Descriptive Geometry and/or Computer Technology? What Mathematics is Required for Doing and Understanding Architecture?

Ivan Tafteberg Jakobsen · Jesper Matthiasen

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Abstract Ivan Tafteberg Jakobsen and Jesper Matthiasen provide an edited transcript of the Nexus 2012 round table discussion from the Nexus conference in Milan, Italy. The topic of the round table discussion was what type of mathematics is required for the practice and appreciation of architecture.

At the Nexus 2002 conference in Obidos, Portugal, a round table discussion was held on the topic of *Mathematics in the Architecture Curriculum* (Nexus 2002 Round Table Discussion [2002a](#)). At the Nexus 2012 conference in Milan, Italy, this general topic was revisited, but this time focusing on the role of descriptive geometry and also broadening the view to include secondary school education in the discussion. This discussion was recorded and is presented here in an edited form.

The Nexus 2012 Round Table Discussion was moderated by *Ivan Tafteberg Jakobsen* and *Jesper Matthiasen* who posed the trigger questions for the event. The panelists for this discussion were:

- *Federico Fallavollita*. Faculty of Architecture, University of Bologna, Italy.
- *Sylvie Duvernoy*. Teacher of architectural drawing, University of Ferrara, practicing architect, Florence, Italy.
- *Cornelie Leopold*. Professor, Head of Department of Descriptive Geometry and Perspective, Faculty of Architecture, University of Kaiserslautern, Germany.
- *Michael J. Ostwald*. Professor, Dean of Architecture, University of Newcastle, Australia.

I. Tafteberg Jakobsen (✉)
Aabyhøj, Denmark
e-mail: Ivan.Tafteberg@skolekom.dk

J. Matthiasen
Aarhus, Denmark
e-mail: Jesper.Matthiasen@skolekom.dk

- *Arzu Gonenc Sorguc*. Professor, Faculty of Architecture, Middle East Technical University, Ankara, Turkey.
- *João Pedro Xavier*. Professor, Faculty of Architecture, University of Porto, Portugal.

An additional member of the roundtable discussion was unable to take part, but sections of his written response to the same questions has been integrated into this report, to ensure a broader geographic coverage of the topic. This additional response is from:

- *Ahmed Ali Elkhateeb* Professor, Department of Architecture, King Abdulaziz University, Jeddah, Saudi Arabia.

JAKOBSEN AND MATTHIASSEN: Is descriptive geometry required as a technical skill for architects, as both a practice skill and for “reading” drawings?

DUVERNOY: The students are using descriptive geometry without knowing it— as soon as they draw plans of a building and on the same page the façade, they are doing descriptive geometry as [Gaspard] Monge did it; projection on the horizontal plane and projection on the vertical plane. This is a basic operation in the first year and is obviously needed in practice. Drawing and representation are not disconnected from descriptive geometry, they are linked. From the beginning of their studies students use it, whether they know it or not.

SORGUC: Students try to create 3D forms from the very beginning. Then afterwards they get the 2D representations of the 3D, so it is vice versa in a way. There is a paradox in the technology that they use, between what we have to do and what is going on. The students are introduced to computer programs from the start, and actually even in primary school they are introduced to SketchUp, which is limiting their perception and their understanding of geometry. These students have no geometric phobia but have very high techno-skills.

XAVIER: I totally agree with Sylvie. I think we need some simple exercises in descriptive geometry to be sure that students can visualize, that they can shape their minds to 3D. Free hand drawing is very important for this.

FALLAVOLLITA: In the first year we teach only drawing by hand and we use only ruler and compasses. In the second and third year we use the computers. This year I began to use computers also in the first year. I think the focal point is that we have a theory, we have a science (descriptive geometry) with methods and with a history. It is really annoying how CAD today is perceived in the school of architecture—there is a kind of chaos about it, it seems there is no more need of theory. From the didactic point of view we have to teach these new technologies; we try to figure out how to give the CAD a past and how to give descriptive geometry a future.

For example, there are two new different methods, mathematical representation methods, that describe curves with a continuous motion, continuous surfaces, and you can have Gaussian curvature on the surface. On the other hand you have a different kind of method, the polygonal or numerical method, where the shapes are described in a discrete way, and you have vertices, and you cannot have a continuous section on the surface, if you have a small mesh you have an

approximation of the surface. What do you think of giving a name to the things, these two theories?

Secondly, I think the computer is a tool like the ruler and compasses, but I want you to notice that until the eighties the ruler and compasses were the only tools used. The computer revolution is really a big revolution for our topic. We don't know where it is leading.

LEOPOLD: For me sometimes this is an overestimation of computers. The main point is that the students come to our universities with no spatial visualization abilities and no spatial thinking. We have to work on their education in spatial imagination. I would not say we have to teach descriptive geometry in the Monge sense, but my experience of now nearly 30 years of teaching is that we have to start with a spatial understanding of things and introduce also the system of Monge systematically. They have to understand: how can I represent spatial objects, which possibilities do I have. With a computer they have a flat screen and when I have only one window I do not understand space, I am surprised perhaps when I work with a program for the first time that the point is not where I wanted to have it, because I work with a flat screen. The students need a systematical introduction into the representation of space. We do it in the first year by hand, because there is a difficult combination between eye, mind and hand. After several years in our faculty all of the architectural professors decided that in all subjects in the first year we do it all by hand.

OSTWALD: Returning to the original question, if we are talking about education of professional architects, I could say that for many years the professionals have been telling me 'we don't need this descriptive geometry'. It might be desirable, but that is a different thing. My school is the last school of 22 in Australasia to still teach hand drafting, we think it is valuable, but we are under constant pressure to stop it and move completely to digital and computational representations of space and form.

FALLAVOLLITA: Before Monge they really did some good stuff without knowing the things we know today, so the question is: do the architects really need what we are proposing?—I don't know, that is a really tough question. If you ask me, if this is a good didactic thing for students, I think yes. The first goal of descriptive geometry is to try to give a person the ability to think in space. With computers you can design directly in space, this is a huge thing. We did not have this possibility before. We could design physical models, but I think it is completely different now.

SORGUC: I think this is an important question: 'What kind of tools do we need to teach?' more than 'is it necessary to teach or not?'

XAVIER: I would like to put on this table a claim by Frank Gehry, made some years ago. He said, 'I do not need descriptive geometry for anything'. But how many perspectives did he have to do by hand before CAD was available, and after when he produced more and more physical models and used 2D drawings to correct things, not only the model. So he was lying!

FALLAVOLLITA: What Gehry refers to is descriptive geometry, and now the visualization is automatic. I think the stuff Gehry is doing is high level descriptive geometry; also, for example, the study of [Helmut] Pottmann is really descriptive geometry at the highest level.

POTTMANN (from the audience): I think you should distinguish between descriptive geometry and geometry. We should teach geometry and teach it with the best possible means, and imagination has to be brought in at school, not at university level.

LEOPOLD: We have only our students as raw material, and we have to work with it. But I agree with you, it should really be earlier. There is a very good movie about the work of Gehry, and in it you see he is working like a sculptor, he is only sketching, and then he is working as a sculptor. I also introduce 3D modelling at the very beginning of my teaching, but not for producing drawings.

FALLAVOLLITA: If we decide that the purpose of descriptive geometry is just to teach perspective, axonometrics and the Monge methods, then descriptive geometry is quite dead. But if the definition of descriptive geometry is not like this, then it has two main purposes. The first—to visualize the shape, how to draw a perspective, etc.; the second is to study the shapes in the three-dimensional space, the properties of space, the passage from the known to the unknown.

ELKHATEEB: Is descriptive geometry needed or should it be transformed into a shape that fits in with the computer technology? No, it should stay and be enhanced by adding it as an elective course in the secondary education for the students who intend to study architecture as their major. I should mention here the Egyptian experience regarding study of arch drawings and descriptive geometry. Egyptian students still draw with the traditional tools (drawing board, T-square, pencil, compass and protractor...etc.) in their first 2 years of study. Based on my experience as I learned and then taught architecture, drawing by hand and experiencing the different architectural items (lines, circles...etc.) are very important in the early phase of the architectural education because in this phase of education two things occur. First, students' graph memory and imagination grow up and are established. Without this graph memory, students lose some important architectural skills such that the ability to estimate and feel the scale of their designs. Second, students' hand and (free) hand skills are trained and developed. Even with advanced CAD software, it is difficult to generate the complicated models without a strong imagination and good knowledge about the math of solid geometry, descriptive geometry and parallel projection.

JAKOBSEN AND MATTHIASSEN: Liapi, in *Geometry in Architectural Engineering Education Revisited*, argues that, 'Despite the unquestionable significance of geometric thinking for the conception, design, and realization of buildings, the role of geometry in the education of architectural engineers, a role that traditionally constituted a significant part of their education, has been downplayed' (Katherine A. Liapi 2002). We have three questions. First, is this true for your institution and your country? Second, is there a reasonable explanation for this? Third, should it be remedied?

LEOPOLD: How can you defend your own subject in your faculty? For me it is an old debate, and I think we have overcome this debate. In the first enthusiasm of computers it was, like, 'now we have computers and they can draw', but I think this is over, because clearly you do not come to the idea that children do not have to learn hand writing in school or the operation of calculating, and it is the same point that you need geometry. Perhaps the word descriptive geometry is not so fixed as to

what it means and there may be different traditions in different countries. For me geometry is really necessary. I am also working on introducing design geometry, which goes in another direction. But the word descriptive geometry is for me graphical representation instead of analytical representation.

OSTWALD: The Australasian environment is extremely bureaucratic and controlled with very little finance or resources to achieve anything other than what is explicitly required by our professional bodies. We also have a culture of risk mitigation wherein various agencies write extensive protocols to govern what architectural students must know when they graduate. There are over 300 complex competencies required of every architectural graduate in Australia, and none of them are about geometry. That is probably a sad state, but it is the state. But having said that, almost everything my students do is about geometry when viewed in a certain way; it is probably not formally taught, but they use geometry constantly, they actually love geometry, they are fixated on all sorts of computational and topological forms. But it is not a well-informed or intelligent use of geometry. It is very low level, intuitive, even lazy. So it is probably true, we have a much diminished emphasis on formal teaching of geometry in Australasia and across Oceania. Should it be remedied? Can it be remedied? I do think the enthusiasm relating to geometry is something that could be harnessed. But one of the positives of our environment is that research now has to be undertaken by every academic, research is no longer a hobby you can do if you feel like it, it has to occur for all staff and all students. At my university, for example, no one has ever been taught graph mathematics, but because my bored students somehow read my papers on the topic there is now a bunch of them who know a large amount about graph mathematics. And it is in those ways we get this great enthusiasm for geometry, but it is not formally taught.

SORGUC: I cannot say it is downplayed, but the way we approach the problem is different. The teachers have some responsibility, because the way we teach geometry and mathematics is not very valid for today's students. Their minds have changed so much, the way they think has changed too much, so I believe one of the reasons geometry is dying, or teaching mathematics is still a problem, is the discrepancy between the views of teachers and students. The profile of students is changing drastically. Our speed [as teachers] is not fast enough to catch their speed in changing their minds. The curriculum starts to diminish all these boring parts, because the students' acknowledgement is very important as a success criterion. But we are still teaching mathematics and geometry in a more implicit way, we have our back doors, and it works somehow. It is not downplayed, but it has changed.

In my school, it is partly the fault of the mathematicians, because those from the department of mathematics are usually so afraid of being in the department of architecture, they think that teaching mathematics to architectural students is a very special thing and additional effort for them, so they resist being part of it. And then we started to design our own mathematics and we started to give our lectures in addition to classical mathematical lectures. But it is not enough, because it is a very contaminated environment at the same time, because students are playing very freely with geometry without really knowing what they are doing. But they have to find a way to understand the reasoning behind it.

DUVERNOY: I can make a comparison between how I was taught and how I teach now. When I was a student I had 2 years of descriptive geometry, there was Monday morning dedicated to geometry for 2 years in a row. In the same 2 years we had two afternoons with hand drawing with a teacher of art. So we had a very complete and progressive education. When I myself started to teach at the University of Florence, I taught architectural drawing, and the course would last for 1 full year. We taught free hand sketching, hand drawing, architectural drawing and technical drawing. The descriptive geometry course was another course done by another teacher, and it lasted also for 1 year. Now we have one semester of 3 months in which we have to combine sketching, architectural drawing, descriptive geometry. It is called *collaboratio di rappresentazione*, and even here in Milan there are some lessons on measured surveying. So there is a problem of time. The quality obviously has lowered, but not because the students are different or the teachers are different, but because there is not enough time. We are not given the time necessary to teach and for the students to understand and to assimilate and to produce results.

XAVIER: In Porto we have a first year class of geometry and architecture. The geometrical thinking is in some ways reinforced, because we have now in the third year another class. In the first year we ask, 'should we teach the idea of projection?' For me it is important to do that still, to make the students understand what it is to project a point into the plane. If we use computer software, this is not the question. I can quote a Spanish teacher who said 'descriptive geometry is dead, long live geometry!'

ELKHATEEB: Before answering the question I think it is important to give a brief background about the educational system in Egypt. The educational system in Egypt can be divided into two main periods. The first is the *pre-university period*: 12 years divided between the compulsory basic education (9 years) and secondary education (3 years). Students in the secondary education study many courses in mathematics. Among these courses are: analytical geometry, solid geometry, calculus and matrix algebra. There aren't any advanced courses for the students who intend to study architecture as their major in the future, except an elective course in which they study a very abstract approach to perspective. The second is the *university period*: after completing the secondary education, the student chooses among the different available colleges. According to the specialty of each college, the student spends 4–7 years in this college (the university includes many colleges such as: engineering, medicine, law...etc.). One of the crucial factors that determine the college in this phase is the student's grade point average in the secondary education.

To acquire a major degree in architecture, students must join the college of engineering and complete 5 years of study. According to the Egyptian educational system, the department of architecture is a part of the college (or faculty) of engineering. Before entering any department, all students must finish one (preparatory) year as general studies. In this year the students study more advanced courses in analytical geometry and calculus in addition to descriptive geometry and engineering drawings. After completing the preparatory year and entering the department of architecture, the Egyptian arch students do not take any advanced courses in pure mathematics. Instead, they study applied mathematics such as theory

of structure, reinforced concrete structures, steel structures, acoustics and artificial lighting, environmental control and advanced installation in building.

There is relatively little emphasis in the upper secondary education on classical geometry, more on the use of computer technology. Is that a problem? No, as the courses in the secondary education still work in the traditional way. I mean it does not rely so much on computer technology. In this phase of study, the problem appears to be the contents of the course, not the way used to teach it.

ELKHATEEB: [Returning to the quote from Liapi] As Egyptian students, we all reach university full of mathematical concepts, theories and equations. There are many mathematical courses in the secondary education, as mentioned previously, that introduce formal, solid geometry and calculus to the students in this phase. Engineering is the science of application, or in reverse words, it is an applied science. Thus, what we really miss here is the application and the physical meaning of all of these theories and equations in architecture. Is there a reasonable explanation for this?

In my opinion, the reasons could be the way the math courses are taught. If you ask any student at the end of his secondary education to solve any differential or integral equation, he or she will do it very easily. But if you ask many of them about the physical meaning of this differential equation, what does it really mean in our existing world, most probably he will not give you any answer. The problem maybe goes back to the math teachers in the secondary education. Those teachers put most of their attention and effort on transferring the theoretical concepts rather than its physical meaning. As a result, when the students enter the faculty of engineering, many of them experience difficulties when they deal with the applied concepts of math in engineering (such as theory of structure, reinforced concrete structures, steel structures...etc.) and also the advanced courses in architecture (such as descriptive geometry, architectural drawings, architectural design, building construction, shadows...etc.). Should this be remedied? Of course it should. I think these courses must be reshaped to help the students who intend to study architecture as their major. Principally, this will be easy if some elective courses have been added in the phase of the secondary education.

JAKOBSEN AND MATTHIASSEN: A famous quote is, 'If the input is lousy, the output is lousy.' Sylvie Duvernoy states that 'my students are still convinced that the computer is going to produce a perspective view better and quicker than what they could do by hand. [...] I hope to witness the reverse tendency some day: students and junior architects will be hired for their ability to sketch and draw by hand, a skill that seniors will have lost because the excitement about computer technology was paramount in their youth' (Duvernoy 2012). But another quote, from Cristiano Ceccato of Zaha Hadid Architects, is that 'The availability, and indeed the necessity, of formal geometric education for aspiring young scholars of architecture are [...] paramount. This is achieved in two ways: through calculus and geometric algebra; and the study of formal descriptive geometry, over a number of years, without any computational aid. Regrettably, this is nowadays more the exception than the rule in that this level of knowledge must be persistently acquired during high-school; at university, it must be there to be readily applied, or it is often too late' (Cristiano Ceccato 2010). This raises two questions for the panel. First, of

the students who go on to be architects and designers, is their mathematical background good enough? Next, with less emphasis on classical geometry and more on analysis and the use of computer technology, is this a problem for the education of future architects?

FALLAVOLLITA: The best students in Italy, in science and engineering, are coming from the classical studies.

DUVERNOY: In Italy architectural studies is open to everybody, you can come from any line in high school. This means that the students in the first year have very different knowledge. Some are already skilled in drawing, because they went to *istituto tecnico*, and some never drew because they come from classics and studied Latin and Greek. And it is true, that those that come from classical studies make the most interesting progresses in their first year, because they start from nothing and they learn something, so they really make progress, while those who already studied drawing in school studied only the practice of drawing, and they think they know everything already and they do not listen to the lessons or invest themselves in learning.

XAVIER: In Portugal we have a very interesting and now perhaps rare situation because we have descriptive geometry in the high school for 2 years. All the students that go to architectural schools have this background. They have mathematics too in high school, and now they combine this background in descriptive geometry with less knowledge of mathematics, and this is much worse than the situation we had before, when they had better preparations in mathematics too.

LEOPOLD: In Germany there is very good education in analytical geometry. In the last years there is a lot of calculation of intersection between planes and surfaces, they can calculate all, but they have no special imagination of what they calculate. It is just algorithmic calculating. There is no descriptive geometry in any schools, only some technical schools. So from geometry I can nearly only refer to what they learned when they were 12 years old. They learn some basic plane geometry, but even this is very much behind. Mathematical background in analytical geometry is wonderful, but it is too much what they know there, and it is not enough in the spatial imagination, and I agree with the quotation. My experience is that the best students are those that did a vocational training before their studies, for example they work with wood, so hand craft education, because they train their spatial imagination by working with their hands.

SORGUC: I recommend that you visit toy stores to see what they are selling to children. I am sure you all played with Lego. In Lego there is an enormous amount of creativity while you are a child and you can make whatever you like. But now it is very customized, so there are Lego for any specific purpose; if you want to make a space craft, there is a space craft Lego, if you want to make something else, there is something else. Even in kindergarten they tell the children to colour between the lines, imagination is dying in that way. They know many things, they have mathematics in our country as well, there is an entrance examination which is very hard, and in order to be an architect they have to have very high scores in science and mathematics, they are very good students. In the compartments they have information and then you have to retrieve it and make them do the syntheses and you have to mediate their information.

OSTWALD: In Australasia architecture is typically only taken by the top percentage of students, so it is meant to be reasonably elite, and a student ideally needs to have completed some mathematics and science. So hypothetically we get the best of our high school students in, but that does not necessarily mean they are very good for our needs. For this reason I end up observing it is not so much that we have a slight shift away from classical geometry into mathematical analysis or computer technology. I see even the best of our students have a fear of numbers, even these students who have gotten through mathematics don't enjoy it. And another thing is that they are often seduced by the computer. Maybe they have grown up with them for so long that they are used to asking the computer any question they want an answer to. Thus, if I had any thoughts on what a high school system should do better, it would be to remove the seduction and implied power of the computer, at least partially, and make students far less afraid of mathematics.

ELKHATEEB: Should drawing be learned by hand? Yes, I absolutely agree. Again, I will speak about my experience in teaching architecture in the Arabic region. I was involved in the architectural education for two different groups. The first did not use any CAD software until the fourth level, where the second group used CAD programs from the first day. For the first group I noticed that they had more "feeling" about the drawings; they could sense and recognize very well the scale of their designs, their hand and free hand skills were more mature. On the contrary, the second group had no "graph memory", consequently they had no "feeling" about the drawings, could not recognize and estimate the scale and their hand skills were very weak. In architecture education, I believe that the best results will be achieved if the students start with hand drawings till their graph memory and imagination are trained and established.

JAKOBSEN AND MATTHIASSEN: All kinds of students at all levels see and live in architecture, but is mathematics relevant for their understanding and experience of architecture? Or, is it important for the students' general education (Bildung) to acquire that mathematical understanding?

KIM WILLIAMS (from the audience): I don't think there is any education, at a primary or a secondary educational level, of how to see and live in architecture. Mathematics at that point is not relevant. If you are not taught at all, it does not enter.

JAKOBSEN AND MATTHIASSEN: A lot of students are actually taught architectural history in connection with general history, they are taught the different periods, baroque period, renaissance period etc., and the question is, if they are taught that, would mathematics be relevant for a better understanding of the subject?

SORGUC: There are several means, but we are missing many chances in teaching. If you look at books, I will give you two examples: Gulliver's Travels and Alice in Wonderland. I think they are the best books to teach how to look at your environment, and actually that was the idea of the authors to teach how to look at the environment. So there are many chances that we miss, it is only a little shift in the way you look at the problem, so we don't have to explicitly teach what the geometry is, what a space is, but we have to allow them to understand, to experience, to feel it. Just a little quote, if you remember Gulliver's Travels, the Lilliput people make their buildings from roof to down, which is weird in our world,

or make Gulliver's clothes by measuring with straight rulers. Actually the scale, environment, the sizing of the environment, trying to find the viewpoint, I think this should be taught at the very first level with little things, and then I don't believe this is a special issue for architectural students, this is an issue for everyone; if you look at the weather and if you understand the formation of clouds you can learn many things, like many architects if you get the wings of a bird, the way you see and the way you interpret is different, it is not really related with disciplines, I believe, this is very general problem. Yes, mathematics is very important, but mathematics is very scary for many students, math phobia is an acknowledged problem. So you have to overcome this with daily examples I believe. Then I trust that we will be more successful.

LEOPOLD: One problem with our school system is that all the subjects are so much divided from each other, this is so at university and this is also a problem at secondary schools. It would be a wonderful case, if you combine architecture with the education in arts together with mathematics and to make some projects which go over several subjects. What is also very important for architecture is education in aesthetics, there is no education in aesthetics at all in our schools. This can also be combined with mathematics, proportions and so on. This would be a good point, but not separated in disciplines, integrated in projects.

FALLAVOLLITA: I think that what mathematics can do in high school education and even in first year of architectural school is, for example, how can we teach to see the space, how can we teach our students to perceive the space? I think one simple solution is to explain how perspective works. I read a book of a really famous mathematician in Italy, and I think also in other countries, his name is Odifreddi, and he wrote a book called *Una via di Fuga*, where he said the perspective is not the true way in which we see the space; there are some artists who understood that, and he told about Van Gogh, and said that he knew how to see the real space. If we think that perspective is not the way we look at the space, I think we are doing a really wrong thing, because perspective is the way we are really looking through the space. So the first thing to teach how to see the three dimensions is to teach the rule of perspective. That is for me one of the first things we can do to teach to look at things. There is no space without perspective for human beings.

MAURIZIO VIANELLO (from the audience): We have a course in aesthetics here in Milan, and it is for sure not about proportions but about modern theories of aesthetics. My question: When you are student of architecture you should learn something about statics and broader speaking, mechanics of buildings. For those fields you need some mathematics. You cannot understand it if you don't know what a vector is. But there are many more mathematical tools which might be used. My question is: in your experience, what is the connection between the content of the mathematical courses and the content of the courses in statics and mechanics? For instance, would the students at your universities be able to understand what a double integral is in order to compute the moments of inertia of a section of a beam? There are places where this is far away from what they will do, and there are places where this is done. The other thing is, for instance, if you talk about stresses, of course we know that in a solid there are stresses and in a three-dimensional solid you have the stress tensor which is in fact a linear map in the end, but do they have a (vague) idea

of what an eigenvector or an eigenvalue are, do you think that in your university this is something that is vaguely taught or not? There are very different situations in the world—the mathematics in the schools of architecture has a very different role depending on where you are. There are cultural traditions and places, where they think architectural students should have some basic knowledge of statics and mechanics.

JAKOBSEN AND MATTHIASSEN: Are there any final comments?

XAVIER: I would like to stress in relation to the quotation from Sylvie that free hand drawing is still one of the most important tools for architects. It is cheap, it is easy, it is quick. It is good to combine this elementary and basic tool with all the tools that technology can give us.

ALEXANDER HAHN (from the audience): I'd like to underscore a point that professor Leopold made. It has been my experience in the United States that our students come to the university with an algebra box, a trigonometry box, a geometry box and within each of these boxes they can operate reasonably well. But when it comes time for them to confront and solve and consider a problem that cuts through the boxes, then most of the time, at least in my experience, they are helpless, they don't know where to begin. So the idea that, given the connectivity of mathematics and geometry and related disciplines, the fact that they are related to a wide variety of questions in art, questions in architecture etc. etc., the earlier we can represent these topics in a broader interdisciplinary context, the better it is going to be for the subsequent success in education for the students we are talking about.

ELKHATEEB: I noted from the discussions that took place in Nexus 2002 roundtable, there is no consensus on what math courses should be taught to arch students. I can add also from my experience in the Arabic world that we have also the same debate here. The importance of mathematics in architecture is unquestionable, but the real and difficult question is, 'What math courses should be taught to arch students?' In this subject I will quote the words of Maurizio Vianello in Nexus 2002 roundtable, because it really touches the core of the problem:

"I have never met a book which is really a general book of general mathematics, not a specific book on one topic because you can find something like that, but a general book oriented towards the general student of architecture, written by a mathematician but oriented towards an architecture student." (Nexus 2002 Round Table Discussion 2002b).

In other words; if we decided to prepare such a math book (written and oriented specifically to architecture students), *what should be the contents of this book?* I would ask the colleagues in this valuable discussion to think about these two questions. Perhaps these could be the theme of another future discussion.

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Ivan Tafteberg Jakobsen is a retired teacher. He received a M.Sc. in mathematics and physics from Aarhus University, Denmark, and a Ph.D. in mathematics from University of London in 1971. He taught mathematics at upper secondary school level from 1973 to 2009, during which period he became interested in the history of mathematics and especially the relationship between mathematics and architecture. He has been involved in developing educational material in these areas, in arranging in-service courses for mathematics teachers about mathematics and architecture, and in arranging study tours for teachers to places especially interesting in this respect, most recently four study tours to Barcelona during the years 2008–2011, jointly with Jesper Matthiasen. The main purpose of these efforts has been to present mathematical aspects of buildings that are understandable at an elementary level, mathematically interesting, and important for the overall understanding of buildings and designs. Apart from this he has also been interested in the border areas between mathematics and historical navigation and surveying, where, also jointly with Jesper Matthiasen, he has developed teaching material and created collections of historical instruments that can be borrowed by secondary schools. In June 2011 his book *Antoni Gaudí. Geometrien bag arkitekturen* was published (in Danish). This book tries to present the many geometrical thoughts behind Gaudí's architecture in a way accessible to secondary school students.

Jesper Matthiasen received a M.Sc. in mathematics and physics from Aarhus University, Denmark, in 1988. He has afterwards made supplementary studies in history of arts at Aarhus University due to an interest in mathematics combined with both architecture and visual arts. Since 1989 he has been teaching mathematics at upper secondary school level at Aarhus Akademi, and during 1998–2000 he was a lecturer in History of Arts at the University of Copenhagen. Since 2002 he has been engaged in the training and education of new math teachers at the upper secondary schools, and he is an external examiner for both universities and schools of engineering throughout Denmark.