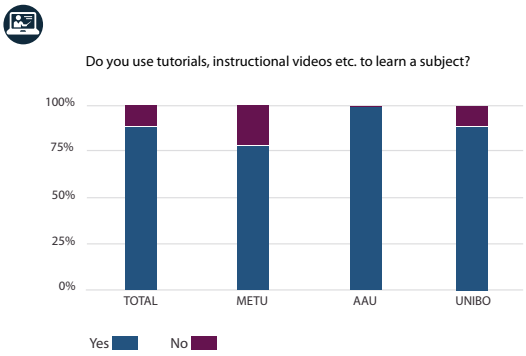


Figure 35: Student's answers to the question of "Do you use tutorials, instructional videos etc. to learn a subject?"

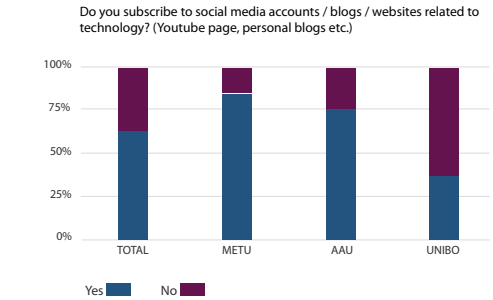


Figure 36: Student's answers to the question of "Dou you subscribe to social media accounts/blogs/websites related to technology?"

MEANS OF COMMUNICATION

Phone and email are the preferred means of communication for majority of the respondents while physical mail and fax are used rarely or never. For this question, responses from universities are not shown separately as no significant difference is observed.

Most of the students regardless of their university uses search engines via their mobile phones on daily basis. This ratio is divided between "often" and "everyday" for AAU and UNIBO cases.

Most of the students regardless of their universities take advantage of tutorials, instructional videos or alike material to learn subjects. All of the students from AAU responded positively, denoting that for AAU students, use of such material is not only for self education but also used as a teaching material by instructors.

Even though majority of students from METU and AAU subscribe to social media accounts, blogs and/or websites related to technology, most of the students from UNIBO answered the question negatively.

2.2.3.4. DISCUSSION

Student survey is conducted to have an insight on the perception of students, especially of freshman students, of architecture as a discipline, tendencies on the modes of education and how they interrelate STEAM disciplines with architecture. It is obvious that a questionnaire on students from three universities doesn't provide enough information to cover the tendencies and perception globally. Yet, when detailed analysis of curriculums and questionnaire on instructors from three universities are taken into account, a correleation is observed providing a general picture of architectural education.

Several outcomes of the survey can be listed as below:

- Students do not perceive mathematics and life sciences as highly related disciplines to architecture regardless of their university and respective architecture education.
- Majority of the architecture students use ICT in their daily life and in their studies. They also prefer mobile learning tools.
- Most of the students utilizes social media accounts, blogs and websites to get relevant

information on fields they consider highly related with architecture.

- Even though the students frequently use personal electronic devices, majority is not digital natives as they have problems with troubleshooting and prefer to use others help to resolve issues.

As a result, it can be stated that the students are still in the process of saturating the rapidly improving technologies to become digital natives. However, the use of ICT and mobile learning mediums are not efficient to relate architecture with other disciplines and their perception is still bounded with the traditional perception of institutions.

2.2.4. CONCLUSION OF THE RESULTS FOR ALL SURVEYS

It is aimed to analyse the contemporary education in relevance with STEAM disciplines and skills. For this purpose, three different studies are conducted namely; semantic analysis of course titles from top 30 ranked universities to have an overview of architecture education globally, instructor survey and student survey which are conducted in three partner universities. It should be noted that the remarks and findings within the scope of these studies do not intend to make a generalization of the contemporary architectural education in global scale but instead aims to find correlations between the results to pinpoint some tendencies to foresee how the education system can be improved. In this course following findings are observed.

Firstly, life sciences and mathematics have less share among STEAM distribution of the courses in the curricula according to semantic analysis conducted. This is reflected to students' perception of relevancy of STEAM components to architecture which can be interpreted as students perception is directly influenced and shaped by the curriculum and means semantic survey is justifiable also in learning goals and objectives level. This remark does not necessarily state that universities do not cover mathematics or life sciences aspects of architecture, especially when the share of engineering is considered. However, it is possible to conclude that mathematics and life sciences are not acknowledged explicitly in most of the universities curricula resulting in the misconception of mathematics and life sciences are distant disciplines to architecture.

Secondly, a mismatch between demands of students and what instructors provide in terms of using ICT and mobile learning environments is observed. Even though student questionnaire shows that majority of the students find mobile learning tools useful for learning subjects, instructor survey shows course coordinators and instructors are mainly using traditional methods while both conducting and assessing the courses. It is evident that institutions and instructors need to put more effort on adapting themselves to rapidly improving and changing technologies to get to full potential of new teaching mediums.

It is also observed that, embracing traditional methods pose an obstacle for having a holistic approach grasping relevant aspects from other disciplines. The reason of segmentation of STEAM disciplines among the curricula of universities can be a result of instructors' focusing on subjects instead of topics and departmentalization of the education in universities. With the current trend on interdisciplinary studies, architectural education also needs to grasp relevant disciplines to have a holistic approach towards topics. With such an adaptation it is believed that STEAM disciplines and skills will be more blended.

3. ARCHITECTURE IN PRACTICE

The role of design studios in architectural education is undeniable. Most of the discussions on architectural education focus on design studios, which varies in many scales: from countries to schools, years to instructors. Although there is a consent for the objectives, how those studios should be conveyed, what should be new means and technologies to be used, how the subjects and assignments are organised etc, are debatable.

Architectural education is a complex task and the subject matters are continuously changing not only with conjuncture but also with technology expiring the skills and knowledge of the architects very quickly. This fact also consumes education very fast and makes any curriculum obsolete in very short period of time. Hence shifting discussions from contents of curriculum to skills to be expected will be more constructive and contributing the architectural education. In this regard, the EU system of qualifications can be accepted as dynamic guidelines in defining the objectives of architectural education.

These objectives can be defined based on the definition of competency of European Union. According to the report published by The European Parliament and The Council of The European Union[33];

> *"As globalisation continues to confront the European Union with new challenges, each citizen will need a wide range of key competences to adapt flexibly to a rapidly changing and highly interconnected world."*

Furthermore, competences are defined within the same report as "*a combination of knowledge, skills and attitudes appropriate to the context*", thus importance of both professional and survival skills are pointed within this framework. In this context, **EQF Levels** for Architectural Education defining the professional skills and **green skills** enabling architects to sustain their knowledge in the changing and interconnected world are mentioned.

3.1. EQF LEVELS FOR ARCHITECTURE

Qualifications are visited based on the "Descriptors defining levels in the European Qualifications Framework" (EQF) declared by European Commission. Levels indicated in the framework, and according to descriptors, Level 6,7 and 8 referring to Bachelor, Master and Ph.D. degrees are embraced in the scope of this project.

At this point, a recent EU project titled as "EQF Level Descriptors Architecture" [34] defining EQF levels 6 to 8 in architecture reveals as a source that defines knowledge, skills and competence of graduates of architectural schools. The structure which is referred with tables below are developed based on the parameters of architectural creation which is published in the project website and listed in this report as such[35]:

- *"Design Thinking and Doing (DES). Under this heading all competences related to the act of designing are grouped, as this is the fundamental outcome of architectural education.*
- *In order to be able to design an architect has to have a significant input from the Humanities (HUM). So the parameter Thinking /considering the human groups all competences related to this input.*
- *In order to be able to design, an architect has to have a significant input from the part of engineering (ENG). Technical and environmental considerations group all competences related to this input.*
- *In order to be able to design, an architect has to develop an architectural culture (CUL). This means that a number of competences have to be developed related to the history and theory of architecture, to the understanding of their operational value and to their impact on the way that graduates conceive architecture.*
- *Architects have to communicate the outcomes of their work. Communication is a significant*

33 OJEU (2006). Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning (2006/962/EC). Brussels, Official Journal of the European Union.

34 http://www.unideusto.org/tuningeu/images/stories/HUMART/EQF_Level_Descriptors_Architecture.pdf accessed on 17.05.2017

35 http://www.unideusto.org/tuningeu/sqf-humanities-and-arts/outcomes/architecture-level-desc.html accessed on 18.05.2017

parameter of the profile of the graduate and this heading covers all competences relative to communication.

- *Architects have to be innovative. Experimentation and Research on architectural innovation is fundamental for architectural creation. This heading groups all competences related to the innovative thinking, doing and knowing."*

These descriptors are stated in the tables below.

Table 4: Descriptors defining Level 6 for Architecture

LEVEL: 6		ARCHITECTURE		
	EQF CATEGORIES →	KNOWLEDGE	SKILLS	COMPETENCE
Architectural Creation & Architectural Creativity		Architectural Creation & Architectural Creativity		
	7 DIMENSIONS	GRADUATES IN ARCHITECTURE AT LEVEL 6 ARE EXPECTED:		
	Conceptualising, Designing, Materialising Architecture	To have advanced knowledge of the processes, concepts and cultural values guiding architectural creation	To have the advanced skills to formulate critically , elaborate creatively and translate innovatively into spatial forms their own architectural concepts	To be able to draw upon the knowledge and skills gained within their architectural studies so as to act and respond critically and creatively in different situations
	Re-thinking, Considering and Interpreting the Human Aspect of Architecture	To appreciate how architectural practice and creation both stems from, and shapes, our humanity	To demonstrate interpretative skill and a reflection of the human dimension in their creative architectural practice	To be able to draw upon experience gained within their architectural studies to operate with an ethical awareness and to encourage the development and foster the well-being of other individuals and groups
	Experimenting, Innovating & Researching through Architecture	To be aware of the research and experimentation dimension inherent in the architectural practice and creation relevant to architecture as creative discipline	To experiment in their architectural creative practice and demonstrate an emerging ability to handle complexity and unpredictability	To be able to draw upon experience gained within their architectural studies to respond with curiosity and an enquiring outlook to the world around them
	Theories, Histories & Cultures of Architecture	To have advanced knowledge and critical understanding of the main theories of architecture, as well as the dominant principles, values and core body of works created in different periods of history of architecture	To be able to access the information necessary to develop their architectural knowledge, using all appropriate media and sources, and to apply this knowledge to the creative architectural design processes	To be able to draw upon experience gained within their architectural studies to access knowledge and exercise critical judgement outside their discipline
	Technical, Environmental & Contextual Issues relating to Architecture	To have advanced knowledge of the range of materials, construction techniques, environments and contexts which underlie the act of architectural creation	To demonstrate the necessary technical mastery to achieve basic architectural creations	To be able to draw upon contextual awareness gained within their architectural studies and apply this in different situations
	Communication, Collaboration & Interdisciplinarity in Architecture	To be aware of disciplines outside architecture and of the dynamic ways in which they interact with architecture	To demonstrate the capacity to work collaboratively with other architects as well as with specialists from other disciplines in creating architecture and communicate it effectively to others	To be able to contribute to the execution and management of activities or projects in an open and communicative manner
	Initiative & Enterprise through Architecture	To be aware of how architecture functions as a profession and as part of the creative industries To be aware of the key financial, business and legal aspects of the architecture as profession	To be pro-active in generating artefacts, events and opportunities for work within architectural practice	To be able to act resourcefully, initiating projects, innovative ideas and contributing decisively to the success of others

Table 5: Descriptors defining Level 7 for Architecture

LEVEL: 7		ARCHITECTURE		
	EQF CATEGORIES ➔	KNOWLEDGE	SKILLS	COMPETENCE
		Architectural Creation & Architectural Creativity		
Architectural Creation & Architectural Creativity	7 DIMENSIONS	GRADUATES IN ARCHITECTURE AT LEVEL 7 ARE EXPECTED:		
	Conceptualising, Designing, Materialising Architecture	To have highly advanced knowledge of the processes, concepts and cultural values guiding architectural creation, some of which will be at the forefront of their field	To have developed to a high professional level their ability as architects to formulate critically , elaborate creatively and translate innovatively into spatial forms their own architectural concepts	To emerge as well-developed personalities, able to draw upon the knowledge and skills gained within their architectural studies so as to act and respond critically and creatively in situations that are complex, unpredictable and require new strategic approaches
	Re-thinking, Considering and Interpreting the Human Aspect of Architecture	To have developed highly advanced understanding of how architecture stems from, and shapes, our humanity	To demonstrate a high professional level of interpretative skill and a distinctive reflection of the human dimension in their architectural creations	To be able to draw upon experience gained within their architectural studies to operate with integrity and ethical commitment, encouraging the improvement of other individuals' and groups' life into public and privet space and fostering the well-being of society at large
	Experimenting, Innovating & Researching through Architecture	To have highly advanced knowledge of concepts, methods and precedents that provide a basis for originality, innovation and/or research in their creative practice as architects	To demonstrate advanced skills in architectural creation, innovation and/or research, enabling them to use new means and develop new approaches, awareness and insight in their architectural practice	To be able to draw upon experience gained within their architectural studies to contribute innovative approaches, awareness and insight within society at large
	Theories, Histories & Cultures of Architecture	To have highly advanced knowledge and acute critical understanding of contemporary and historical architectural creations and the architectural theoretical discourses articulating related arts, technologies and human sciences	To have built upon their studies advanced skills to retrieve the basic issues, themes and values of the past and present day architectural debate and practice and to identify cultural representations on architectural forms To demonstrate specialised skills in accessing the information necessary to further develop their architectural knowledge, using all appropriate media and sources, and in applying this knowledge to their architectural creations	To be able to draw upon experience gained within their architectural studies to process and manipulate present and past knowledge and exercise sophisticated critical judgement outside their discipline
	Technical, Environmental & Contextual Issues relating to Architecture	To have highly advanced knowledge of the range of materials, techniques, environments and contexts which underlie the act of creating architecture	To demonstrate fully the advanced technical mastery required to achieve their architectural works such that technical and environmental issues offer no impediment to the creation, realisation and expression of their own artistic concepts but on the contrary to be creatively integrated into the design process	To be able to draw upon contextual, cultural and environmental awareness gained within their architectural studies and apply this effectively in a range of different situations
	Communication, Collaboration & Interdisciplinarity in Architecture	To be critically aware of issues at the interface between architecture and disciplines outside it, and of the dynamic ways in which architects interact with their counterparts in the other creative & performing disciplines, humanities, engineering and sciences	Demonstrate advanced ability to integrate elements from different fields when working collaboratively in their discipline and communicating about it to others Demonstrate advanced skills to develop a trans and inter-disciplinary understanding To talk or write and sketch in a mature and sophisticated way about their architectural ideas and proposals To master fully the behavioural and communicative demands of public performance	To be able to draw upon experience gained within their architectural studies to manage and transform activities or projects in an open, confident and communicative manner, taking full responsibility for contributing to professional knowledge and practice
	Initiative & Enterprise through Architecture	To have a highly developed understanding of how architecture functions as a profession in its own right and as part of the creative industries	To have a proven track record in generating architectural forms and pro-actively creating opportunities for work for themselves and other architects	To be able to act resourcefully, autonomously and with self-confidence, frequently initiating projects and otherwise contributing decisively to the success of those in which th team role

Table 6: Descriptors defining Level 8 for Architecture

LEVEL: 8		ARCHITECTURE		
EQF CATEGORIES ➔		KNOWLEDGE	SKILLS	COMPETENCE
Architectural Creation & Architectural Creativity		**Architectural Creation & Architectural Creativity**		
	7 DIMENSIONS	GRADUATES IN ARCHITECTURE AT LEVEL 8 ARE EXPECTED:		
		to have knowledge at the most advanced frontier of their specialised architectural field and at the interface between this and other fields and disciplines.	**to demonstrate in the formation, articulation and expression of their own architectural concepts or/or creations the most advanced and specialised skills and techniques**	**to be able to draw upon experience gained within their advanced architectural studies to command authority in areas of specialist expertise and demonstrate conspicuous innovation and autonomy**
		Because of its individual nature, study in Architectural Creation & Architectural Creativity at Level 8 may embrace any or all of the 7 dimensions of the Creative & Performing Disciplines. However, in most cases, it will be expected to embrace aspects such as the following:		
	Making, Performing, Designing, Conceptualising	Knowing in depth all the relevant methods and techniques of inquiry related to a particular field of study of architecture	Integrating previous experience so as to demonstrate original creative insights in the domain of architecture Functioning with complete creative autonomy	Comprehending the transferability of their research capabilities to other fields Displaying professional, creative and scholarly integrity
	Re-thinking, Considering and Interpreting the Human	Being fully familiar with architectural research dynamics, conclusions and implications of the results in the particular field of study of architecture	Extending and redefining in a significant way our understanding and/or relationship with architecture	Seeing their own shortcomings and untapped potential, and devising strategies for maximizing their performance
	Experimenting, Innovating & Researching	Distinguishing between valuable and irrelevant inquiry and innovation in architecture, whether in the theoretical, practical and/or creative spheres	Framing research questions rigorously and lucidly - whether pertaining to practical, theoretical or creative issues, or a combination of these	Showing sustained commitment to the development of new ideas or practices at the forefront of any work or study context to which they apply themselves, including research
	Theories, Histories & Cultures	Understanding high standards of architectural excellence in their own field		
	Technical, Environmental & Contextual Issues	Knowing the national and international context of architectural knowledge and practice production into which their work has been/will be disseminated		
	Communication, Collaboration & Interdisciplinarity		Talking or writing with complete authority about their special field within their discipline	Disseminating highly specialised information clearly and appropriately, in any relevant form and to different target audiences so as to improve public understanding of their field Establishing and maintaining cooperative relationships within the scholarly and creative community Responding with understanding and responsibility to critical considerations
	Initiative & Enterprise	Understanding the ownership rights of those who might be affected by their research work (e.g. copyright, intellectual property rights, confidential information, ethical questions) Appreciating the economic potential and utilisation of their output	Realising goals defined at the outset of their projects, whilst making appropriate adjustments to these in the light of their research experience	

3.2. GREEN SKILLS

In addition to aforementioned 'professional skills', today, one of the most important aims to reach sustainable development may be achieved by pursuing green economy strategies. The term "green economy" was first declared by UK in 1989 and defined by UNEP as "as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is low carbon, resource efficient and socially inclusive"[36]. An important aspect of green economy is "regeneration of individuals, communities and ecosystems"[37].

Green economy necessitates educated individuals together with innovation. They are implied as "prime movers of sustainable growth in green economies, where innovation, green skills and the capacity to cope with change will be significant drivers of each economic sector"[38]. It might be anticipated that societies comprised of well-educated and adaptable professionals in order them to cope with rapidly transforming technologies in any industry. It is crucial to underline the fact that the industries such as construction, waste management, energy, green design which are direct and/or indirect relationship with architecture have undeniably huge effect on economy so that architectural education needs to be put on focus in terms of introducing new green skills.

On top of these qualifications, architectural education should also be ready for industrial and technological advancements in order to align itself to 21st century skills. The proposed approach in the scope of this project in order to achieve the skill sets in architectural education is introduced in the next chapter of the report.

36 http://www.unep.org/greeneconomy/AboutGEI/WhatisGEI/tabid/29784/Default.aspx
37 http://www.greeneconomics.net/what2f.htm
38 http://unesdoc.unesco.org/images/0021/002133/213311e.pdf

4. ARCHITECTURE AND TECHNOLOGY : 4.0 AND BEYOND

Architecture has always been in close relation with the technology of its era from stone age to today. This close connection has become much more clear with the first industrial revolution (industry 1.0) spreading from England, Europe to North America. Proliferation of machines and the mass production of iron did not only change the building materials but also the architectural practice of 19th century. Architecture had to be re-acquainted with engineering especially mechanical engineering and the term manufacturing had been introduced to architecture and construction. Almost 100 years later, despite the social turmoils, economic crisis, two world wars, industry 2.0 which was identified by mass production and assembly lines, internal combustion engines, electricity shaped the first half of the 20th century technology and architecture as well.

The transformation of industry starting from 1970s with advents of electronics, IT, robotics, automation which usually named Industry 3.0 has a deeper impact that forced to change education and practice of any field. The mind-sets of the past has no longer helped us to cope with the rapidly developing technologies obsoleting/expiring skills that we gained.

Industry 3.0 is not only a change how we produce but it changes how we work, how we think and how we learn and thus how we should teach. ICT liberates knowledge from the silos of the disciplines, blurring the borderlines of them forcing to collaboration and interdisciplinary approaches.

Learning/teaching is not only inside the walls of the schools, and any information is reachable, in a click time of a keyboard or a mouse. We are exposed to a large amount of information and data than we can process. This dramatic change brings the question of what should be achieved in education, what should be the objectives, the new skill sets and many more for the digital natives of this age in regard with rapidly growing technologies.

Hence discussions on architectural education should be extended beyond the walls of the institutions, and qualifications expected from the graduates should be revised with the future waves of the coming ages. When we consider industry 3.0, we can claim that there is an Architecture 3.0. This relation can be mapped as follows:

Table 7: Industry 3.0 and Architecture 3.0

Major features of Industry 3.0	Architecture 3.0
Electronics, IT	Performance based design, Responsive architecture, smart buildings
Industrial robotics	New construction technologies, challenging forms and structures, new forms and materials
Advanced automation of production	Construction from site to factories fromfile to anywhere

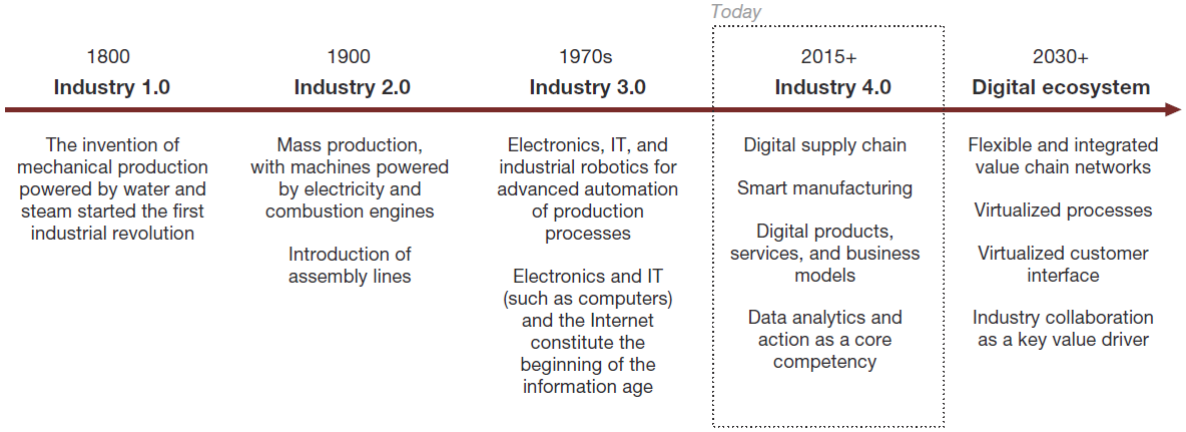


Figure 20: Architecture 3.0 implicitly/explicitly evolve architectural education and today, curriculum of many universities include those subjects. (http://www.strategyand.pwc.com/media/file/Industry4.0.pdf)

Table 8: Industry 4.0 and Architecture 4.0

Major features of Industry 4.0	Architecture 4.0
Digital supply chain	Construction management and supply chain management
smart manufacturing	digital design and fabrication technologies
digital products, services and business models	E-officies
Data analytics and action as core competency	BIM and incorporation of Big Data into soft models

Architecture 3.0 implicitly/explicitly evolve architectural education and today, curriculum of many universities include those subjects.

Considering Industry 4.0 which is characterised by digital supply chains, smart manufacturing, digital products, services and business models, data analytics and action as core competency requires new mindsets and not only knowledge based skills but also soft skills. Anyone who would like to be a game player/game changer in this era should also be able to understand new economics, social and cultural changes as well as to cope with the pace of rapidly changing technologies.

Industry 4.0 already begun and unfortunately education systems in general are not that flexible to follow up the changes. The impact of Industry 4.0 on architecture might be named as Architecture 4.0 and be mapped as shown in Table 7.

Starting with Industry 3.0 and continuing with 4.0, it is seen that the coming age will create a new ecosystem which is mostly acknowledged as digital ecosystem. In this ecosystem flexibility and integrated value chain networks, virtualized process, virtualized customer services/interfaces and collaboration will be the drivers. In this context, it is possible to foresee that design methods, and processes cannot be the same and both education and practice should evolve in content wise and skill wise.

Hence what will be the architecture of digital ecosystem and who is the architect of that new ecosystem are should be elucidated starting from now. Digital ecosystem is more complex and competitive compared with physical one.

Table 9: Industry X and Architecture X

Major features of Industry X	Architecture X
flexibility and integrated value chain networks	Concurrent design, new office and business models, management skills for data
virtualised process	Computational design and advanced modelling, new business models and data control, surviving and managing cloud
virtualised customer services/interfaces	virtual/immersive environments and design
industry collaboration	new construction and fabrication technologies, new techno skills, new communication skills

In the digital ecosystem, there is no border, no limitations of time and space, there is immense amount of complex data, interactions are virtual, cyber physical materials and processes are the new realities. It is evident that, economies, social and cultural structures in this ecosystem cannot be sustained with contemporary approaches and models. It is relatively easy to portray Architecture 4.0 but what 'Architecture X' of the coming (or even happening) digital ecosystem is not an easy task, since digital ecosystem itself is a big data intertwining many disciplines, fields of expertise requiring new competencies and skills. In Table 8, Architecture X as a reflection of Industry X or as acknowledged digital ecosystem is proposed in a similar manner to what is presented in Table 6 and Table 7 for Architecture 3.0 and 4.0.

The past 70 years of discussions on architectural education shows that designing a curriculum and its formalisation is a very difficult task and it also requires time to be accepted by the architectural communities. However, industry 4.0 and beyond will expel those who will not cope with the pace of the change.

Every discipline as in the case of architecture is continuously in the process of defining the skills and competencies for their domains and try to tune educational system with the practice. In this pursuit, understanding the real meaning of "technology" is important. Fernandez39 defines technology as "a measure of human ability to configure tools and develop processes" which can be accepted as the baseline for generic skills and competencies since technology itself is very broad and changing.

39 Fernandez, J.E. Material Architecture: Emergent Materials for Innovative Buildings and Ecological Construction; Architectural Press: Amsterdam, The Netherlands and Boston, MA, USA, 2006.

In this regard, focusing on the skills and competencies rather than the content of curriculum is more viable and contributing on the ongoing discussions related with architectural education.

Objectives of education to fulfil such new skills and competencies should not only incorporate the ones already defined but also the new ones regarding the features of coming ages. In this report, several discussions related with design education and curriculum are discussed as well as EQF which is proposed for three levels 6,7 and 8 for architecture has been referred. Another important reference is the document prepared by Partnership P21 "Framework for 21st Century Learning".

What is important in this document is the articulation of the aim of these new skills and knowledge as "the skills and knowledge students need to succeed in work, life and citizenship" which they are already changing praxis with new technologies and rapidly developing digital ethos.

In this study, key subjects and themes which are also themes of today and tomorrow are grouped under four major categories as:

> *"global awareness (collaboration open to dialogue, understanding different cultures, being able to dress global issues) , Financial, Economic, Business and Entrepreneurial Literacy (entrepreneurial skills, conscious in economy and business), civic literacy (being an active citizen, aware of rights and obligations, assessing the results of civic decisions), health literacy (understanding health information and services, preventive health care),*
> *environmental literacy (understanding ecosystem and balance, environmental problems, conscious and contributing to the environmental solutions, individual or collective initiative for solving environmental problems)"*
>
> *In the very same study, skills are also grouped as "learning and innovation skills, information, media and technology skills, life and career skills" which are described under several sub categories. "Creativity, critical thinking and problem solving, communication and collaboration, information, ICT and media literacy" are some of the skills addressed in the study. P21 organisation defines skills related with life and career by the following features "flexibility initiative, self-direction, and adaptability, social and cross cultural skills, productivity and accountability as well as responsibility and leadership".*

The themes and skills framed in the study are generic and any discipline which would like to be an actively engaged part of the future should shape the education accordingly. How the disciplines achieve those skills is also related with customisation of them in the context of related curriculum as well to develop a rubric for the assessment as aimed in this project.

STEAM approach in architecture provides a very plausible curriculum to achieve to reach the skills necessary for the coming ages. In the previous sections of the study, it is shown that STEAM approach exists (implicite or explicitly) in many of the architectural programs yet, the complexity of the design phenomenon and its formalisation in education make the definition of skills in the curriculum very hard.

There are different taxonomic approaches in defining the skill sets related with the domain of interest. For example one of the widely used definition sets is The European Qualifications Framework (EQF).

EQF defines skill sets regarding to levels from 1 to 8 including descriptors related with learning outcomes (https://ec.europa.eu/ploteus/en/content/descriptors-page), but in this project, it is addressed to green or survival skills of the coming ages as a whole.

In this project it is believed that such skills should be fostered from the very first year first year and should be advanced each and every level of the education.

Expected skills and related competencies of the 21st century and beyond are not only domain specific but rather it requires new mind sets and formation of backgrounds to be able to survive in the new digital-technological eco system.

EQF system has been applied to several domains and each year new subject fields are added and skill sets are defined. There are many other researches and frames outlining skills and descriptors in the literature either generic or domain-specisific. For example Alice Liao suggest that 21st century

architects should be familiar with automation, coding, data mining, and to be people and business savy T(he 21st-Century Skill Set for Architects, by Alice Liao (2015) in JAIA) —

Another important proposal is made by P21 Partnership for 21st Century learning (http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf) This document states that " the skills, knowledge and expertise students must master to succeed in work and life; it is a blend of content knowledge, specific skills, expertise and literacies". This framework has a three-fold structure containing; key subjects, skills and support systems. Global awareness, Financial, Economic, Business and Entrepreneurial Literacy ,civic, health, environmental literacies constitute the key subjects that should anyone be familiar with. Another must feature of individuals of coming age defined in P21 is to be creative and thus be innovative. The importance of critical thinking and problem solving are also highlighted together with communication and collaboration skills. Sustainability of the careers is a prominent problem of the coming ages hence flexibility, adaptability, self-directivity, having social and cross-cultural skills become very important for individual learners. Leadership, being able to have initiatives are also key for the success in the 21st century as defined in P21. It is very clear that the role of media literacy and ICT is crucial and education should foster all those skills and competencies in general.

In this project, the following skills/competencies addressed as survival skills. As it can be seen they are aiming learners/individuals to be able to sustain their profession and their life and be able to cope with changes.

- critical thinking
- being able to orchestrate a large amount of data
- Being able to survive in the cloud
- being able to work in groups but to develop individual skills
- being able to self-assessing his/her own capabilities/deficiencies
- being able to transform/reflect knowledge and information of different domains into his/her own profession
- Being able to self-critic and whenever he/she feels that some of the skills are expiring s(he) should replace them with new ones so self-learning self-motivated
- Being able to evaluate ethical implications of technology.
- Being able to navigate in emerging technologies while also maintaining a deep aspiration towards existing excellence.
- Being able to operationalize data-driven insights by relating them to real physical/concrete implications and conditions.
- Being able to demonstrate pragmatism, cultural and political awareness.
- Being able to revisit and revise steps in a process according to systematic feedback loops.
- Being able to shift between critical and creative thinking.

In the realm of the skills listed above, STEAM approach is very prominent due to diversity of the subjects and yet the holistic way of learning and teaching. These generic skills can be fostered with self-learning, self-motivated, self-directed individuals and in this regards ICT gains a new and more important position in education and life.

5. CONCLUSION AND REMARKS

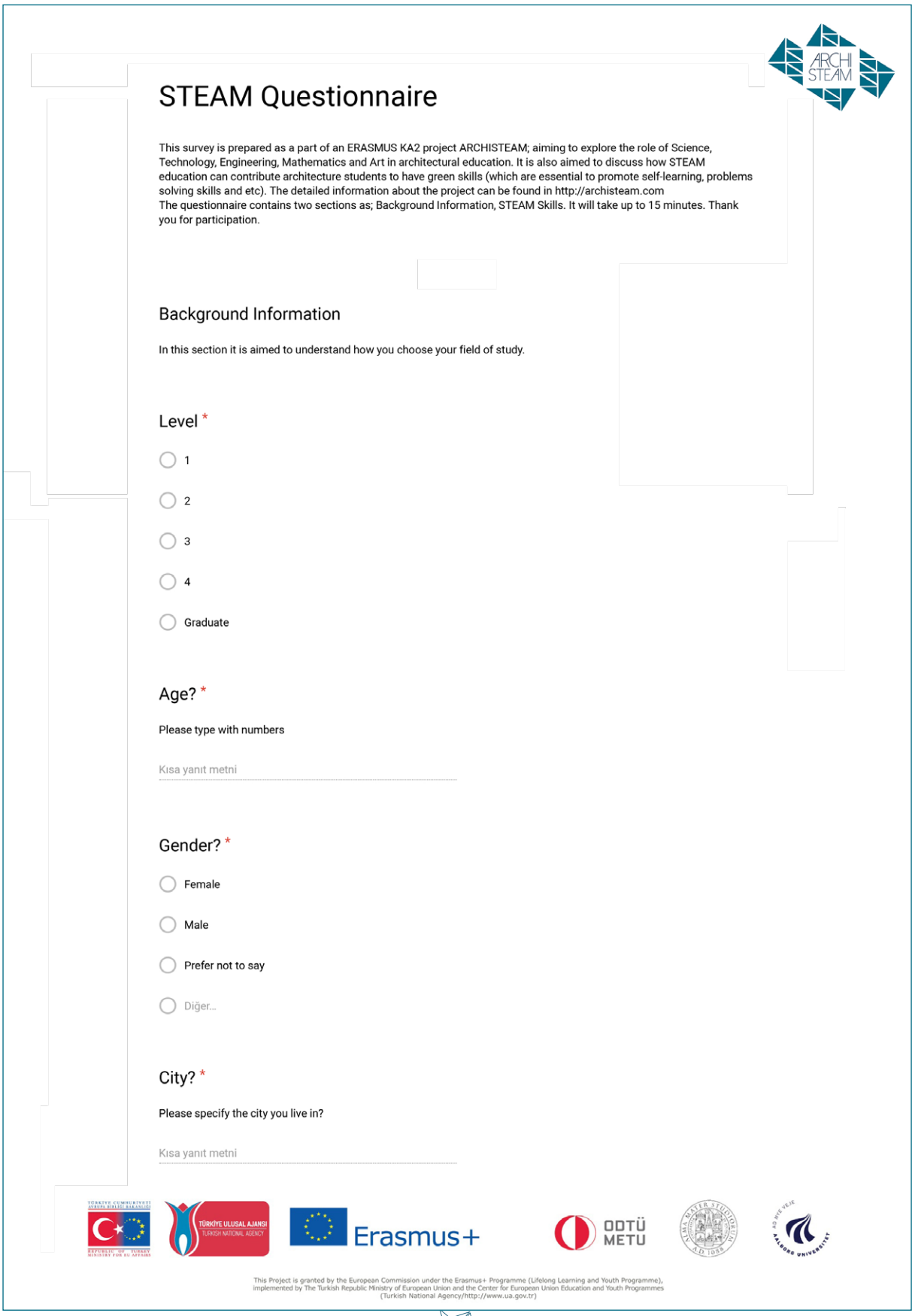
In this phase of the project, it is aimed to define new skills as we acknowledged as "survival skills of the coming age" are explored and how they can be improved through STEAM is discussed. The discussions on design process in general including the discussions on creativity are summarised in order to depict the current situation in the field of architecture both in practice and in education. Both discussions dating back to 1920s and the the contemporary ones show that architecture and in general design education is an amalgam of science, technology, engineering, mathematics and art since the very beginning of the profession. Architects of the past, or today or the ones in future should be able to incorporate and conduct a large amount of knowledge and data as well as to be able to cope with changes related with technology, culture, sociology, economy and more. They are expected to be creative, innovative in order to compete and to survive in the world of change. STEAM which is more holistic education perspective of all these fields is a very promising structure in architecture as argued in the previous sections. The idea of STEAM is actually exist almost in every curriculum of schools of architecture.

This fact is illustrated by analysing the curriculum of highly acknowledged schools of architecture and the results are shown in the second section of the report. Yet how STEM and Art are combined and how STEAM is formalised are debatable. In the second section, the survey conducted among students aims to understand their ICT skills and their perception of their own education in regard with STEAM in order to further the discussion of future skills.

How the industrial revolutions starting from 1.0 are affecting the architectural education and practice is also shown in order to discuss further what should be the new mindsets and skill for architecture 4.0 and beyond. It is believed that focusing on skills (hard and soft) is more viable than focusing the curriculum which are diverse in terms of their structure but very similar in terms of aims and objectives.

6. APPENDICES

6.1. SAMPLE QUESTIONNAIRE FOR STUDENTS



STEAM Questionnaire

This survey is prepared as a part of an ERASMUS KA2 project ARCHISTEAM; aiming to explore the role of Science, Technology, Engineering, Mathematics and Art in architectural education. It is also aimed to discuss how STEAM education can contribute architecture students to have green skills (which are essential to promote self-learning, problems solving skills and etc). The detailed information about the project can be found in http://archisteam.com
The questionnaire contains two sections as; Background Information, STEAM Skills. It will take up to 15 minutes. Thank you for participation.

Background Information

In this section it is aimed to understand how you choose your field of study.

Level *

- 1
- 2
- 3
- 4
- Graduate

Age? *

Please type with numbers

Kısa yanıt metni

Gender? *

- Female
- Male
- Prefer not to say
- Diğer...

City? *

Please specify the city you live in?

Kısa yanıt metni

Erasmus+

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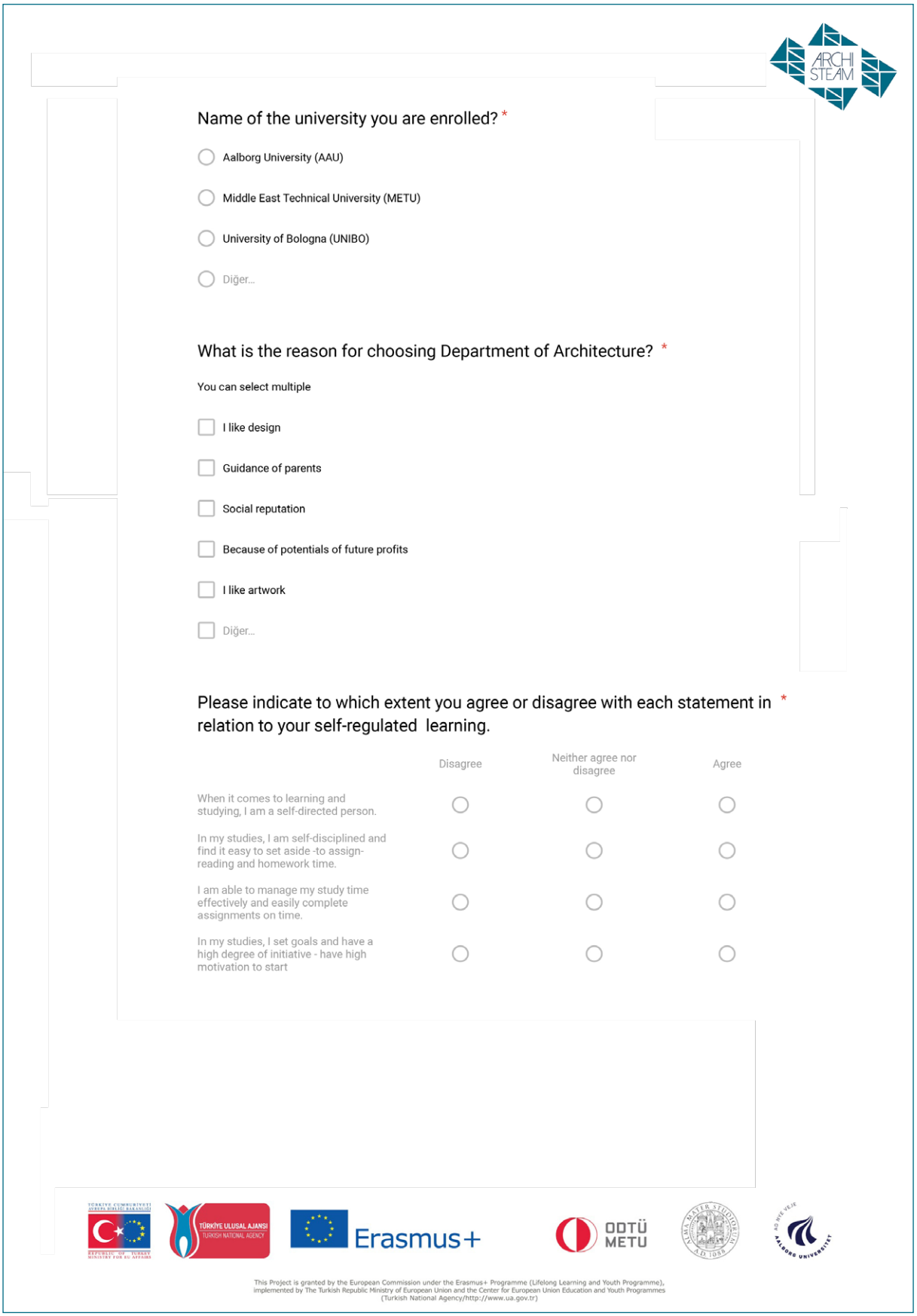

Name of the university you are enrolled? *

- Aalborg University (AAU)
- Middle East Technical University (METU)
- University of Bologna (UNIBO)
- Diğer...

What is the reason for choosing Department of Architecture? *

You can select multiple

- I like design
- Guidance of parents
- Social reputation
- Because of potentials of future profits
- I like artwork
- Diğer...

Please indicate to which extent you agree or disagree with each statement in relation to your self-regulated learning. *

	Disagree	Neither agree nor disagree	Agree
When it comes to learning and studying, I am a self-directed person.			
In my studies, I am self-disciplined and find it easy to set aside -to assign- reading and homework time.			
I am able to manage my study time effectively and easily complete assignments on time.			
In my studies, I set goals and have a high degree of initiative - have high motivation to start			

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STEAM Skills

In this section, it is aimed to explore how you perceive STEAM and how you are using STEAM background in your current education.

To which extent do you think the fields below are relevant to architecture? (1-3) *

	1	2	3
Math	○	○	○
Design	○	○	○
Arts (creative arts, liberal arts)	○	○	○
Engineering	○	○	○
Science	○	○	○

Do you think life sciences courses (e.g. physics, chemistry, biology) you took before are now contributing to your architecture education? *

	1	2	3	
No	○	○	○	Fully

Do you use social media accounts such as blogs and websites to get relevant information about life sciences? *

- ○ Yes
- ○ No

If your answer is YES, please list the names of these accounts / blogs / websites.

Uzun yanıt metni

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Below is the list of applications for smartphones.Please indicate the ones that you use most frequently for academic/educational purposes. (check all that apply) *

- [ ] Dropbox/GoogleDrive/iCloud
- [ ] Whatsapp/Viber/FacebookMsngr/Viber, etc.
- [ ] TED Conferences
- [ ] Youtube
- [ ] iTunes-University/ Khan Academia/Udemy/Coursera
- [ ] SesliSozluk/ Tureng/ Dictionary
- [ ] Newspaper apps
- [ ] Facebook/ Twitter
- [ ] Wikipedia/Wikiwand
- [ ] PDF reader
- [ ] MS Office Apps
- [ ] E-book reader
- [ ] Google/Yandex/Yahoo search engines
- [ ] Pinterest
- [ ] Instagram
- [ ] WordPress/iBlogger/Blogger/BlogPress/Tumblr
- [ ] Linkedin/Kariyer.net
- [ ] LibAnywhere
- [ ] Diğer...

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For which of the following services you find mobile learning might be useful for learning any courses related to architecture (e.g. maths): *

	Not Useful	Neutral	Useful
to access educational content online	○	○	○
to access educational content offline	○	○	○
to access supporting educational information (e.g. math concept, examples) via WWW.	○	○	○
to receive supporting educational information via messages (e.g. SMS, WhatsApp, other messengers)	○	○	○
to collaborate with other students	○	○	○
to collaborate with instructors	○	○	○

Please give an order number to the following actions which you take when you have a problem with your electronic devices (e.g. computer, ipad, smartphone *

	1	2	3
I take the device to service man	○	○	○
I take online support	○	○	○
I ask a friend	○	○	○

Please indicate how often you use the following means of communication *

	More than once a day	Once a day	Couple of Times a week	Once a week	Once a month	Once or twice a year	Never
Phone	○	○	○	○	○	○	○
E-mail	○	○	○	○	○	○	○
Mail (physical)	○	○	○	○	○	○	○
Fax	○	○	○	○	○	○	○

Do you use search engines via your mobile phones when you need to access information? *

○ Yes

○ No

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If your answer is YES, please indicate how often do you use them *

	1	2	3	
Rarely	○	○	○	Everyday

Do you use tutorials, instructional videos, etc. to learn a subject? *

- ○ Yes
- ○ No

Do you subscribe to social media accounts / blogs / websites related to technology? (Youtube page, personal blog pages, etc.) *

- ○ Yes
- ○ No

What do you think about the relationship between Architecture and Engineering Disciplines? *

	1	2	3	
Irrelevant	○	○	○	Very relevant

Do you get relevant information from social media accounts / blogs / websites related to engineering ?(Youtube page, personal blog pages, etc.) *

- ○ Yes
- ○ No

If your answer is YES, please list the names of these accounts / blogs / websites.

Uzun yanıt metni

Do you get relevant information from social media accounts / blogs / websites related to Arts?(Youtube page, personal blog pages, etc.) *

- ○ Yes
- ○ No

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Is there a field of art which you actively engage? If yes, please list them *

Uzun yanıt metni

Did you take courses related to art in your high school education? *

- Yes
- No

What do you think about the relationship between Architecture and Art? *

	1	2	3	
Irrelevant				Very relevant

How comfortable are you with mathematics? *

	1	2	3	
Very uncomfortable				Very comfortable

What do you think about the relationship between Architecture and Mathematics? *

	1	2	3	
Irrelevant				Very relevant



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6.2. SAMPLE QUESTIONNAIRE FOR INSTRUCTORS

Architecture and Design Course Questionnaire

This questionnaire is developed within the framework of the Erasmus+ KA2 Project ArchiSTEAM: Greening the Skills of Architecture Students via STEAM Education.

The purpose of the questionnaire is to survey courses in architecture and design education, focusing on what is taught and how, as well as what types of outcomes and modes of evaluation are used.

The questionnaire has 9 sections including this introduction. Sections 2 and 3 concern general course information and course type. Section 4 and 5 concern instructor information and course content. Section 6 and 7 concern the modes of instruction and materials used in the course. Finally, section 8 and 9 concern the types of assignments which are given and the modes of evaluation used in the course.

Apart from section 1, the questionnaire contains mostly multiple choice questions. Most sections have a comment box for optional additional information. If you have a good overview of your course, the questionnaire should take approximately 20 mins. to fill out.

* Required

Course Information

In this section, we ask basic information about the course.

1. **Course title** *
   Please state the course title as defined in the course syllabus of your program

2. **Course Code**
   If the course has a course code (short title), please state it here

3. **Study program** *
   Please state the name of the study program which is offering the course

4. **University** *
   Please state the name of the university which is offering the study program

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5. **Credit system** *
Mark only one oval.

- ECTS (Europe)
- CATS (UK)
- Credit hours (USA)
- Other: _____

6. **Credits** *
Please state the number of credits of the course in the credit units stated in the previous question

_____

7. **Instruction** *
Mark only one oval.

- I teach this course alone
- I teach this course with colleagues
- I teach this course with colleagues and teaching assistants
- I teach this course with teaching assistants
- Other (please specify in comment)

8. **Comment**

_____
_____
_____
_____
_____

9. **Link to course syllabus**
If available, please add a link to the course syllabus from the program website

_____

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Course type

Some courses are required, while others are optional. Sometimes optional courses must be chosen from a predefined set of course, and sometimes courses can be taken as voluntary extra activities. To help you determine the course type, we have given some definitions:

MANDATORY: Courses which students must take to satisfy the program requirements.

RESTRICTED ELECTIVE: Courses which must be chosen from a stated group of courses to satisfy the program requirements.

OPEN ELECTIVE: Courses which students can take out of their own choosing.

EXTRA-CURRICULAR: Courses which are not counted in the number of credits necessary to satisfy the program requirements.

10. **What is the type of the course?** *

Mark only one oval.

- ◯ Mandatory
- ◯ Restricted elective
- ◯ Open elective
- ◯ Extra-curricular
- ◯ Other (please specify in comment)

11. **Comment**

Instructor information

In this section, we ask basic information about the you.

12. **What is your age?** *

Please indicate the answer in years

13. **What is your gender?** *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Other: _____

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14. **In which field did you earn your Bachelors degree?** *

Mark only one oval.

- Natural science
- Social science
- Engineering
- Architecture / Design
- Humanities
- Mathematics
- I do not have a Bachelors degree
- Other (please specify in comment)

15. **Comment**

16. **In which field did you earn your Masters degree?** *

Mark only one oval.

- Natural science
- Social science
- Engineering
- Architecture / Design
- Humanities
- Mathematics
- I do not have a Masters degree
- Other (please specify in comment)

17. **Comment**

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18. **In which field did you earn your Doctoral degree?** *

Mark only one oval.

- Natural science
- Social science
- Engineering
- Architecture / Design
- Humanities
- Mathematics
- I do not have a Doctoral degree
- Other (please specify in comment)

19. **Comment**

20. **What is your teaching experience?** *

Please indicate the answer in years

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Course content

Courses can be subject or topic oriented. Subject oriented courses focus on one particular subject, while topic oriented courses integrate different fields of knowledge. Please tick the area of study which are covered in your course. if your course covers only one area of study, your course is probably subject oriented. If it covers more areas of study, your course is probably topic oriented.

If you are in in doubt about which areas of study are covered in your course, please add a comment. This will help us compare your course to other courses.

21. **Which fields of knowledge are covered in the course?** *

Please add the most appropriate fields of knowledge which are covered in the course (see examples in parentheses)

Mark only one oval per row.

	None	A little	Some	A lot	Exclusively
Natural science (such as physics, chemistry, bilology)	◯	◯	◯	◯	◯
Social science (such as law, economics, sociology)	◯	◯	◯	◯	◯
Technology (such as BIM, GIS, simulation, programming)	◯	◯	◯	◯	◯
Engineering (such as construction and mechanical engineering, HVAC and materials)	◯	◯	◯	◯	◯
Art (such as history, drawing, design)	◯	◯	◯	◯	◯
Mathematics	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

22. **Comment**

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Modes of instruction

Traditionally, courses have a particular format, such as lecture courses, seminars or tutorials. But increasingly, these boundaries are blurred. Please specify the modes of instruction which are used in your course. To help you determine the modes of instruction, we have given some definitions:

LECTURES: The instructor typically talks in front of a large student audience, while pointing to a set of slides or writing on a blackboard. The instructor may ask questions to the audience during the lecture and the class may ask questions after the lecture, but the format is predominantly one of one-way communication from instructor to students.

SEMINARS: The instructor typically sits with a smaller group of students who present their understanding of course readings. The instructor may be conveying information but will mostly ask questions. The format is one of two-way instructor-student and student-student communication.

TUTORIALS: Students typically present work in progress on a project or an assignment individually or in small groups. The work is discussed and/or commented upon by the instructor. The format is one of two-way instructor-student communication.

WORKSHOPS: Students typically work individually or in groups on a particular problem or

EXCURSIONS: Students go to a particular destination outside the university to study a phenomenon. This may be a site visit to survey a project site, a visit to a professional office or institution, or a study tour to visit several locations. Students may go on their own or in the company of an instructor. The format is predominantly one of (group-based) self-study.

ONLINE LEARNING: Any combination of assignments, media, materials and readings are offered in an online platform, typically with some form of online submission system. Submissions can be individual (only for the instructor to see) or shared (for peer learning and/or Assessment). The format is either one of (group-based) self-study or peer learning.

23. **How is the course taught?** *

Mark only one oval per row.

	Never	A little	Some	A lot	Exclusively
Lectures	◯	◯	◯	◯	◯
Seminars	◯	◯	◯	◯	◯
Tutorials	◯	◯	◯	◯	◯
Workshops	◯	◯	◯	◯	◯
Labs	◯	◯	◯	◯	◯
Excursions	◯	◯	◯	◯	◯
Online learning	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

24. **Comment**

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Course materials

Most courses have different readings which the students should study in order to complete the course. Some courses may also include physical artefacts. And increasingly, digital media and software are also included as course materials. To help you determine the different types of course materials, we have given some definitions:

TEXTBOOKS: teaching books which are more or less tailored to the course in question.

ACADEMIC TEXTS: Peer reviewed scientific conference and journal articles, academic monographs and anthologies.

REFERENCE TEXTS: Reports, manuals, handbooks, company or institutional websites, etc.

VIDEOS: Films, documentaries, online videos, video recordings

SOFTWARE APPLICATIONS: CAD, simulation, graphic, or calculation programs, etc. (web-based or stand-alone)

PHYSICAL MATERIALS: Gypsum, clay, styrofoam, cardboard, wood, etc.

PHYSICAL ARTIFACTS: Works of art, design objects, prototypes, scale models, material samples, etc.

25. **Which types of course materials are used in the course?** *

Mark only one oval per row.

	None	A little	Some	A lot	Exclusively
Textbooks	◯	◯	◯	◯	◯
Academic texts	◯	◯	◯	◯	◯
Reference texts	◯	◯	◯	◯	◯
News and social media	◯	◯	◯	◯	◯
Fiction	◯	◯	◯	◯	◯
Audios	◯	◯	◯	◯	◯
Videos	◯	◯	◯	◯	◯
Software applications	◯	◯	◯	◯	◯
Physical materials	◯	◯	◯	◯	◯
Physical artifacts	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

26. **Comment**

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Assignment types

Assignments are ways to engage students in the learning process and are linked to submissions, which are the products that students must produce during the course. Different assignments are linked to particular submissions, which, in turn, offer different forms of evaluation. To help you determine the different assignment types, we have given some definitions:

QUIZZES: Series of multiple choice questions which the students must answer. Answers can be correct or wrong.

WORK SHEETS: Series of small tasks which the students must solve. Answers can be correct or wrong.

ESSAYS: Short texts in which the students present a discussion, an argument or a reflection on a specified topic. Answers can range from good to bad.

DRAWINGS: Visual representations of existing objects/spaces (still or life drawings), of ideas/concepts (sketches, diagrams), or of design proposals (presentation drawings). Drawings can be hand made or made using blended techniques, and are presented on paper.

PHYSICAL MODELS: Spatial representations of existing objects/spaces, ideas/concepts or design proposals. Physical models can be hand-made or made with the use of rapid prototyping technologies such as 3D printing CNC milling, etc.

REPORTS: Multiple-page texts documenting the outcome of a project. Reports may contain different sections covering analysis, methodology, process, outcomes, reflections, and more.

DYNAMIC DIGITAL PRODUCTS: Videos, 3D and VR models, interactive media

PROTOTYPES: Functioning exemplars of a design. Prototypes can be physical or digital, depending on the nature of the design

27. **Which types of assignments are used in the course?** *

Mark only one oval per row.

	None	A little	Some	A lot	Exclusively
Quizzes	◯	◯	◯	◯	◯
Work sheets	◯	◯	◯	◯	◯
Essays	◯	◯	◯	◯	◯
Drawings	◯	◯	◯	◯	◯
Physical models	◯	◯	◯	◯	◯
Reports	◯	◯	◯	◯	◯
Dynamic digital products	◯	◯	◯	◯	◯
Prototypes	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

28. **Comment**

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Modes of evaluation

Course evaluation can be summative, formative, or a combination thereof. Summative evaluation attempts to assess how the student knows by the end of the course and is typically expressed through grading in the form of numbers, letters or pass/fail. Formative evaluation attempts not only to assess how much the student knows, but also to have the student reflect on his/her own learning. Therefore, formative assessment contains an element of learning in addition to assessment. To help you determine the modes of evaluation, we have given some definitions:

REVIEW OF SUBMITTED WORKS: The students' performance is evaluated from the quality of submitted works, such as texts, visuals, models and prototypes. Students are not present during evaluation.

ORAL EXAMINATION: The students' performance is evaluated from the quality of answers to questions/discussions in a live session. Short oral presentations (with visuals) by the student(s) may be part of an oral examination.

ORAL EXAMINATION BASED ON SUBMITTED WORKS: Similar to oral examinations. The examination takes its point of departure in a work which has been submitted prior to the examination.

FINAL REVIEW: Students present their final work to a public audience of other students and typically invited quest critics. Instructors, guest critics and sometimes other students comment and discuss the presented work. The format may range from judgment to discussion.

CRITIQUE (CRIT): An interim evaluation of work in progress, similar to a final review, but less formal.

PIN-UP: A short informal evaluation anytime during the design process. Students pin up current sketches which may not have been design specifically for presentation and describe their design problems to an audience of typically one or two instructors and a small number of fellow students.

PEER EVALUATION: Students' work are evaluated by other students. This is typically a qualitative evaluation (good/bad, recommendation) rather than a quantitative evaluation (grading).

SELF-EVALUATION: Students assess their own performance, either individually or as a group (for group work). This is typically a kind of reflection, either orally or in writing.

29. **How is the course evaluated?** *

Mark only one oval per row.

	Never	A little	Some	A lot	Exclusively
Review of submitted works	◯	◯	◯	◯	◯
Oral examination	◯	◯	◯	◯	◯
Oral examination based on submitted works	◯	◯	◯	◯	◯
Final review	◯	◯	◯	◯	◯
Critique	◯	◯	◯	◯	◯
Pin-up	◯	◯	◯	◯	◯
Peer evaluation	◯	◯	◯	◯	◯
Self-evaluation	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

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Oral examination based on submitted works	◯	◯	◯	◯	◯
Final review	◯	◯	◯	◯	◯
Critique	◯	◯	◯	◯	◯
Pin-up	◯	◯	◯	◯	◯
Peer evaluation	◯	◯	◯	◯	◯
Self-evaluation	◯	◯	◯	◯	◯
Other (please specify in comment)	◯	◯	◯	◯	◯

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30. **Comment**

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