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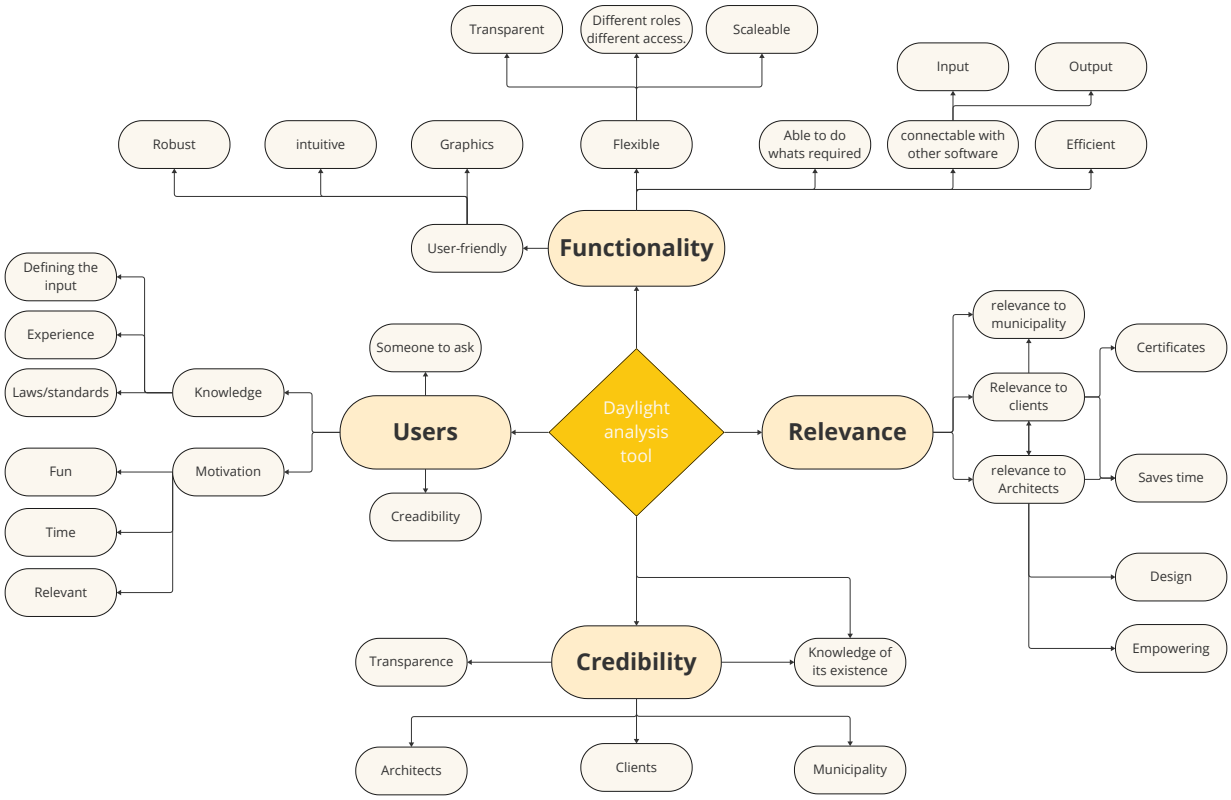

Design practice integration of a daylight analysis tool

Master's thesis in structural engineering and building technology

Markus Gustafsson

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
CHALMERS UNIVERSITY OF TECHNOLOGY

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In loving memory of
Birgitta Pettersson

MASTER'S THESIS ACEX30

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ABSTRACT

Building performance tools are an important part of building design and are used to verify functional requirements. For instance, daylight analysis verifies that the access to natural light in the interior space is adequate. Daylight is important for our circadian rhythm, affects our alertness and mood and is of increasing importance as we spend more time indoors. In current practice, forementional analyses of the building are mainly used in retrospect by engineers, after the conceptual design phase of architects.

If the building does not fulfill the functional requirements this can lead to expensive changes where critical design ideas are lost. A consequence of rule of thumb approach by architects is lost opportunities during the design phase. It is therefore motivated to have sustainability tools usable for architects in early phase design. However, even though the use of tools is motivated and exist, they are not integrated into the practice to a considerable extent. There is a missing link between the developed tools and the architects, where many of the tools are externally developed and the research regarding these tools is driven by computational performance improvements.

To instead focus on the process of tool uptake in architectural practice, this thesis evaluates different educational approaches experimentally to teach and implement an internally developed daylight tool within one architecture practice. The three educational approaches which have been explored experimentally are a presentation for the office, a course for the users, and one-to-one teaching sessions. Each approach is directed to different roles at the office with different objectives and will be evaluated through surveys. In connection to this an interview study has been done to better understand the needs of the architect in relationship to the digital tool.

It was found that the different roles at the practice expressed different needs for the tool, where the lack of focus on roles beyond the tool user might explain the lack of uptake of developed tools. The different educational approaches were well-received with new users of the tool, but more approaches were requested, such as a manual for the tool and a presentation focusing on sales for the seniors. A framework explaining the need of the tool has been organised based on the work with this integration, where the need for the tool is divided into four categories, the need for users, functionality, relevance, and credibility.

Keywords: Sustainability, Digital Tools, Daylight, Practice based research, Digital development, Practical implementation approaches, Building performance analysis, architecural practice

Contents

1. Introduction

Building performance analysis tools such as daylight analysis tools, are often used after the architectural design phase of a building, as a retrospective control to ensure the design complies with requirements. This can lead to lost opportunities and expensive changes if the design is found invalid. The use of early phase building performance analysis tools is therefore motivated and exist but are not integrated to a considerable extent. This thesis focus on how different educational approaches could improve the practical integration of an existing daylight analysis tool within one architecture practice.

1.1 Background

Architect are faced with increasingly intertwined and complex information in their design projects which they need to integrate from the start of the design project (Bourbonnais, n.d.). In combination with this lies the architects desire for innovation which require constant change in the way they work (Castelo-Branco et al., 2022). This creates a demand for tailorable tools which are easy to use.

1.1.1 Importance of designer's tools

Figure 1. Cross-section of St Pauls cathedral.

Design and design tools are interlinked.
New tools enable new design. Before Robert Hooke published his theorem on the catenary chain in 1670s, which states how a chain acts in tension an inverted arch with the same shape will act in compression, it was not possible to construct innovative shapes such as the St Pauls cathedral shown in Figure 1 (Addis, 2021). Tools can also limit us (Moinet et al., 2014), for instance, practitioners state that they are able to recognise stairs drawn in the design tool Revit, because of the difficulty to draw stairs in the tool where it guides the user to the same designs. According to Stolterman & Pierce (2012), the design tool can enable certain designs, guide the user in a certain direction, and be an extension of the designer's brand and interlinked with their work. The link between Zaha Hadid Architects fluid building design and parametric design tools such as 3ds Max is apparent (Lee, 2015). Therefore, how- and what a tool is doing is of vital importance.

1.1.2 Building performance analysis tools in early phase design

According to Meex et al. (2018), the LCA tools is more used as an analysis performed from a retrospective perspective instead of a design tool during the early stages, whereas the architect decision making is more based on rule of thumb (Mahmoud et al., 2020). The rule of thumb leads to lost opportunities, where the building performance is worse (Attia et al., 2013). Attia et al. identifies contextual integration as well as user's skills as inhibiting factors for the uptake of building performance tools. Mahmoud et al. (2020) argue that the issue is not the lack of tool production, but rather the integration of tools for architects in the design phase. There is a gap between what the architecture practices need and what the software developers produce, and therefore there many of the tools which are produced are not utilised (Säwén et al., 2024).

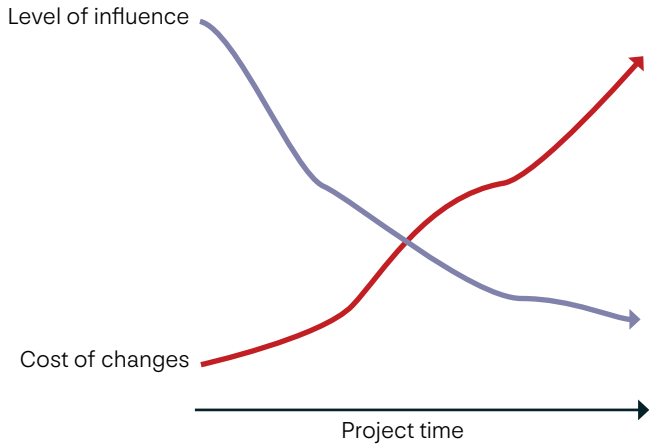


Figure 2. Diagram highlighting how cost of changes increases and influence decreases as the project time progress (adapted from Paulson, 1976).

According to Paulson (1976) and shown in Figure 2, the cost of making changes to the design is increasing as the project is being developed. From an economic standpoint it is better to avoid major changes later in the process and make well-considered choices early on. Major changes may occur late in the design phase if the building performance does not comply with the requirements and regulations (Boverket, n.d.).

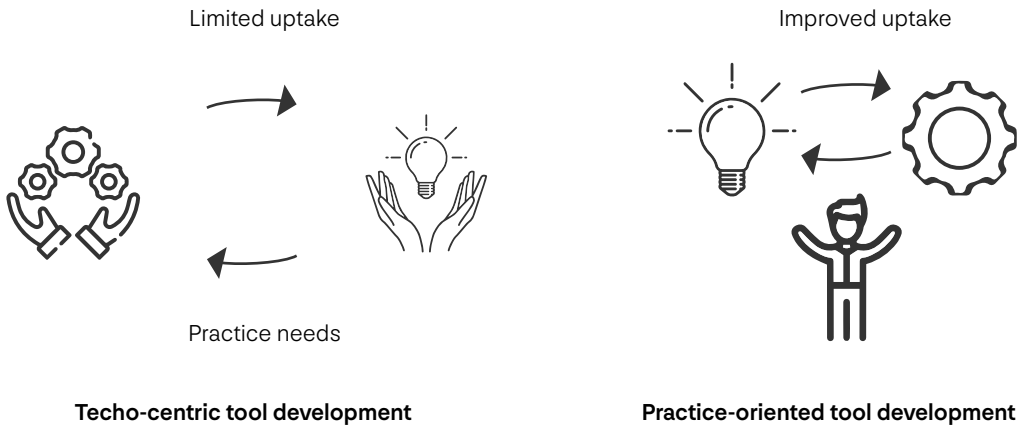


Figure 3. Illustration of techno-centric and practice-oriented tool development. (Adapted from Säwén et al., 2024).

There is a limited uptake of tools from the practice because there is gap in the understanding of what the tools are intended to do and the integration of the tool (Säwén et al., 2024). Using a practice-oriented tool evaluation and development instead of a techno-centric, the disconnect between the developer and the practice may be much less, where the practice-based tools are better connected to the practice and better answers the needs of the practice (Säwén et al., 2024). MacLean et al. (1990), state that it is impossible to create a tool for all situations and users and propose tools which are tailorable to the specific practice.

The practice-oriented development of tools can function as the tailorable systems explained by MacLean et al. (1990) and shown in Figure 4, where different roles have different levels of tailoring power. To achieve these kinds of systems a broad perspective must be considered (MacLean et al., 1990). The focus area must be wider than the end users and tool development. Most of the tools today are not written by professional tool developers but rather people who develop their own tool to support their own goals in their own expertise, i.e. practice-centric development (Ko et al., 2011). This approach requires a user with the expertise of building performance within the architect practices since it is not naturally an architecture expertise (Bleil De Souza, 2012). According to Säwén et al., there is a lot of studies on tool development but very few that focus on tool integration. This is as well expressed in the research by Stolterman & Pierce (2012).

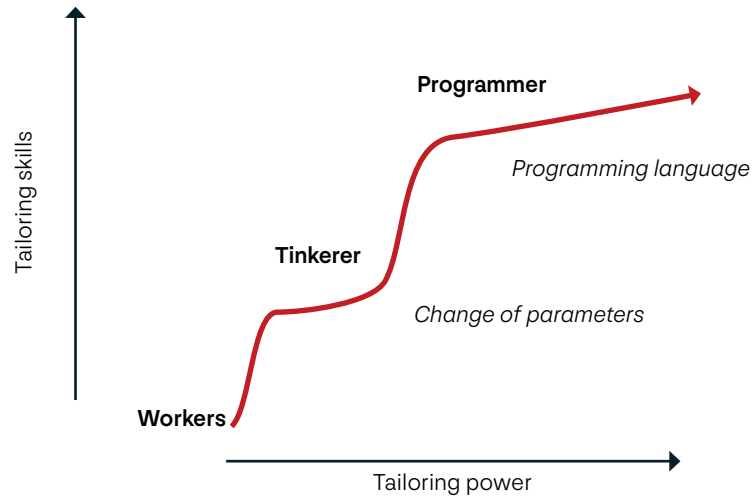


Figure 4. Diagram of the *tailorablility mountain and its inhabitants*. Users with different level of tailoring skills and changes in tailoring power are placed. The slopes highlight barriers (adapted from Maclean et al., 1990).

As previously explained, there is no lack of developed tools and researched of how to develop, but the uptake of the tools into the practice is poor, as well as the research of how to improve the uptake. This study will experimentally explore different educational approaches with the objective to improving the uptake and integration of the developed tool in the practice, where the different approaches will be evaluated with the help of surveys and interviews. Improved uptake will be measured in self-evaluation through surveys.

1.1.3 *Learnability*

Shown in Figure 4, tools can have learnability barriers which can be explained in learning curves. This has been elaborated on by the work of (Aish & Hanna, 2017) and is shown in Figure 5, where they express that there is a lack of research regarding empirical experiments to make conclusions regarding what factors influence the learning curves.

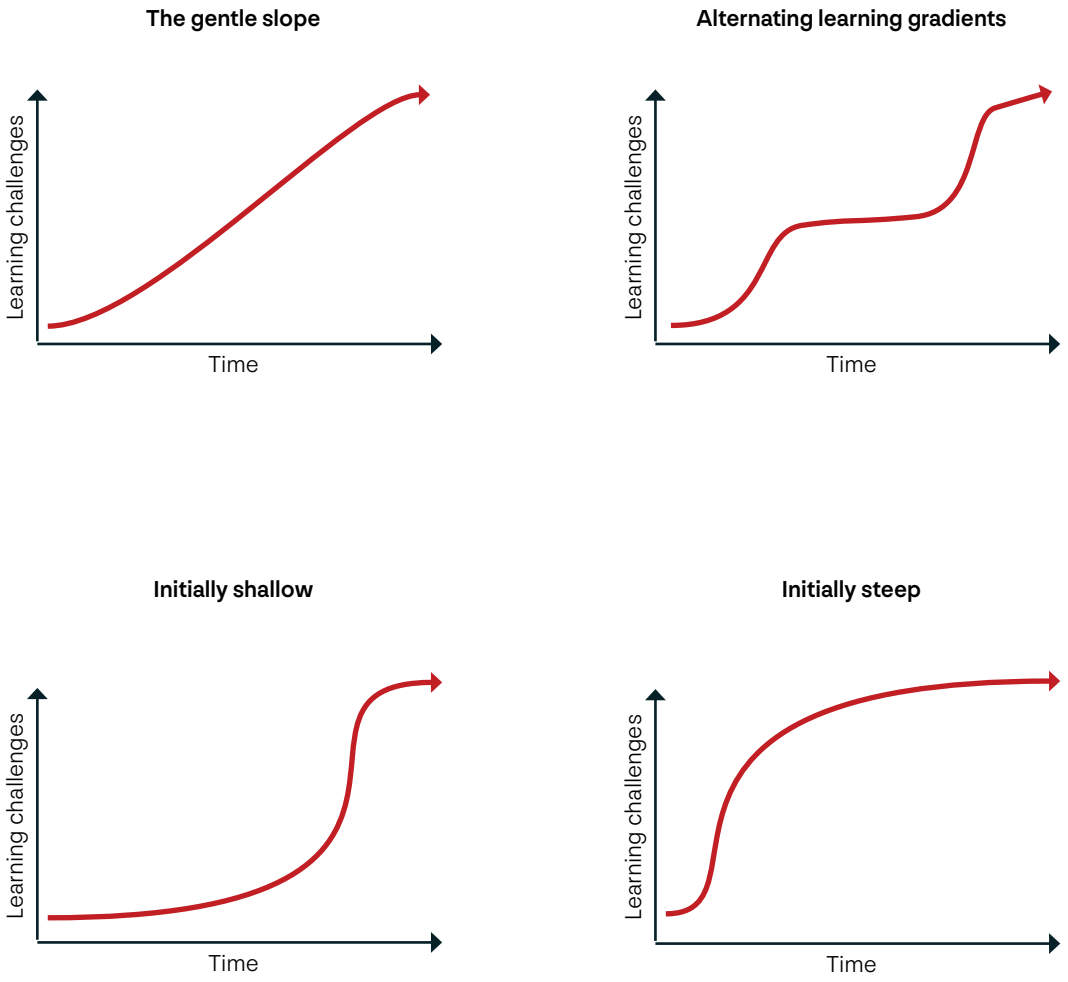


Figure 5. Possible learning curves. (Adapted from Aish & Hanna, 2017).

Presented in the paper by Mahmoud et al., (2020), the lack of time for learning new tools is expressed by many architects. This requires easy to use tools which is expressed by architects in the research by (Weytjens & Verbeeck, 2010). Mahmoud et al. also divides the learning into two, the need for the user to learn the analysis method as well as the tool. Weytjens & Verbeeck (2010), states that younger architects might be more motivated to learn new methods and tools. The motivation is as central to the learned response. According to Huitt (2004), without motivation no learning will occur.

To teach architects technical disciplines is difficult due to their focus on architectural design according to Banerjee & Graaff (1996). They propose a problem-based learning approach, where the architectural design is part of the process. Problem-based learning is an approach where the students gain experience-based education. It is an instructional approach where the students learn through solving problems. This approach gives the students self-learning which they can apply on new problems. One problem with problem-based learning is the lack of skilled educators in many settings (Hmelo-Silver, 2004).

1.1.3 The importance of daylight analysis

According to the Swedish public health authority (Folkhälsomyndigheten, 2017), the exposure of daylight has positive effects for our health and is increasingly important as the population tends to spend less time outdoors. The Nobel prize laureates J. Hall, M. Rosbash, and M. Young were awarded in medicine for their study of the mechanism controlling the circadian rhythm, where daylight plays an essential role (The Nobel Prize in Physiology or Medicine 2017, n.d.). Daylight is needed for vitamin D production as well as affecting our mood and alertness. The effect of these cannot be reproduced with electrical light (Knoop et al., 2020).

The Swedish authority for building and planning and the Swedish authority of working environment have therefore decided a minimum level of daylight in spaces humans spend more time in than temporary. This requirement is the major reason why daylight analysis of the buildings designed are performed. It also exists several certificates which demand certain levels of daylight in the building which is another reason.

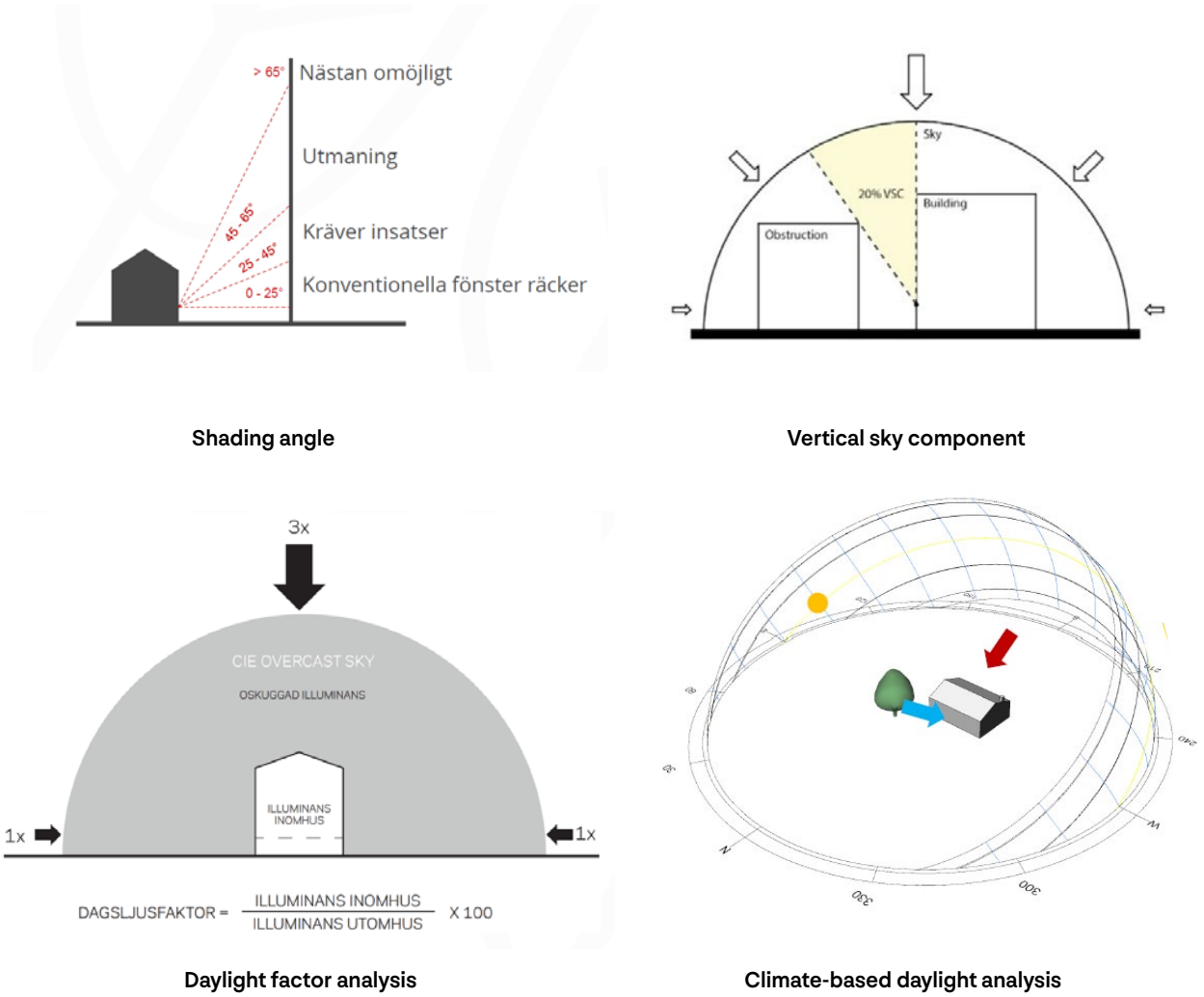
1.1.4 Design parameters which affects daylight

There a several factors which affect the interior daylight quality (Wang et al., 2024). Some of the more important are:

- The context. i.e. buildings next door, ground, Trees etc.
- room depth.
- Balconies.
- Windows size.
- Reflectance values of the materials.
- Windows light transmission factor – factor of how much visible light which gets transmitted through the window.

The orientation matters as well as the skys illuminance, although not in all kinds of daylight analysis, this will be elaborated in the next Section.

1.1.5 *Daylight metrics*



Shading angle

Vertical sky component

Daylight factor analysis

Climate-based daylight analysis

Figure 6. Illustrations of the four different levels of daylight analysis.

There are many different algorithms to measure daylight where they can be divided into different clusters of complexity (Ayoub, 2020). In Figure 6 four levels of complexity are shown. The easiest and fastest way is to examine the shading angle of the closest building. The vertical sky component analysis is an extension of this, which calculates how much of the sky is visible from each part of the façade.

The third level is a more advanced method called the daylight factor analysis, which measures how much daylight reaches into the different rooms of the building and puts it in relationship to outdoor space, considering a cloudy sky with equal light from each orientation and different reflection and transmissions values for the different surfaces. This analysis is the most used at the practice investigated in this thesis, as it is most requested.

The fourth level is called climate-based daylight analysis and works in the same manner as the daylight factor analysis but considers the measured daylight and movement of the sun at the specific site of the building, instead of the simplified sky in the previous level. In all of these analyses the context such as surrounding buildings and landscape is considered.

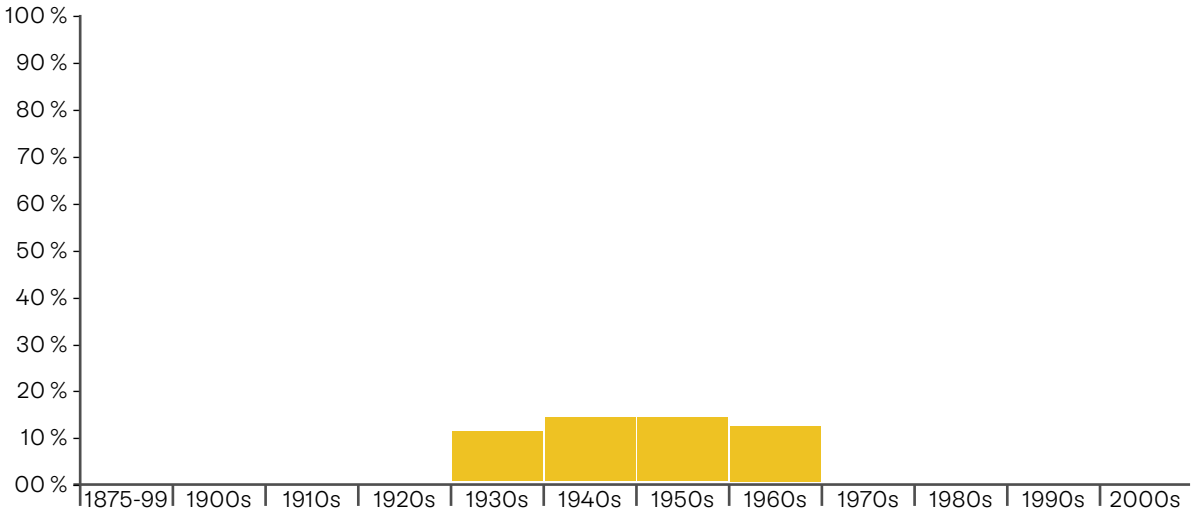


Figure 7. Percentage of buildings where the daylight factor is above 1% in all the required rooms, sorted by the decade when the building was built (adapted from Rogers et. al., n.d.).

Rogers et al. (2018) have analysed 14 000 rooms and examined if the requirement of 1% daylight factor in rooms where people stay more than temporary is seldom achieved. In Figure 7 the results are sorted by decade and highlight that very few of the buildings analysed achieve the requirement. The few buildings which do achieve the requirements have been built between the 1930-1970, where the Swedish architectural style Functionalism was dominating. In Figure 8 a sketch by the architect Gunnar Asplund highlights how the metric shading angle was utilised to achieve these results. It is worth nothing that the analytics tools have developed greatly (Ayoub, 2020), improving the understanding of how the daylight will be in the buildings we design, but the result of the finished building is poorer. The shading angle tool was used by the architects then, but the more advanced tools of today are used as a retrospective checkup, which might explain why the results have declined.

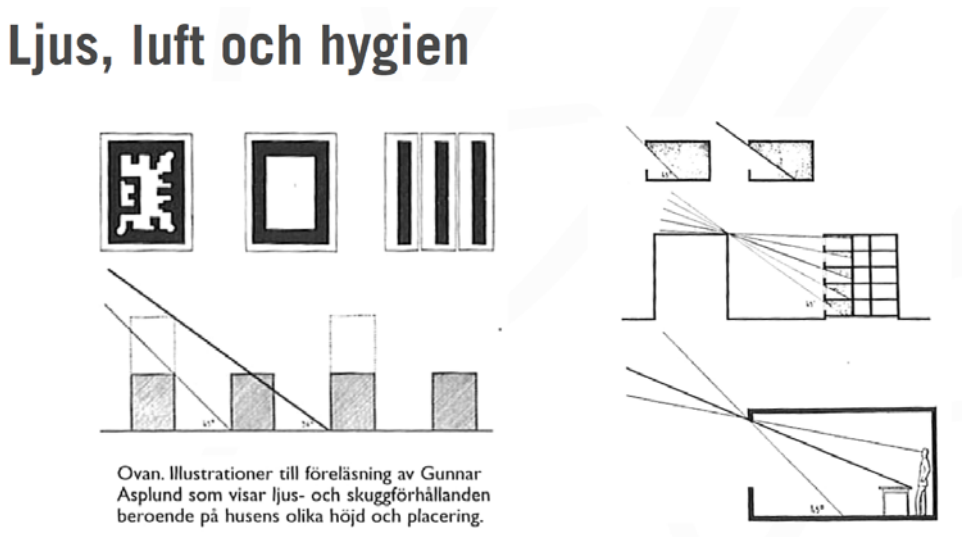


Figure 8. Illustration of the shading angle, in the work by Gunnar Asplund, a Swedish architect during the 1920-1940s.

1.2 Aim

The aim of the thesis is to evaluate different ways of integrating tools developed within architectural practice. The integration process will both focus on educating the potential users and other roles within the office, such as the management, responsible architects, project architects and support group. A second aim is to better understand these groups specific needs and how the tool can better fulfill these, or how the integration of the tool could better fulfill these needs.

1.3 Research questions

How do different educational approaches improve the self-perceived learning of the participants? Which knowledge is relevant for the different roles within an architectural practice regarding building performance tools?

1.4 Intended audience

The intended audience for the thesis is architects and architecture office leadership who is interested of developing their own tools. The academia is an intended audience who can continue the research how to develop tools for architectural practice. Software companies developing tools externally may also have an interest of this thesis to understand the need from architectural practices better.

1.5 Delimitation

This thesis is a qualitative investigation, investigating one integration of one developed tool in one architecture office. The chosen tool is a daylight analysis tool integrated in the softwares Rhinoceros 3d and Grasshopper. The exploration takes place in a Swedish context and at one specific practice.

1.6 Method

An interview study was performed with a representative for the different role within the practice, in addition to three educational approches which were tested and evaluated through self-assessment through surveys. The approaches were a presentation, a course and a problem-based learning approach called in this thesis one-to-one.

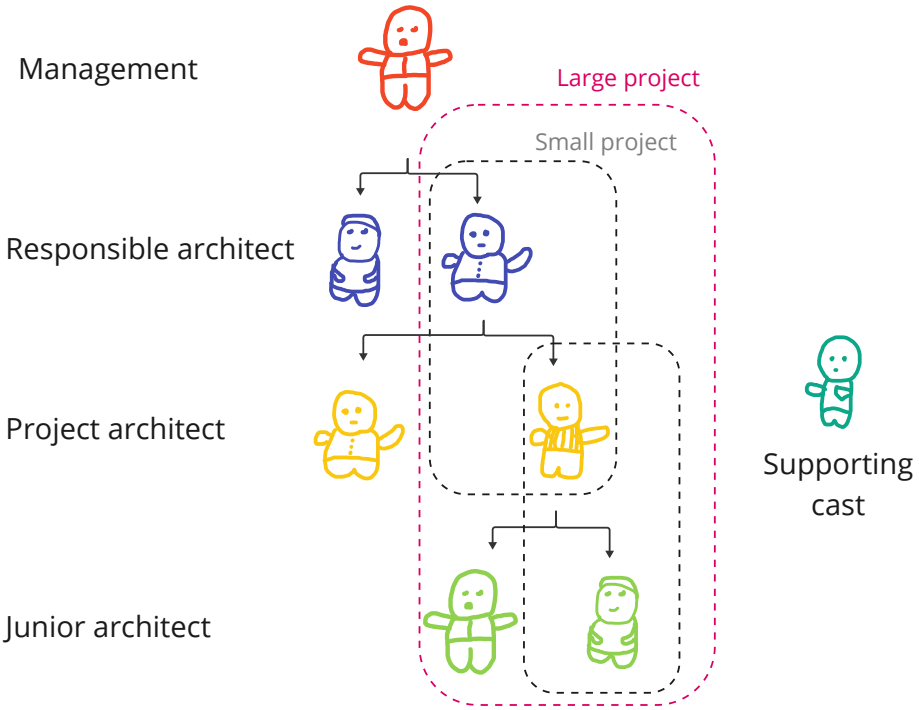


Figure 9. Diagram the structure of the practice

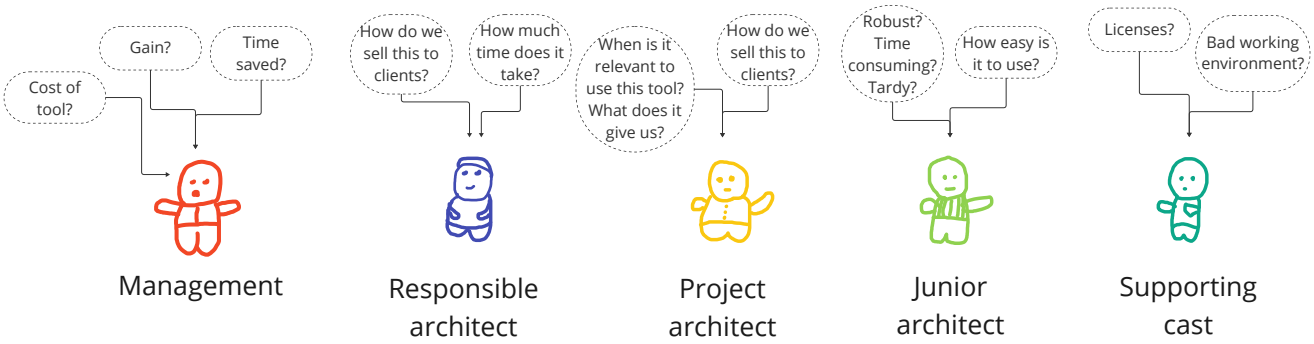


Figure 10. Examples of different potential needs of the different roles of the practice.

2. Study context

2.1 Context of the master thesis

The work of the master thesis takes place at a medium-sized architectural office in Sweden (60 employees). The author started his employment as an architect at the office three years ago and began developing building performance analysis tools based on previous experience, which was missing from the practice. Several analysis tools have been developed but the tool which is most widely used is the daylight analysis tool. Apart from working with building performance analysis tools the author has the role of project architect at the practice.

Before the development of the presently investigated daylight tool, work such as daylight analysis was done externally which created a gap between the designer and the analysis, as well as a limited number of iterations to get a good result, due to the higher cost. Now the office offers this service to clients themselves and the workload keeps increasing which is why the office expressed the need to spread the knowledge and educate more colleagues how to use the daylight tool. Considering the lack of uptake of early building performance analysis tools the focus of this thesis has been to research this work and how it can be done better in the future.

2.2 Structure of the office

To better understand how to integrate the tool into the practice, the structure of the practice has been simplified according to Figure 9 with the different roles defined by Sveriges arkitekter (the Swedish architect union), which has also been confirmed by the respective roles through the interview study (Sveriges arkitekter, 2024).

The practice has been divided into:

- A management segment, which represents the CEO, the owner and office managers. Responsible for the management of the office.
- The responsible architect, which is the role which oversees the different projects the office has and are involved in several projects at the same time. The responsible architect guides the overall direction of the projects. The responsible architect seldom has time to draw or sketch.
- The project architect is more involved into each project than the responsible architect and leads the day-to-day work for the different projects. The project architect both guide the work of the project group and perform design task such as drawings, sketches etc.
- The junior architects conduct drawing work, such as the sketches, drawings, and design explorations.
- The supporting group is working with supportive tasks such as software licenses, computers, human resources, public relations, etc.

To identify the most promising approaches to implementing/integrating the tool this thesis chose to include all segments of the practice rather than only the people which will perform the actual tasks. The hypothesis is that the different parts of the practice have different needs and need to know different things about the tool as shown in Figure 10. Different experiments and interventions have been directed to different roles of the practice.

2.3 Daylight analysis

The tool used in the practice which is researched in this thesis, operates, as described in the Figure 11, from the software Rhinoceros 3d and the visual programming environment Grasshopper, with the help of plugins Ladybug and Honeybee, utilises the ray-tracing engine Radiance (Sadeghipour Roudsari et al., 2013). The tool can import geometry from Sketchup, Rhinoceros and Revit. The tool has been utilised for early phase design and building permits. In Figure 12 and Figure 13 the tool and its output are visible.

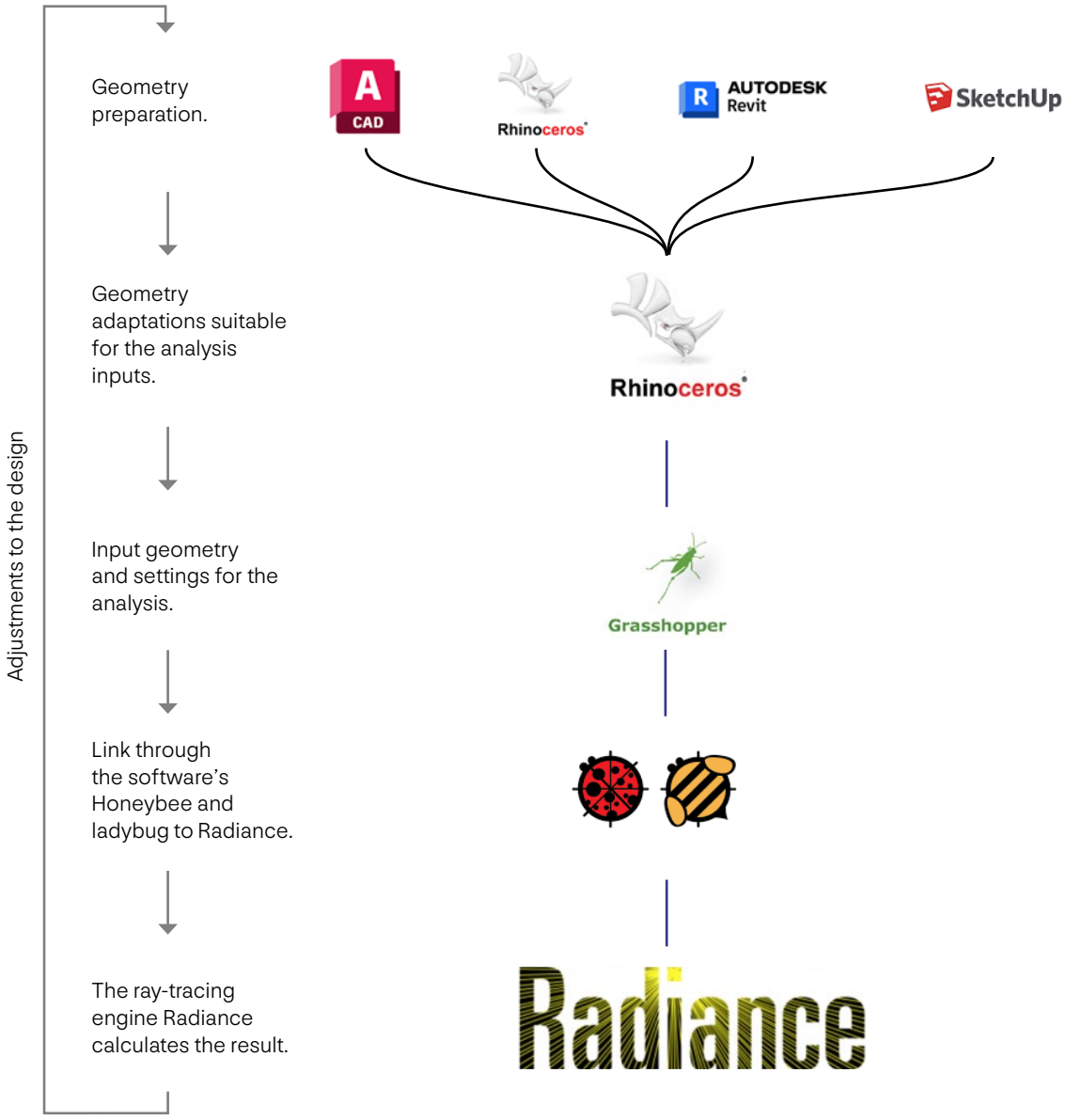


Figure 11. Diagram of the workflow for the daylight analysis tool

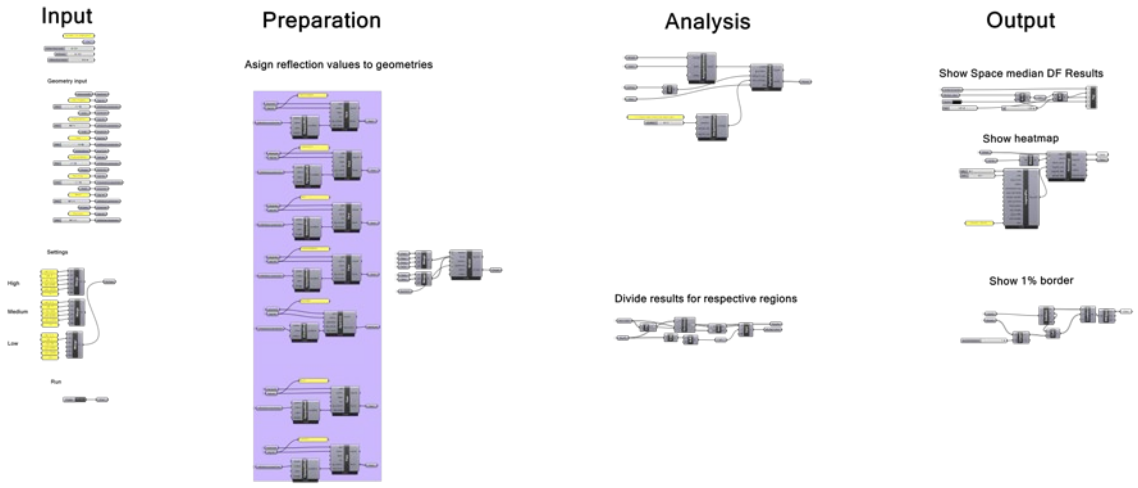


Figure 12. The daylight analysis tool is developed in the visual programming environment grasshopper, and divided into four topics: Input, Preparation, Analysis, Output. Novice users need to be able to input geometry and export output.

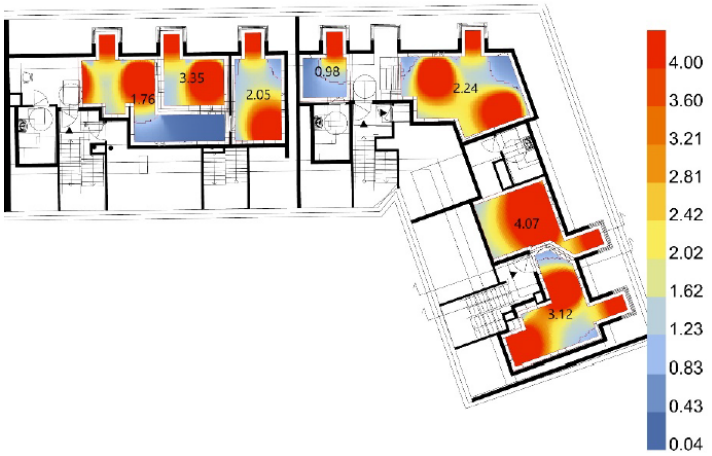


Figure 13. Result from the daylight analysis tool, where the daylight factor heatmap is visible, the median value results is show per room and the border of 1% daylight factor is highlighted.

2.3.1 Importance of early phase analysis

As was explained in Section 1.1.2, the influence of the design decreases as the project is developed further. In the investigated practice, the scenario has occurred where the building is fully designed but when an engineer did a daylight analysis and it showed it would comply with the regulations, the building was rotated 90 degrees. Another occurred scenario is that the daylight engineers dictate the size and placement of the windows which disregards other aspects of the design. If the analysis had been done earlier in the process, and the floor plan and window settings would have been design with the daylight analysis in mind, there would be a higher change of maintaining the original ideas of the building intact. If the analysis is performed externally it can take several weeks to get a reply, and usually its only a yes or no, sometimes with “you have to do this”. When performed internally it is easier to have a conversation and redistribute hours from the budget to perform an extra analysis.

2.4 Framework of the need of the tool (FOTNOTT)

In a similar way as the need from the different roles of the office is sought to be understood better, the topic has also been viewed from the other perspective where the need of the tool has sought to be understood better. Similar frameworks have been developed, in e.g. Säwén et al. (2024) where different perspectives from a meta-review was structured into characterisation criteria, Attia et al. (2009) created criteria in order to rate architectural-friendly building performance software's, and Aish & Hanna (2017) list different cognitive dimensions which affects learnability in a program.

A first version of the framework was initially developed by the author. The framework has since then been utilised in the literature study and the different educational approaches. The framework has been a living document which has evolved throughout the process of the work with the thesis. The framework is shown in Figure 14 and can essentially be read as the daylight analysis tool has certain needs, such as certain functionality, a need to be relevant, credible and the need for users. The users then have certain needs, for instance the need for knowledge and motivation to use the tool, and so it continues.

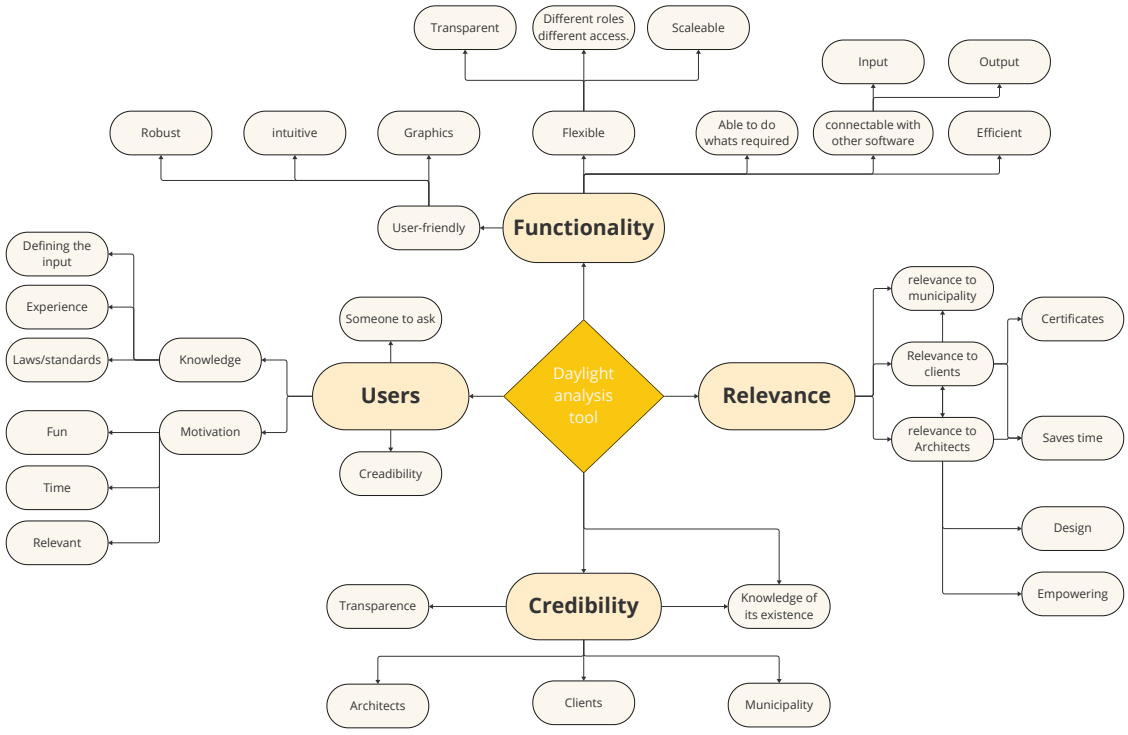


Figure 14. Framework of the need of the tool

The core needs of the analysis tool can be divided into four topics, it must have functionality, users, relevance, and credibility. The tool needs users to be used, it needs credibility in the results it gives to be used, it needs relevance for stakeholders to be used, and it needs functionalities to be used.

24.1 Need for users

Users must have knowledge to use the tool, comeing from experience, laws and certificates or how you define the inputs into the analysis tool. The users also require motivation to use the tool. The motivation can come from satisfaction from using the software or sense of conducting relevant work. Time also affects motivation, with less available time the tasks become less motivating. The user also must have someone to ask if they get obstructed. In some cases, the users themself need to have certain credibility, for instance to make some statements for the certificate Svanen the users must have 3 years of experience of daylight analysis.

24.1 Need of relevance

The tool must have relevance to be used. Either it can come from municipalities who demand this kind of analysis, or it could come from clients who want to apply for certificates which require this analysis. Relevance can also come from architects themself, to create good design or to get more empowered in the decision making, for instance how large windows should be. Since the cost for changes increases as the design process proceeds, taking decisions on proper analysis results instead of guessing could potentially save a lot of money and time which also makes this kind of analysis relevant.

24.1 Need for credibility

It is essential for the analysis tool that it is credible. If the stakeholders do not believe in the result another tool will be utilised. The credibility in the tool comes from among other from transparency, where you can understand how the process of the software functions. Other tools utilising similar processes and giving similar results also increase credibility. Architects, clients, or municipalities also need to know of the tools existence for the tool to be utilised. If more stakeholders know of it, more will trust the results of the tool.

24.1 Need for functionality

The tool must have the functionality to do what is required of it. Better functionality increases how well the tool will be used. The tool should be User-friendly. For the tool to be User-friendly it should be intuitive, have good graphics, and robust and not crash. It is good if it’s flexible and can manage different types of projects and specific daylight analysis requests. It’s good if it’s scale-able and reduces the time of the analysis tasks every time it gets used. It is good if it’s connected to other software and gets geometry input from 3d software and can export the results to presentation software.

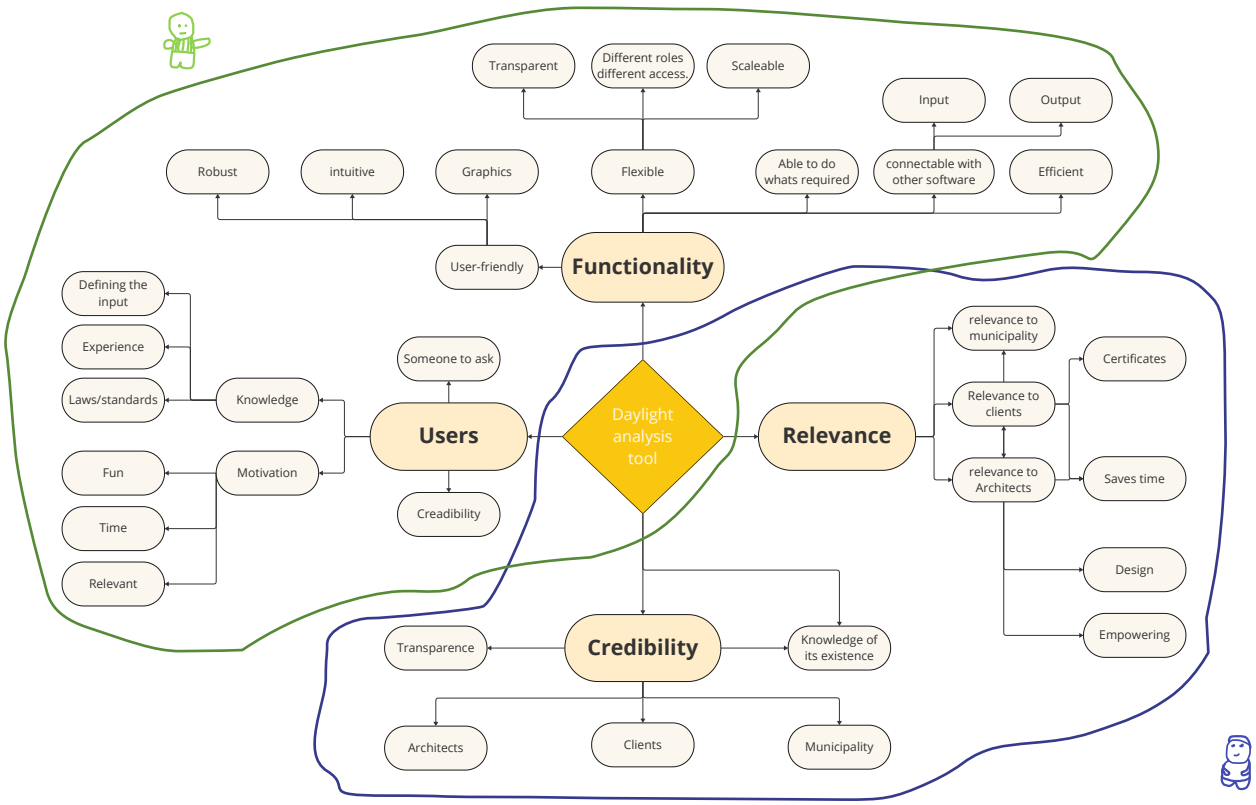


Figure 15. Example of possible difference of needs of the different roles responsible architect and junior architect.

As stated in the research question, a hypothesis has been that not everybody needs to know everything about the daylight topic. In Figure 15 a simplification of it is shown, where responsible architects need to know why the analysis is credible and why it is relevant. They do not need to know how the tool itself functions or have the same knowledge as the users of the software. The junior architect on the other side, which is the person who will conduct the analysis, and is the user in the framework, has the needs of the users and must know about the functionality of the tool.

3. Methodology

In this thesis an interview study has been carried out to get different perspectives from different roles within the practice on tool integration. Additionally different approaches to implement a tool will be explored and evaluated through surveys. Different approaches are directed to different roles of the office, to show which approach is tested to whom the sketched people in Figure 16 will be displayed next to the heading of the different approaches.

Figure 16. Illustration of roles participating in the study.

3.1 Interview study method

An interview study has been conducted to better understand the need for the different roles at the office (Purup & Petersen, 2020). The method used have been semi-structured interviews (Harrell & Brady, 2009). The interview is based on the questions in Table 1, but the interviewee is encouraged to continue to speak of topics of their desire. The interviews were performed by the author and the interviewees were selected by the author as representative for their role and participated anonymously.

Table 1. Guiding Questions of the interview process.

Interview process
Show diagrams of positions
· What position do you have at the office?'
General - In your position...
· What is relevant for you in a tool?
· What do you need to know about the tool?
· How do you want the tool to work?
Specific - Daylight tool - In your position...
· Do you feel the tool is relevant?
· Do you want to use the tool/or make others use it?
Self-Assessment
· How well do you know the tool and its intended use? Is it relevant for you?
· Do you feel you can use the tool by yourself? Is it relevant for you?
· Are you able to show another person how to use the tool? Is it relevant for you?
Experience
· How many times have you used this tool before?
· How many times have you used a similar tool before?
Credibility
· Do you believe the tool gives relevant results?
Other questions
· Do you have any suggestions how to improve the tool?
· Any other thoughts?

The interviews were recorded and transcribed. The representative parts of the interview deemed by the author were then made into a mind map. The mind map was structured into two orders, where the first order is blue squares, where quotes, opinions and figurative expressions are transformed into illustrations, and the second order is themes and topics, which is highlighted in red rhombus shape (Gioia et al., 2013). An example is shown in Figure 17. From the interview of the project architect, which has the same position as the author, the notion occurred that the first order is representative of the person and the second order is representative of the role. I.e. the themes and topics which occupy the mind of the interviewee when discussing the aspects of the tool are the same problems and tasks which the representative must focus on in their work, but the opinions regarding these themes may differ.

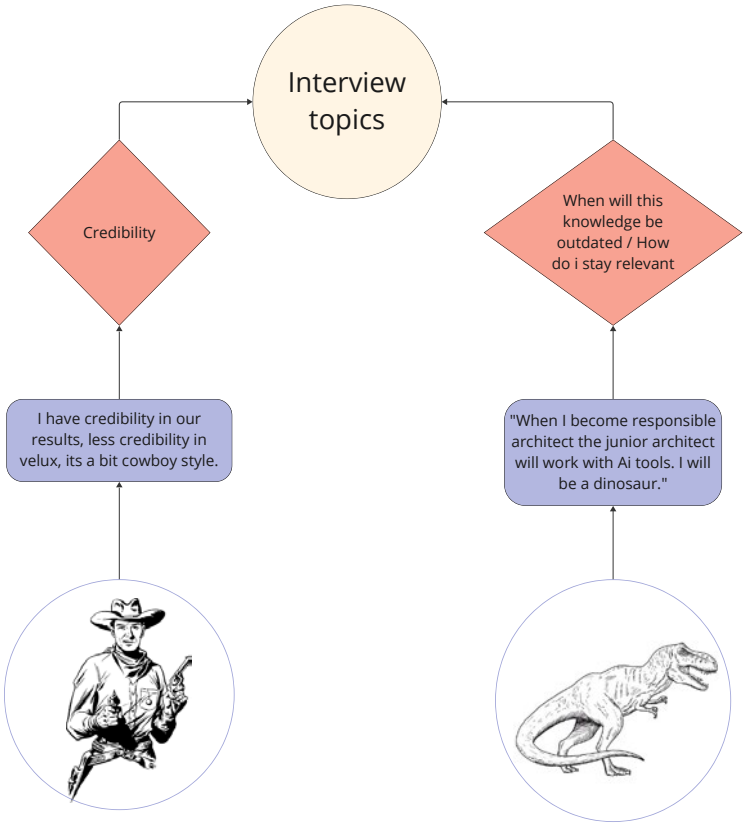


Figure 17. Example of a mind map, where the different levels are visible.

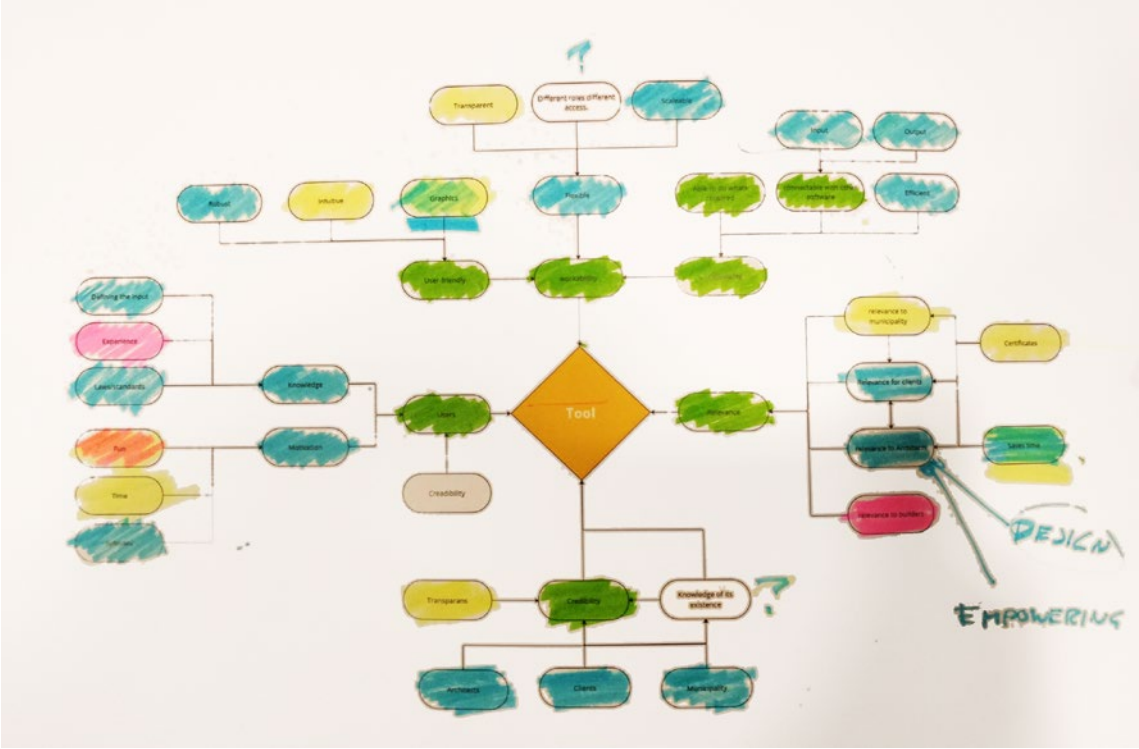


Figure 18. Filled in framework by one of the interviewees.

As a final step of the interview, the interviewee was asked to fill in the framework of the tool's needs, and to color each topic based on how relevant the interviewee perceived it from a scale of 0-4, where 0 was that the topic was irrelevant. The interviewee could also add new topics to the framework, which they thought was lacking. In Figure 18 a filled in diagram from an interview is shown, where the parameters Design and Empowering are added to what makes the tool relevant for architects.

3.2 Educational approaches

In Figure 19 the different educational approaches investigated experimentally are shown. The different approaches were selected and directed to different roles. The presentation is a time effective way to educate several people, where the topic can be discussed at a high level. The course and one-to-one is both directed to the user of the tool. As Mahmoud et al., (2020) states, the learning for the user can be divided into two, both the need for the user to learn the analysis method and the tool, where the course is intended for the analysis method whilst the one-to-one is intended to learn the tool. The course enables further depthh into each respective topic as more time can be allocated to the future users. The one-to-one is a problem-based learning approach which Banerjee & Graaff (1996) proposes for technical disciplines.

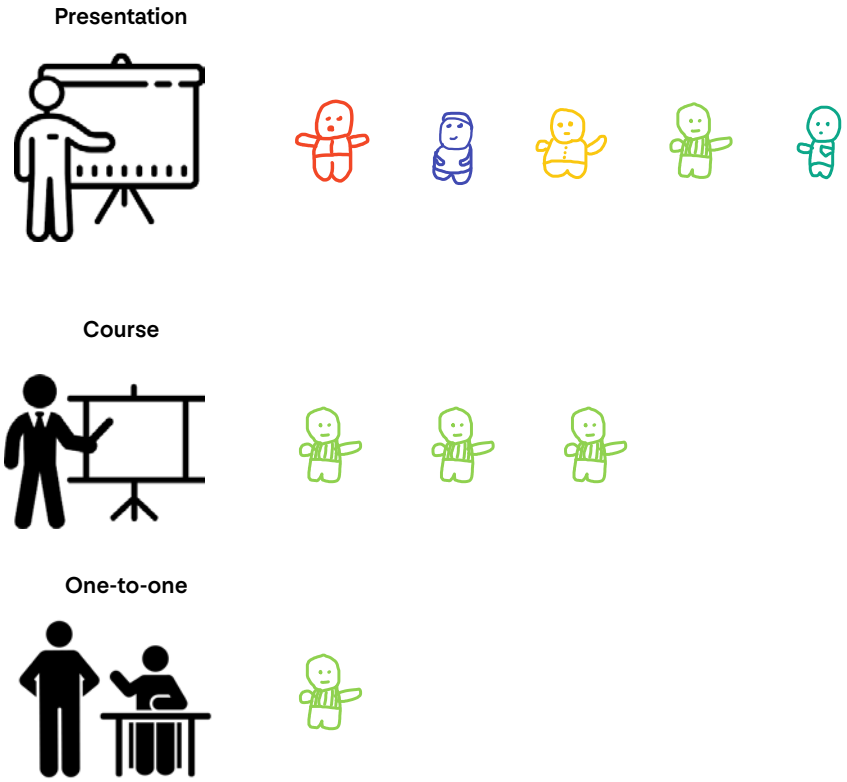


Figure 19. In the diagram the different educational approaches presentation, course, and one-to-one are displayed and highlighted to whom they are directed to.

3.2.1 Educational approach - Presentation

In an ambition to increase the knowledge in general regarding daylight to the entire company a presentation was held for 30 minutes during the office weekly meeting with everyone who works at the company. The presentation was directed at colleagues who do not work with daylight or perform the analysis and was therefore held at a more easily understandable level. The material presentation and the focus for the presentation can be explained by Figure 20. The material of the presentation is also stated in Table 2 and its relationship to the framework in Figure 20.

Table 2. Table of the presented topics and how they relate to the need of the tool framework.

Topics	Relationship to the framework
What is light – a general explanation of electromagnetic radiation, types of irradiances and the different units of light.	User>knowledge
Why is it relevant – health reasons, Folkhälsomyndigheten, The importance of light in architecture, safety, energy use, glare.	Relevance
Laws and certificates – How the planning process works in Sweden, Boverket BBR, arbetsmiljöverket and the design of the workplace, the new BBR rules which will be used 2025, different certificates.	Relevance->Clients Relevance-> Municipality
Daylight metrics – What different simulation methods there is and a general understanding of how a ray-tracing analysis work.	User>knowledge
Daylight history – How the daylight has been in our accommodations in different decades, and how the different global and national crisis has affected the daylight in Swedish buildings.	User>knowledge
Tools – What different tools there is to analyse daylight and a very general explanation of the tool utilised at the practice works.	Credibility
What affects daylight – What affects daylight and how the office can design buildings with better daylight condition, and when to proceed with caution.	User>knowledge

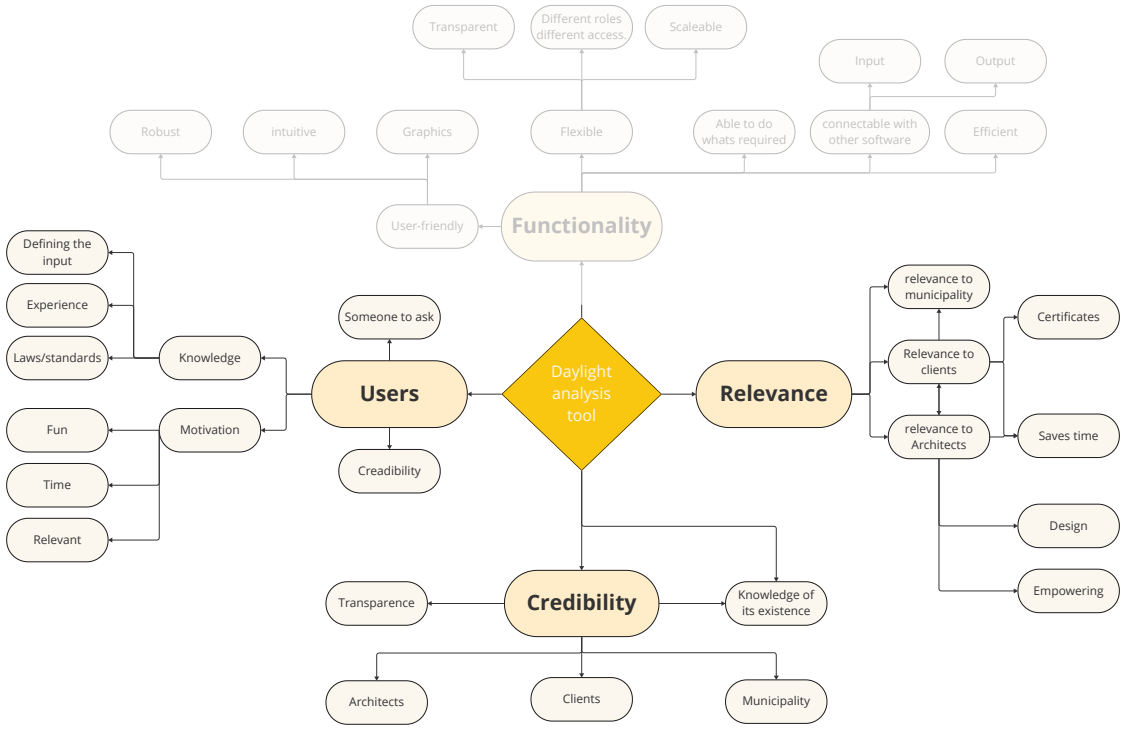


Figure 20. Framework of which topics which were presented at the presentation.

3.2.2 *Educational approach – course*

The course was given to the new users of the tool. Six people took the course, with a variation of experience and reasons. Some attendees asked for it, others were asked by the management to participate. The course was less focused on how the program is practically working and more on theoretical knowledge structured into the different topics in Table 3 below. The course duration was two hours, with a 15-minute break. A presentation was prepared with the topics as well as some exercises on how to define rooms, which is an important part of the daylight analysis, as the compliance for Swedish laws and certificates is room based. After the course the users were asked to perform a test for an additional two hours.

Table 3. Table of the presented topics and how they relate to the need of the tool framework.

Topics	Relationship to the framework
· Inspirational projects in regard to daylight	User->Motivation
· What is light	User->Knowledge
· Why is it relevant	Relevance
· What laws and certificates exist	Relevance->Clients & Municipality
· History of daylight in buildings	User->Knowledge
· Different daylight metrics	User->Knowledge
· What tools exist	Credibility
· What affects daylight	User->Knowledge
· How to create a daylight analysis model	Functionality (Brief)
· General tips and tricks	Functionality (Brief)

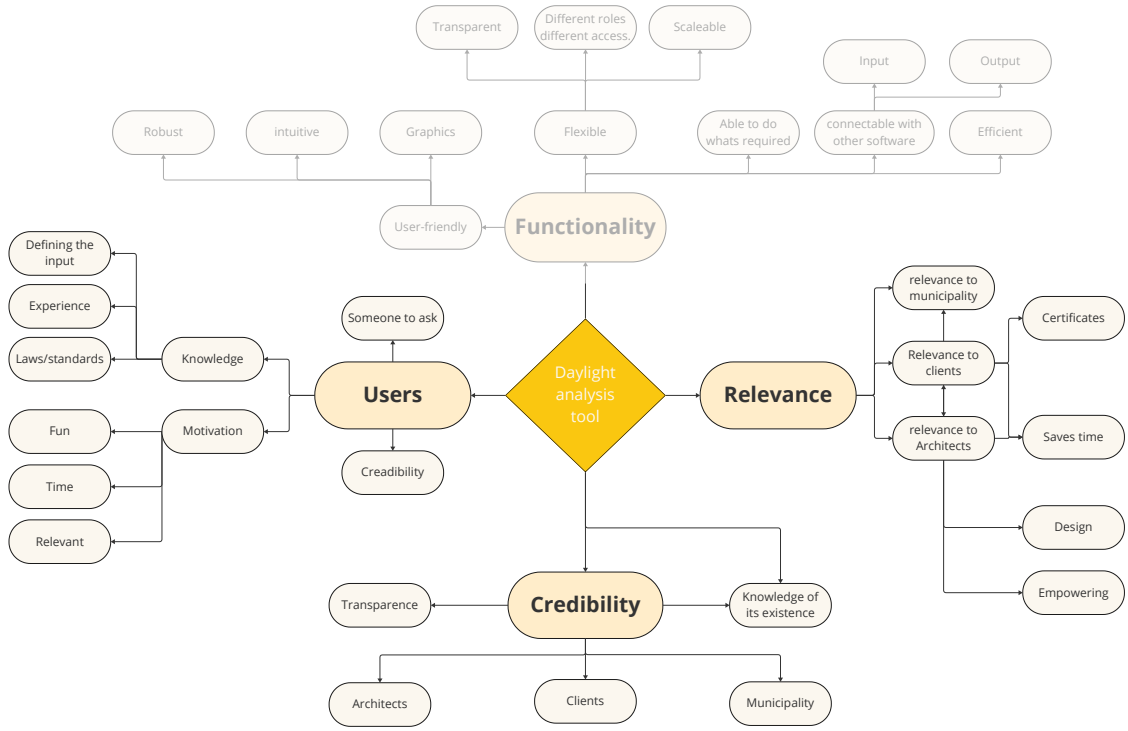


Figure 21. All the parts of the framework were explained during the course, but the focus was put on the topics users, relevance, and credibility.

In Figure 21 which parts of framework which was focused upon during the course. A specific objective with the course was to inspire and motivate the attendees why this kind of task is important, showing reference projects where daylight plays an essential part in creating the atmosphere in the buildings, as shown in Figure 22 and 23.

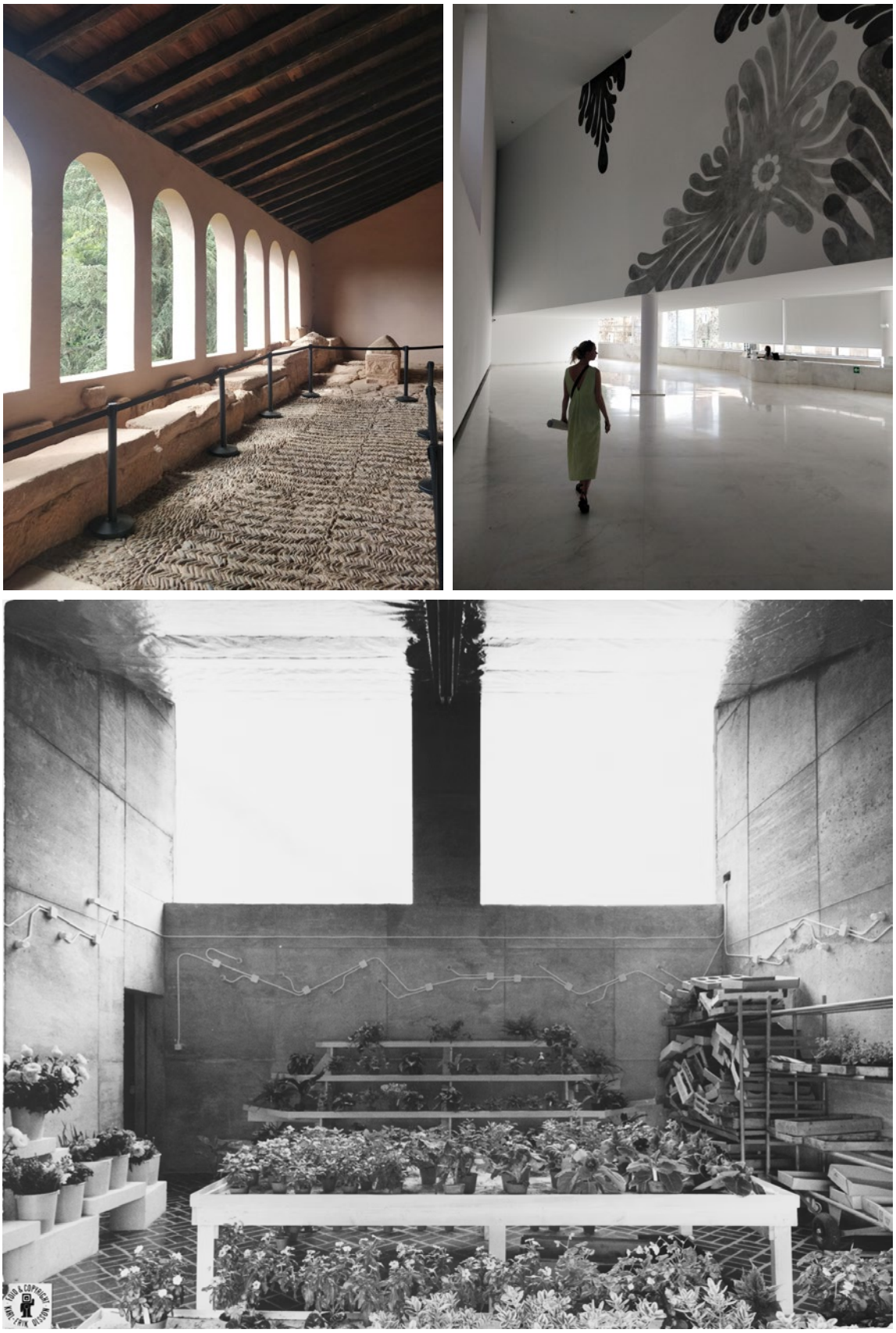


Figure 22. Example of inspirational projects. Upper left image; temple in Rioja, Spain. Upper right image; Contemporary Art Center of Galicia by architect Alvaro Siza. Lower image; Blomkiosk, Östra kyrkogården, Malmö by architect Sigurd Lewerentz.

Figure 23. Example of inspirational projects, Kunsthaus in Bregenz by the architect Peter Zumthor where light played an essential part of the design.

A second objective with the course was to highlight that getting results from the daylight analysis is relatively easy but verifying that the result is correct is an essential part of conducting this kind of work. The software is rather exposed and does not have the same kind of safety nets as more developed software's have, and its therefore especially important to be thorough in this kind of work.

As a final element in the course an exam was prepared, based on a previous task from the practice, where a client asked to refurbish an existing shop area in a building to apartments. The existing and proposed floor plan is shown in Figure 24. With an existing 3d geometry and a proposed new floor plan the attendees were asked to define the relevant rooms to consider in a daylight analysis and to run a daylight factor analysis and control if the Swedish regulations according to Boverkets byggregler was fulfilled, and submit the result in a simple presentation.

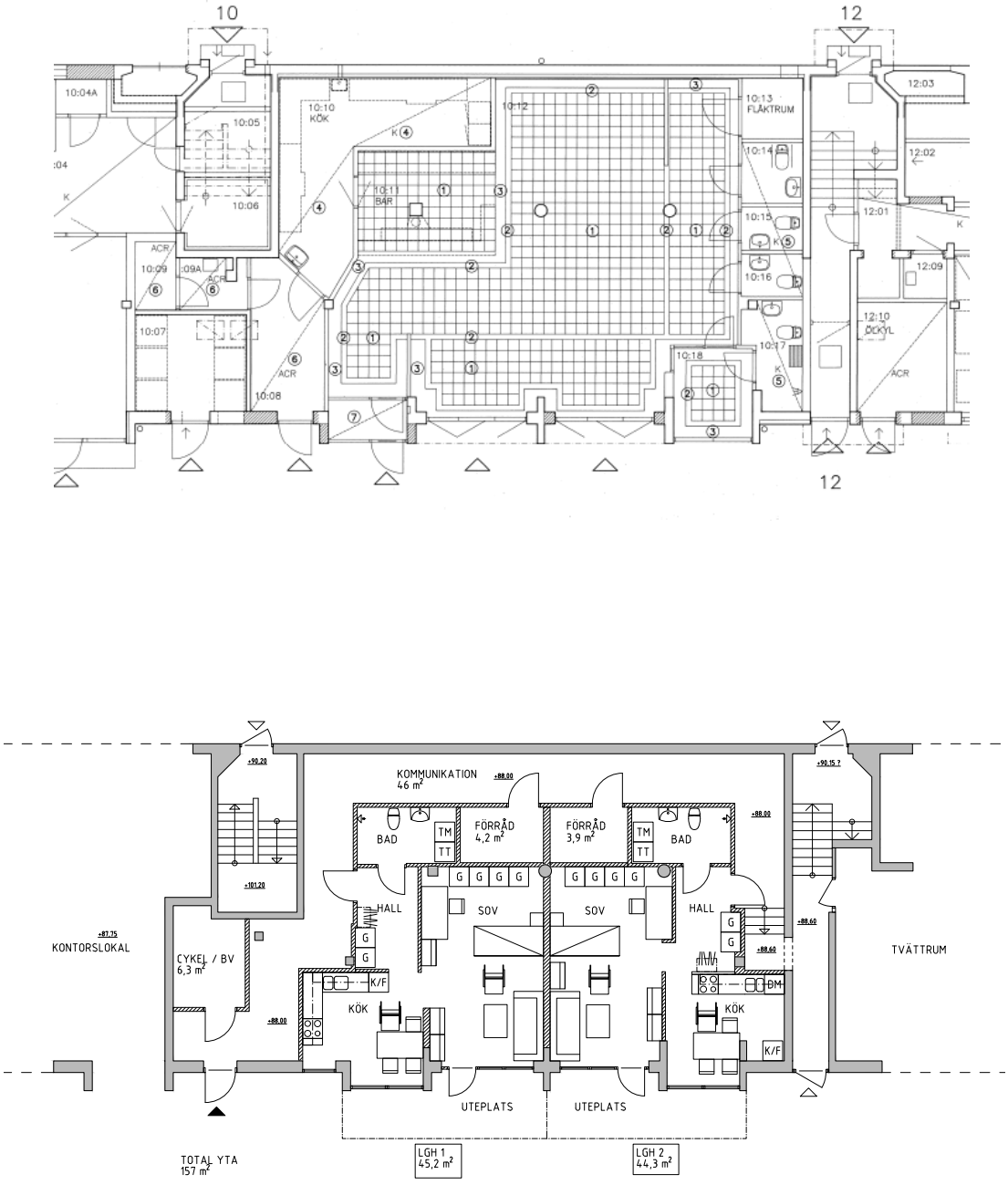


Figure 24. Original and new floor plan to be tested if it will pass the swedish boverkets regulations.

3.2.3 *Educational approach – One-to-one*

A well-practiced approach at the practice among others is the approach which will be called the one-to-one approach in this paper. It is performed by working on actual projects where the user learns the tool and tasks on the fly. The extra time the task takes is removed from the tender. This approach requires someone to ask and someone who verifies the results, which creates one-to-one sessions. In Figure 25, the different parts of the framework which are in focus are highlighted. All topics can come up, but the focus usually lies in user->knowledge->Defining the inputs and the functionality of how to use the tool.

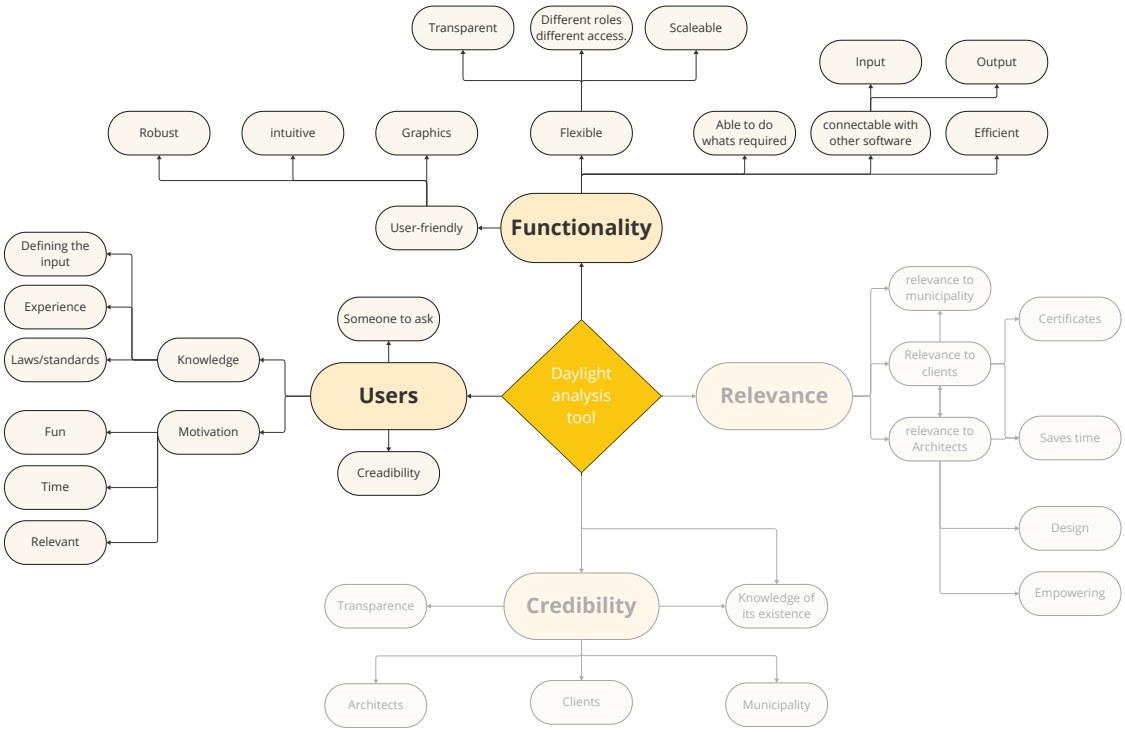


Figure 25. All the parts of the framework can be in focus during these sessions but the focus usually is on the topics users and functionality.

The process is different based on the project and the experience and working preferences of the user, but it always starts with an introduction meeting where:

- The project is explained.
- What is relevant to analyse in the projects.
- The context and input values which should be used.
- Which workflow will be beneficial for this project.
- Reference projects of the level of the result.

After the introduction meeting the instructor gets a more responsive role, where either the users ask when they need help, or the teacher needs to have regular checkups to manage the time and keep the task on the right track. Before the delivery of all material which is being delivered there is a control. In the scenarios where it is a new user it is more important to thoroughly go through the different steps of the tasks. For instance, the analysis model, the analysis settings, and the final presentation with the results.

3.3 Evaluation methods

One way of measuring an educational approach is to measure how well the user thinks they can utilise the tool. To measure the self-assessment surveys were used. To understand the effect of the different educational approaches the survey was sent out immediately after. For the course, a survey was sent out prior as well to be able to measure the difference. There were both multi option replies to questions, shown in Figure 26, and open reply questions shown in Figure 27. All surveys were anonymous to reduce the risk of dishonest replies.

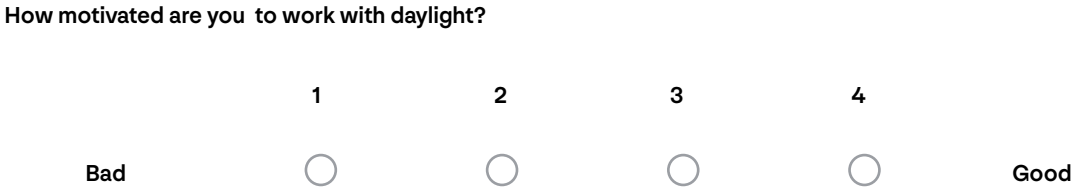


Figure 26. Figure of a four options question, where the responder is forced to be either positive or negative.

Figure 27. Question where the responder was asked to submit a short answer.

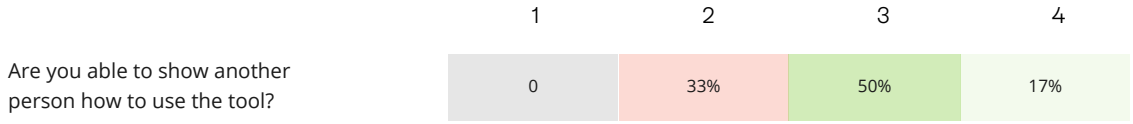


Figure 28. The multi option replies has been percentually divided into each answer option, and colored by the amount, more saturation equals higher percent, red equals lower score, green higher.

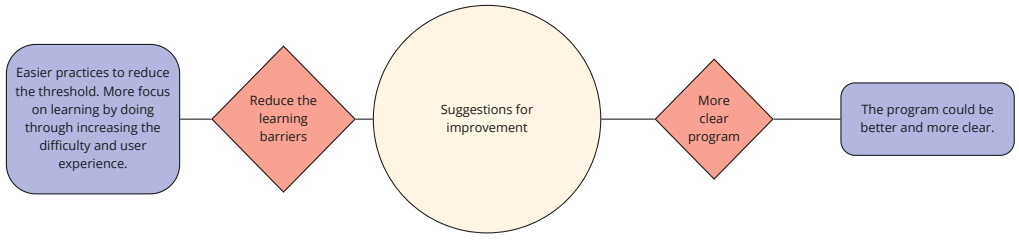


Figure 29. The reply questions were structured in the same manner as the interviews, where red rhombus are general topics and blue squares are personal opinions.

The results were then organised according to Figure 28 and Figure 29. According to Ward et al. (2002), the accuracy of self-assessment can be poor. Therefore, it is important to also consider other evaluation methods to increase the credibility of the analysis, such as expert raters (Ward et al., 2002). The author will in this case review the probability of the replies. The interviews will also be used as a complementary method to get a different perspective of the tool implementation and triangulate the evaluation to get a more qualitative result. (Natow, 2020).

Figure 31. Mind map summarising the interview with the representative of the management.

4. Results

4.1 Interview study

The results of the interview study have been divided by role. Where the mind maps, a summarisation of the interview as well as the answered framework are presented.

4.1.1 Interview with management

The representative from the management expressed the importance of using sustainability tools to inform our design rather than a retrospective check at the end of the design process. With these tools architects get empowered over questions such as window sizes, and it is also an easier workflow. It is also important to be able to offer more services to our clients, both with this existing daylight analysis tool but more functionalities would be good.

The respondent expressed that pen and pencil are good tools, it is communicative, intuitive, and easy to use. It is available for everyone to use and gives us the results we require from it. These are qualities which are good in design tools. The respondent expressed that in the management position it is necessary to know how long time a task takes, if we have the internal knowledge to perform it, what the tool costs and if it is available.

In the framework in Figure 32 the representative from the management added design and empowering as something which makes the tool relevant for architects. The user should not require experience nor feel joy when performing the tasks. It is important that the tool is connected to other software, user-friendly and able to do what is required. It is important that the tool is credible and relevant to clients and architects.

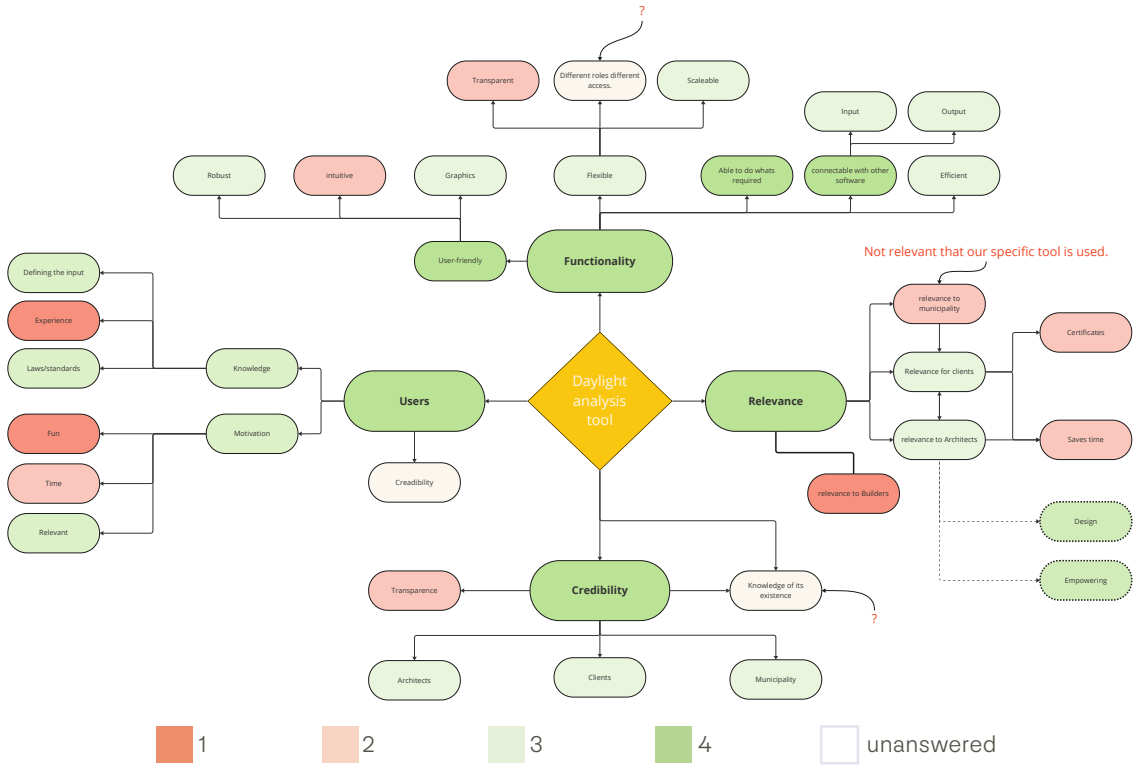


Figure 32. The framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by the representative of the management.

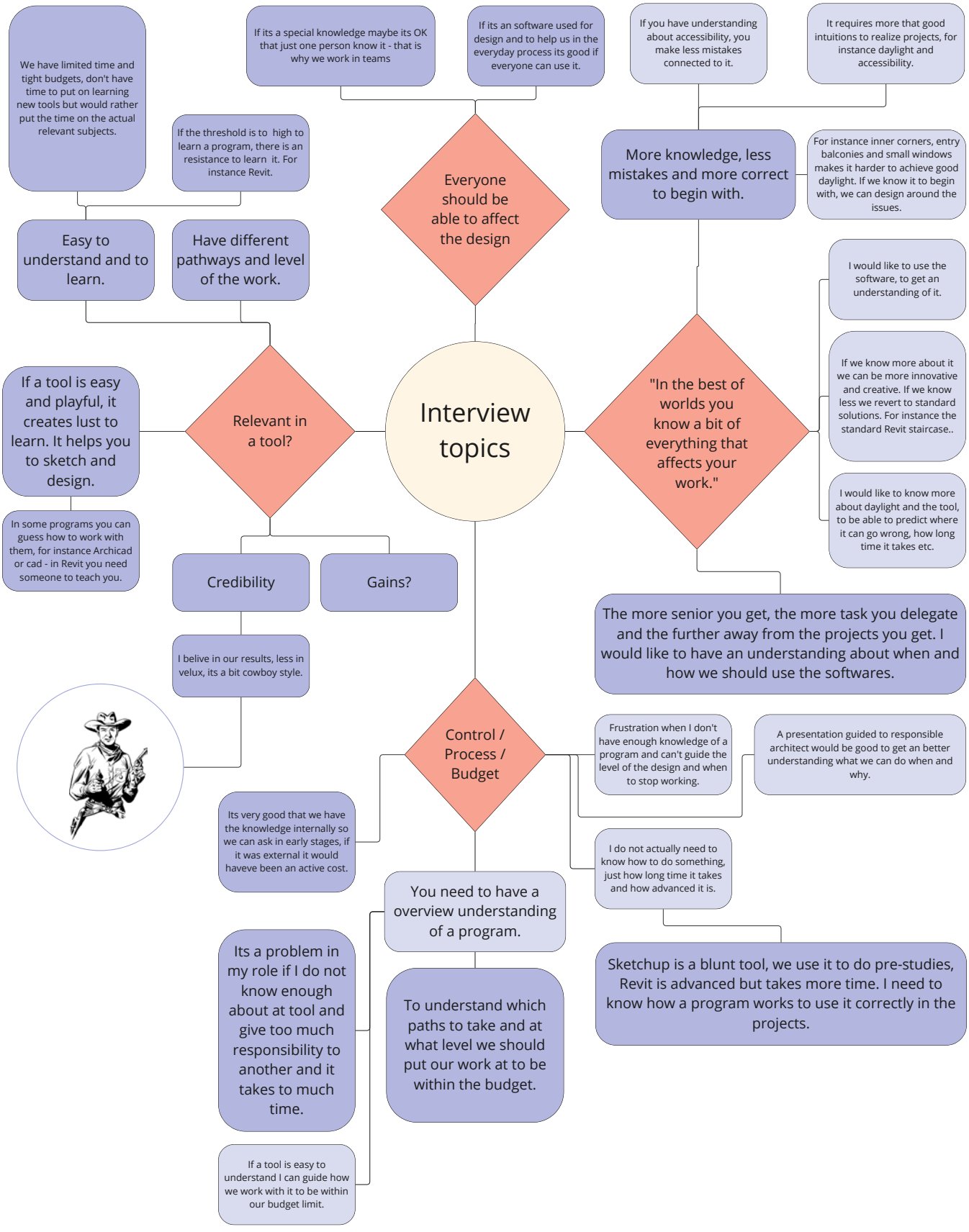


Figure 33. Mind map summarising the interview with the representative of the responsible architect.

4.1.2 *Interview with responsible architect*

The representative for the responsible architects wants design tools to be available for everyone, where everyone should be able to affect the design, but specific knowledge is OK if only specialists know and collaborate in teams. The respondent expressed that in the best of worlds everyone knows a bit of everything which affects your work. It reduces mistakes and makes it better to begin with. The tool should have clear benefits of using it and be credible. If it is easy and playful it also creates lust to use it. It should be easy to understand and learn. The more senior you get the less time you have and the more you must delegate and the further away from the projects you get, but she prefered to understand when and how the software's should be used.

In the interviewees' role they need to have control over the process and budget. They need to understand the possible pathways and possible level of the work. The same with a tool, they need to know how long time a specific task takes, so they can ensure that the work stays within the budget and the software is utilised correctly. It is very good that more competences exist internally, so it does not become an active cost to ask for tips.

For the interviewee most of the topics in the framework was relevant for a tool, but good graphics is not needed if it is user-friendly. Different roles do not need different access, but from the interview the interviewee stated the importance of different pathways and levels of the work, to keep the project within budget.

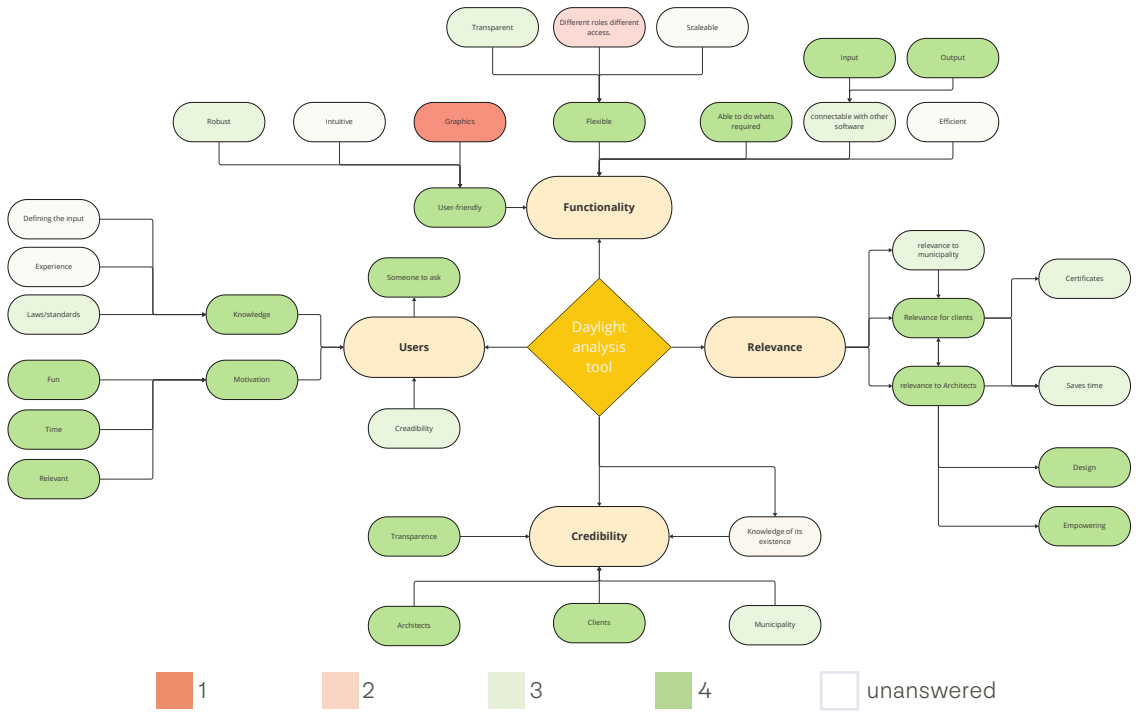


Figure 34. Framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by the representative of the responsible architect.

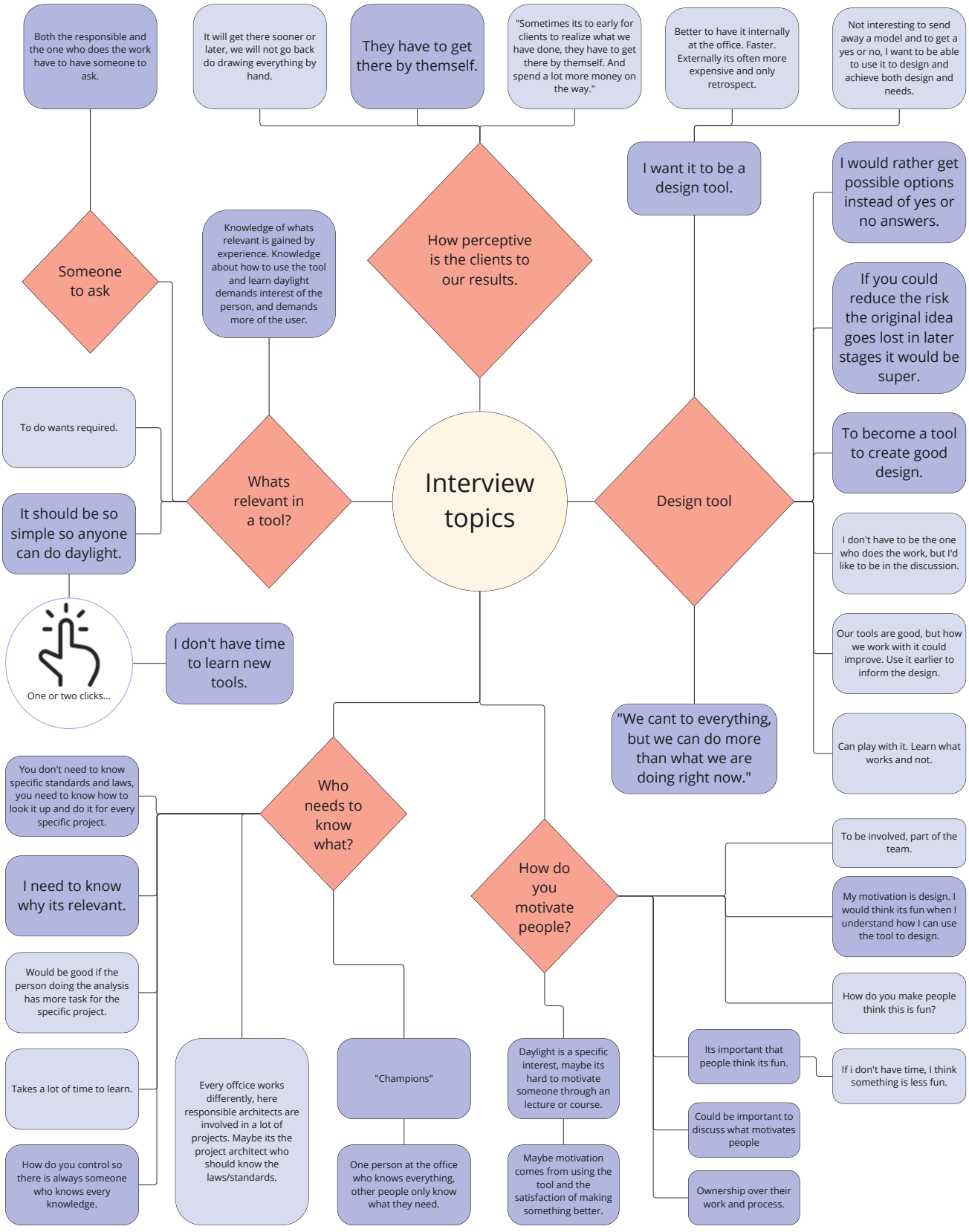


Figure 35. Mind map summarising the interview with the representative of the project architect.

4.1.3 *Interview with project architect*

In the interview with the project architect the topics surrounded how to be motivated and how to make others motivated by the work. She suggests that it could be worth discussing what makes people motivated to adapt the work according to their desires.

For the project architect creating good design was motivating and the tool would be more interesting to work with if it was a design tool and not a retrospective control of pass or fail. Is has improved since we gained the skills to do it internally since it is more expensive externally and only room to do a yes or no checkup.

The project architect expressed the lack of time to learn new tools and wants the new tool to be as simple as one or two clicks, so simple so anyone can do daylight. The need to have someone to ask for help also arises, where the need for a “champion”, i.e. someone at the workplace who knows the topic better and others can ask. The champion needs to know every part of the framework of the tool’s needs, whilst the project architect might only need to know why it is relevant.

The respondent also express that some client must find the path themself. It happens we propose a good design from the start, but it is too early for the clients to realise what we have done, sometimes they must get to the same solution by themself and spend a lot of time and money on the way.

The representative for the project architects agreed with most of the topics in the framework in Figure 36 but disagreed with the need for knowledge for users, as the tool should be possible to use without prior knowledge. The respondent also stated that credibility is something you gain whilst using the tool yourself.

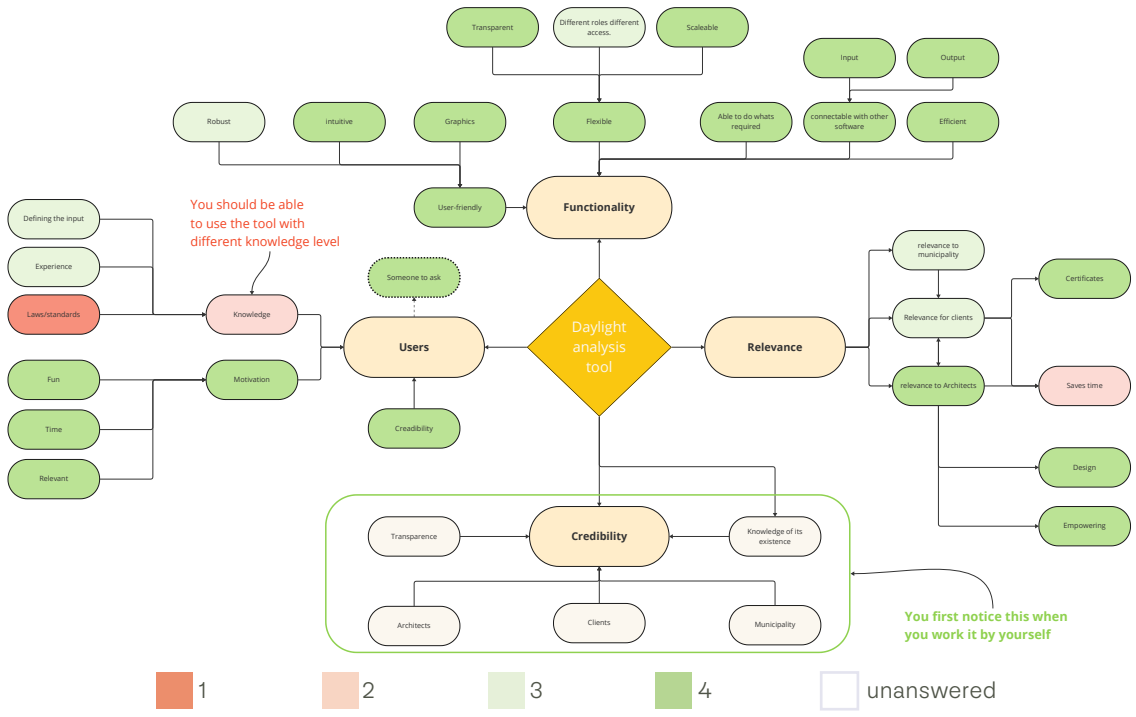


Figure 36. Framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by the representative of the project architect.

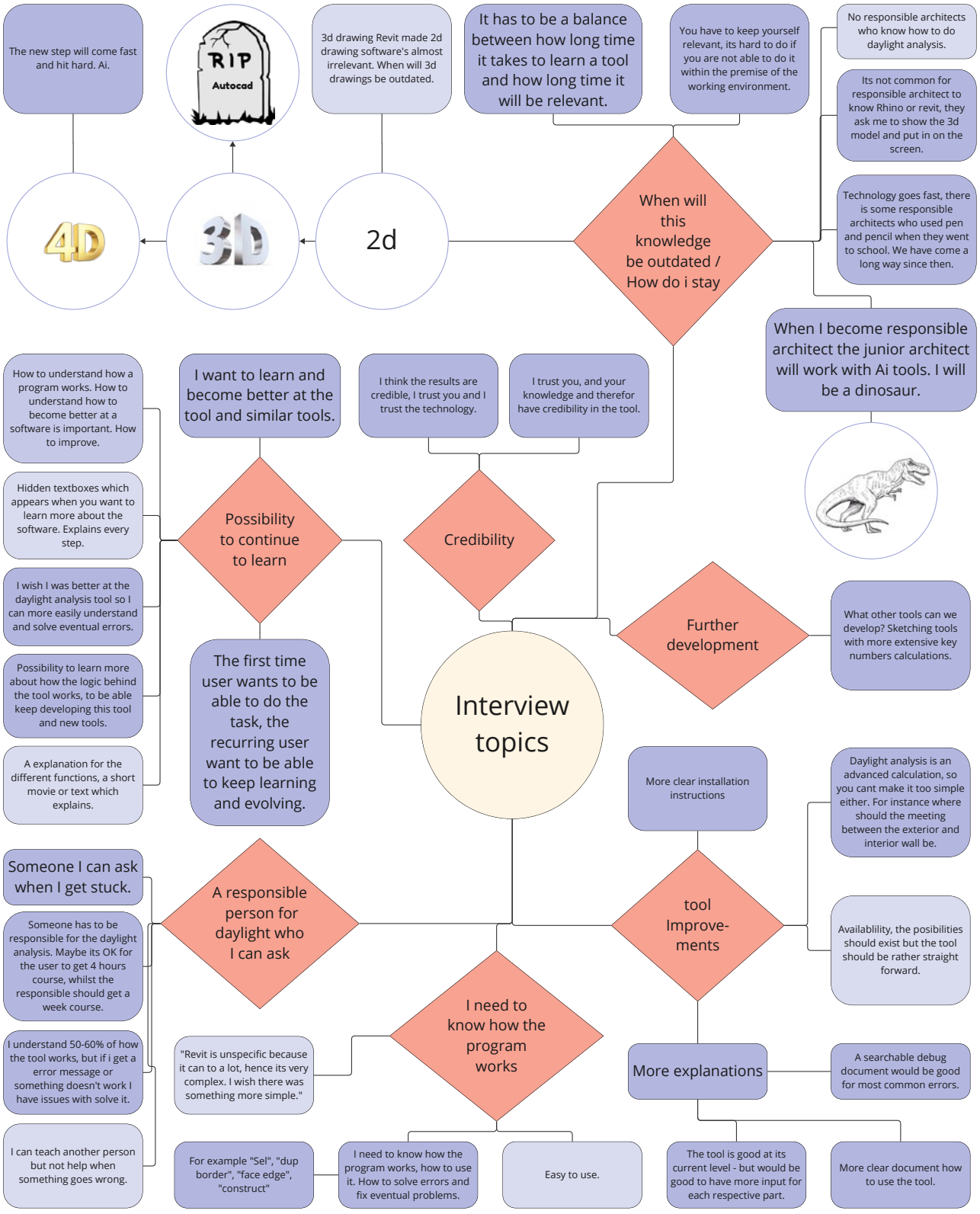


Figure 37. Mind map summarising the interview with the representative of the junior architect.

4.1.4 *Interview with junior architect*

The representative of the junior architect expressed the urge to be able to continue to learn, where the first-time user wants to be able to do the task, whereas the recurring user want to be able to keep learning. Different improvements to the functionalities of the tool were proposed, as well as an urge to keep learning new building performance tools.

The respondent described the need to know how the programs work and stated that several responsible architects do not know the actual software's but ask the junior architect to spin around in the model. The junior architect wonder when her knowledge would be outdated, and she would feel like a dinosaur. Some responsible architect worked with pen and paper in the beginning of their careers, where the 2d and 3d CAD software's changed the tool scene. Now AI influence a new set of tools and a new way of working.

The junior architect stated the importance of having a person who she could ask and described the need for a "champion" user who could help. For the representative the credibility of the tool was interlinked with the credibility of the author.

The representative highlighted the importance of having someone to ask for the users, someone who should have in depthh knowledge regarding the required knowledge of the users as well as in depthh knowledge of how the software works and to be able to debug if an error occurs.

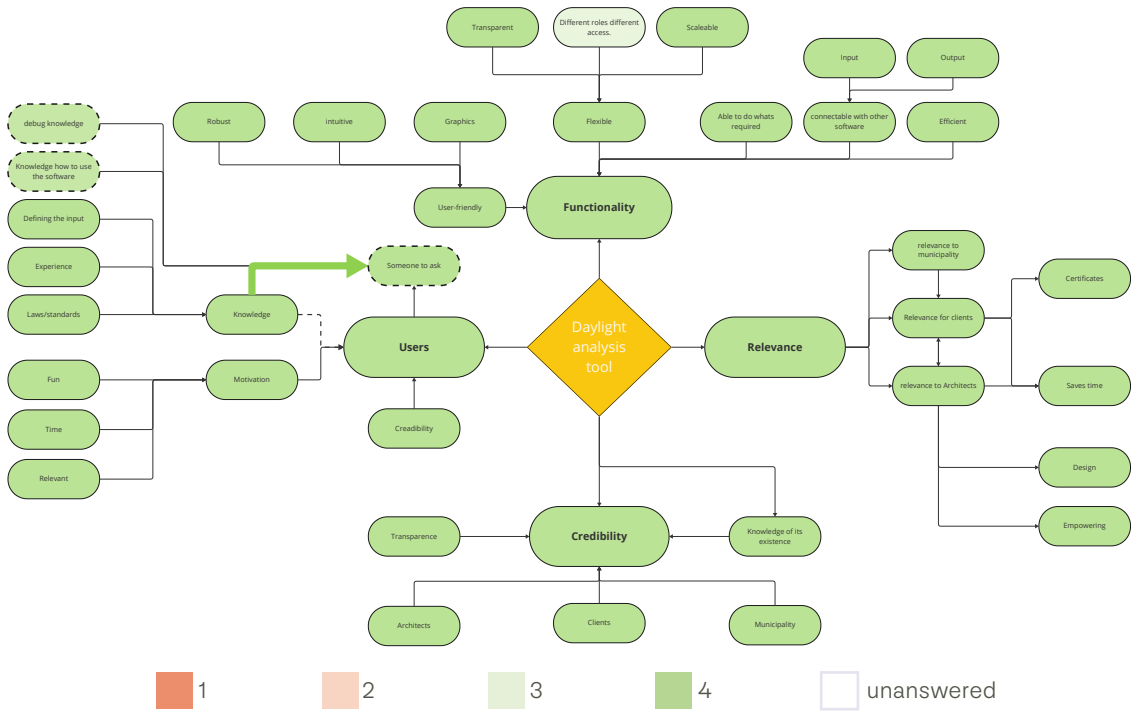


Figure 38. Framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by the representative of the junior architect.

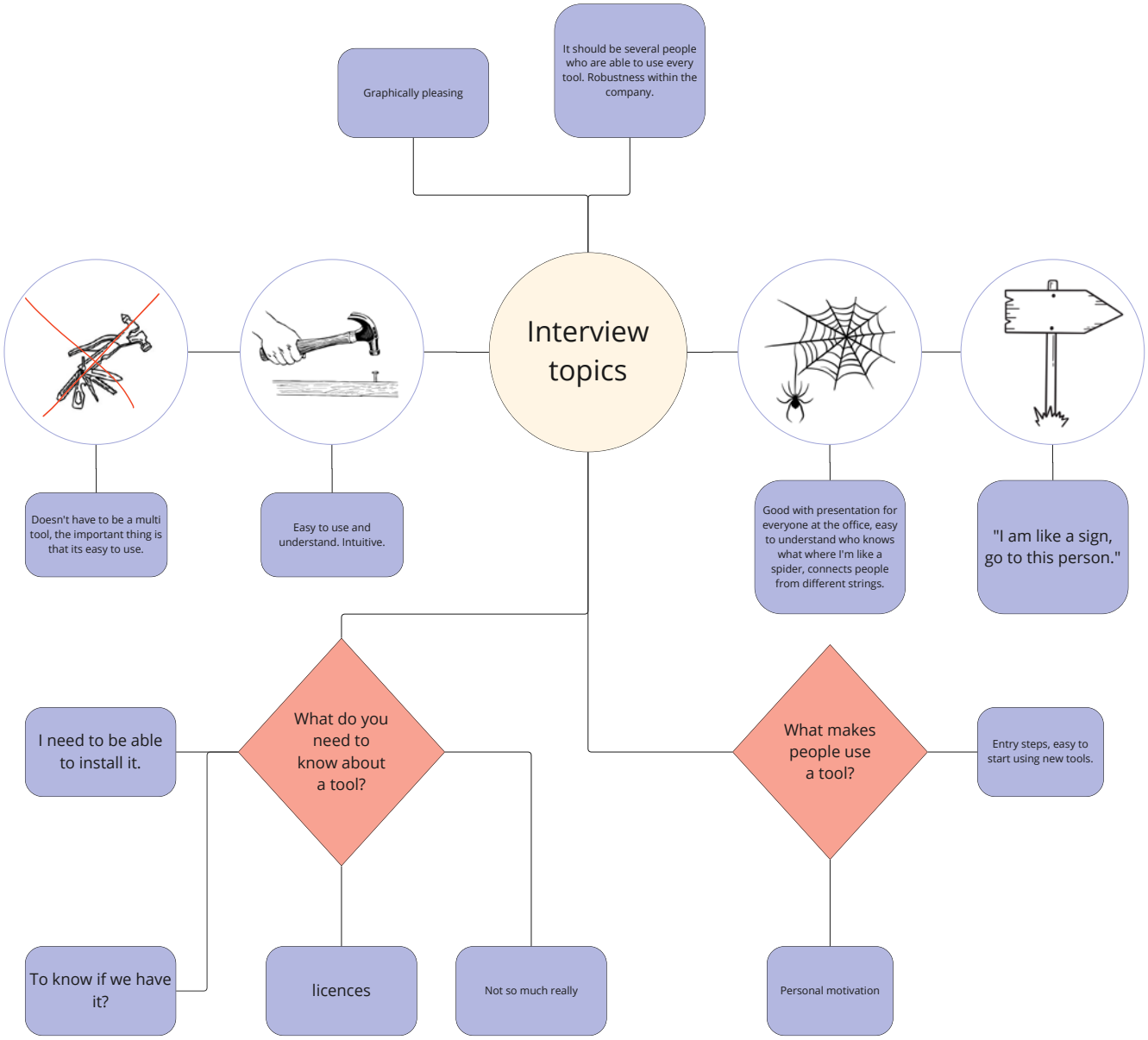


Figure 39. Mind map summarising the interview with the representative of the support group.

4.1.5 *Interview with support*

The support representative expressed the importance of distributing general information through presentation for the entire office. The support group has a need to know who knows what and functions like a spider in the net, who connects people from different strings, or like a sign who directs people.

The interviewee also expressed the need to be able to install the software and to understand if we have it, how licenses work. To know everything which makes the utilisation of the tool as smooth as possible.

The representative for the support group expresses the need for a good tool to be easy to use and intuitive, and it can rather just do one thing - as the hammer's purpose to hit the nail, rather than a complex multi-tool which is hard to use. The importance of keeping competence within the office, where several people should be able to use every tool, so if someone leaves their competence is not lost.

The interview also ventured into the topic of what motivates people to use a certain tool. Some suggestions were personal motivation and entry steps, which makes it easy to start using the new tool.

The respondent agreed with most of the topics in the framework in Figure 40, but not the need for users to know about laws and standards, that amount of time the user has affects the motivation and that knowledge of the tool's existence affects its credibility.

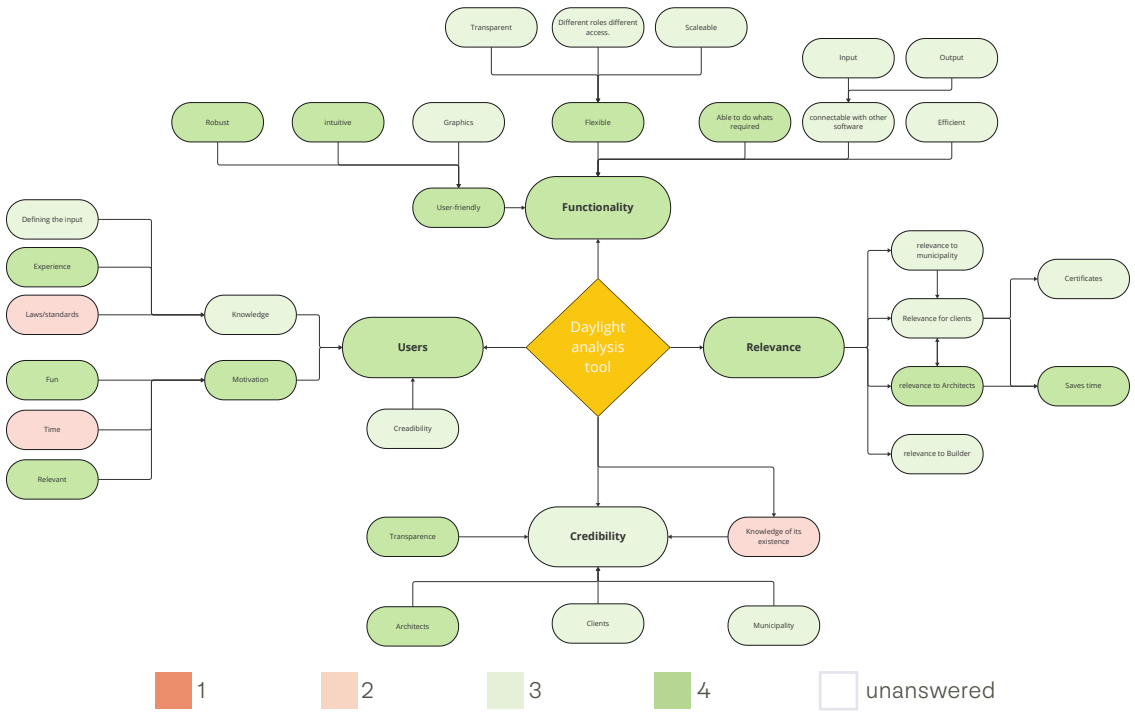


Figure 40. Framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by the representative of the support group.

4.1.5 Interview conclusions

It is apparent from the interview study that the needs regarding building performance tools are different depending on which role you have. For instance, how eager and how much time you have available to learn a new tool. The more senior roles, the management, responsible architect, and project architect, expressed lack of time as a reason for not being able to learn new tools even though they wished to be able to do analysis. They expressed a need for the new tools to be very fast to learn. The junior architect on the other hand expressed the urge to become better and learn more tools.

The representative for the project architect stated:

> "Knowledge of what is relevant is gained by experience. Knowledge about how to use a tool and learn daylight demands personal interest. It requires more of the user. It requires motivation."

The project architect brought forward motivation as an important aspect both in learning a new tool and continuing to perform tasks at a good level, which in turn puts demands on how the tool functions. Whereas the representative of the responsible focused on how to be able to keep the project within budget, and to know how long a task takes to perform and at what different levels you can conduct the work.

> "In the best of worlds, you know a bit of everything that affects your work."

Another aspect brought up was that everyone should feel included in the design tasks, and if the building performance analysis tool is something which affects the design it should be available for everyone. An aspect the representative from the management brought forward was the need for new tools and to sell the services better. The support group expressed the need to know about the tool in general to be able to direct people within the company to the responsible person for the field. Also, the need for easy manageable license services and easy installment process of the software.

Both the project architect and the junior architect stated the need for users of the tool to have someone to ask. They described the concept of a product champion, a person who pushes the development of the tool as well as have expertise who you can ask. In several of the interviews it was highlighted that the interviewees had credibility in the tool because they had credibility in the author. If the author is regarded as a product champion, the concept of product champions may be linked to the credibility of the tool.

Figure 41 is a combination of all the replies regarding the framework from the interviews. The joint answers highlight that most of the topics is relevant, and the most relevant topics is motivation for the users, the tools' relevance for architect where design and empowering are relevant factors. Factors which is extra important for the tool's functionality are user-friendliness, flexibility, able to do what is required, as well as connectivity with other software's.

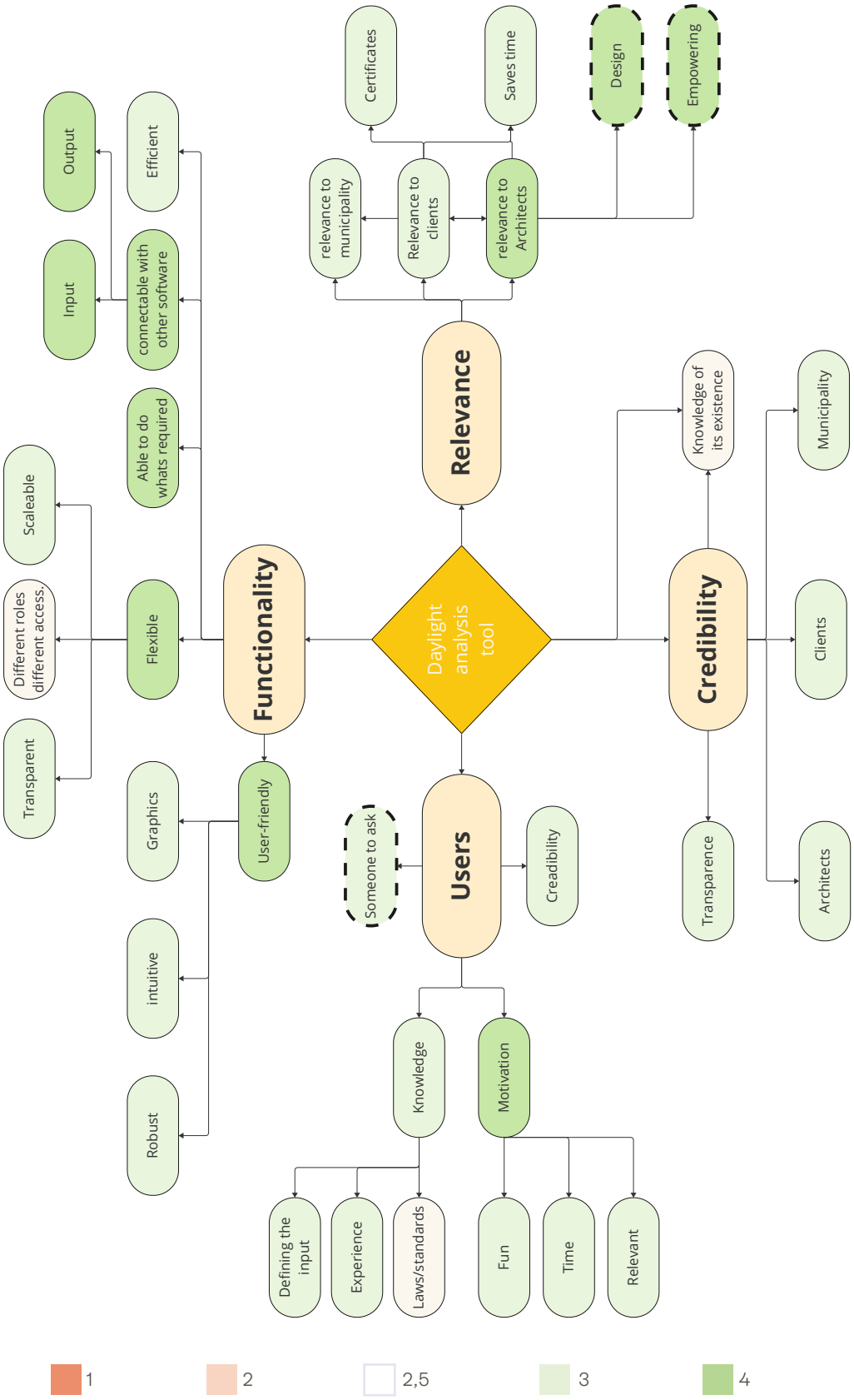


Figure 41. Framework colored from 1-4, from dark red to dark green, of how relevant each topic is for the tool defined by average of the representative's answers. Dashed lines are added topics where everyone have not been able to respond, where a 2,5 response have been inputted.

4.2 Presentation results

After the presentation a survey was sent out immediately with 30 people responding. The representation of each respective role at the office is displayed in Figure 42. Even though the presentation was directed to management, responsible architect, project architect and support, all the office listened to the presentation. The response from project architect accounted to almost half of the responders, which can be explained by the fact that there is more people working in this role at the office.

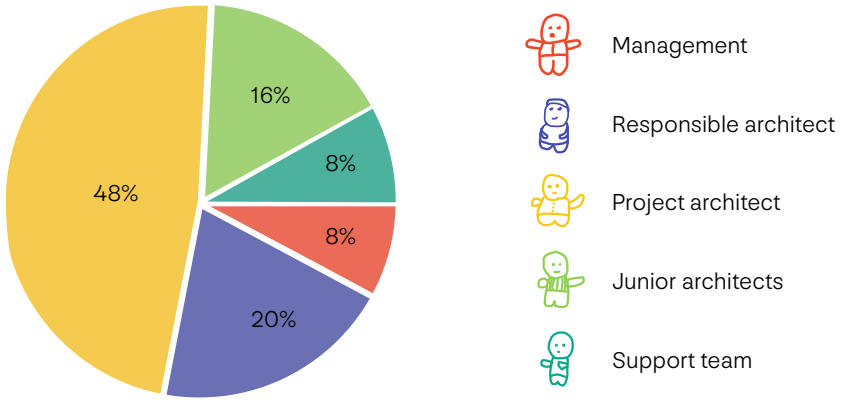


Figure 42. Diagram of the representation of the role of the responders.

The survey had two focus areas, the first one was to map the general knowledge of daylight, daylight tools, motivation of the colleagues. To further understand where further approaches should put extra effort. The second focus area was an evaluation of the presentation itself and how it could be done better the next time.

4.2.1 Self-assessment after presentation

Since there was not a survey made in advance of the presentation it is not possible to compare the results or evaluate if the presentation affected how the responder answered the survey topics in a positive or negative manner. One intention with the presentation was to increase the motivation to work with daylight. The motivation to work with daylight is almost 50/50, with a slight inclination towards “better”.

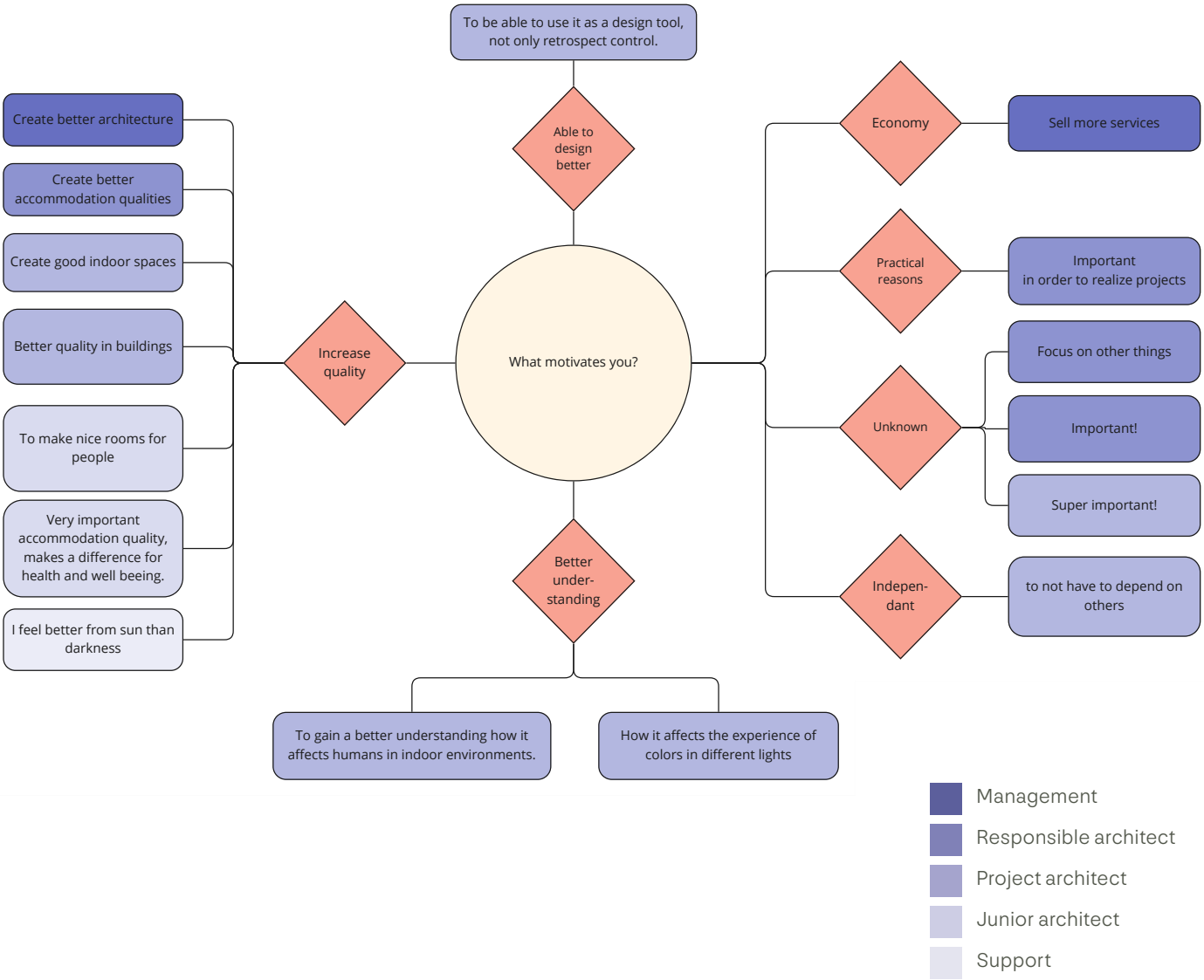


Figure 43. Framework showing what motivates each responders colored by each of the responders role at the company and grouped by topics.

	1	2	3	4
Management	0%	50%	0%	50%
Responsible architect	40%	0%	20%	40%
Project architect	0%	50%	50%	0%
Junior architect	0%	40%	60%	0%
Support	0%	50%	50%	0%
Everyone	8%	38%	42%	12%

Figure 44. Diagram of how motivated each role of the office is to work with daylight on a scale from 1-4, i.e. low to high.

The question was as well asked directly, *What motivates you?,* where the results are shown in Figure 43. Most of the responders stated answers related to increased quality, with representation from each respective role. One representative from the management stated economy as motivation. To understand or be able to design in a better way motivated a few project architects. A responsible architect stated practical reasons as motivation, as daylight analysis is needed to realise the projects.

The self-assessment of people's knowledge of daylight visible in Figure 45 was more negative than positive. Since the presentation was a lighter version of the course material, where each topic was explained more briefly, maybe this influenced how well the responders felt they knew the topic. The bigger picture was explained, but the specifics were not delved into. It is interesting although that junior architect, the employees with the least experience, felt they had the best knowledge regarding the topic, whereas the responsible architect, the architects with the most experience, felt they had the least knowledge regarding the topic. This could be explained with the Dunning–Kruger effect, where people with limited competence in a specific topic overestimate their ability.

	1	2	3	4
Management	50%	0%	50%	0%
Responsible architect	0%	60%	40%	0%
Project architect	17%	50%	33%	0%
Junior architect	0%	40%	60%	0%
Support	50%	50%	0%	0%
Everyone	15%	46%	39%	0%

Figure 45. Diagram of how well each role estimate their knowledge of daylight on a scale from 1-4, i.e. low to high.

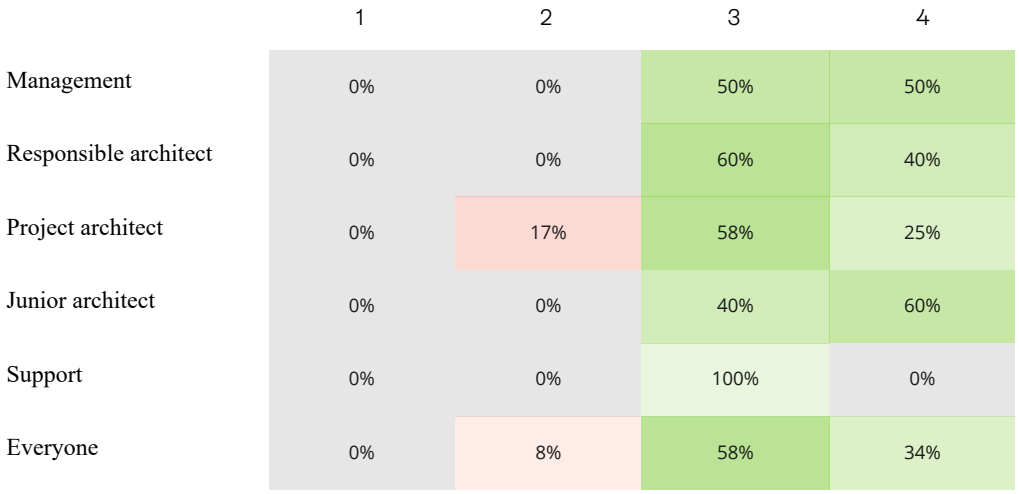


Figure 46. Diagram of how well each role estimate their knowledge of the relevance of daylight on a scale from 1-4, i.e. low to high.

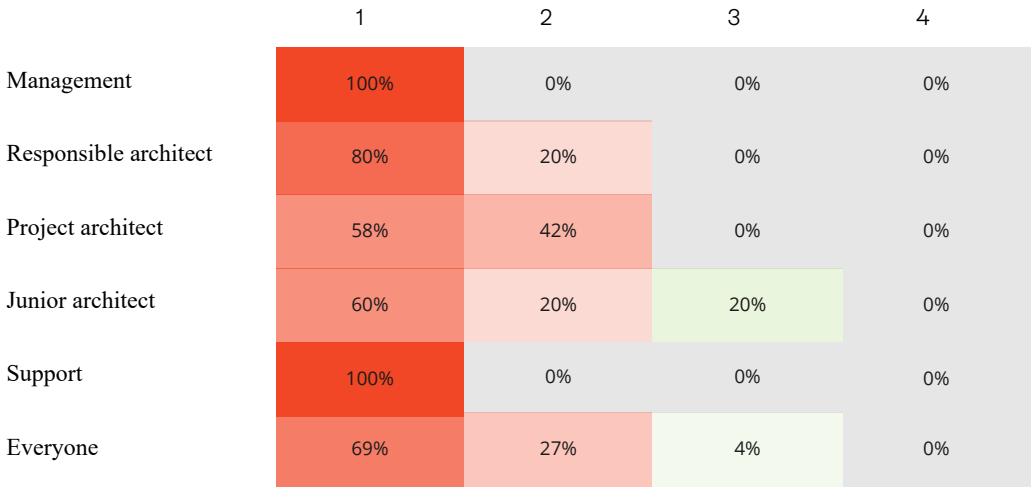


Figure 47. Diagram of how well each role estimate their experience of our internal daylight tool on a scale from 1-4, i.e. low to high.

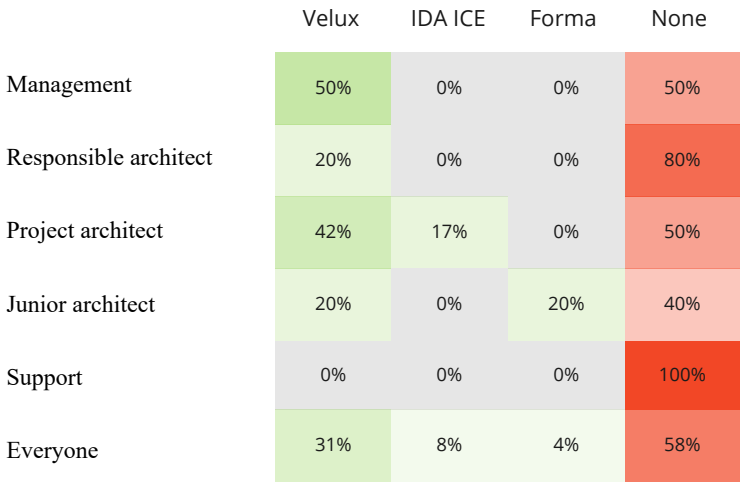


Figure 48. Diagram of if previous experience exist from other softwares, yes or no.

The understanding of why daylight is relevant to work with was overall good within the office according to their self-assessment visible in figure 46, again best amongst the junior architects and lower for responsible and project architects.

	1	2	3	4
Management	0%	0%	50%	50%
Responsible architect	0%	0%	40%	60%
Project architect	0%	17%	50%	33%
Junior architect	0%	0%	80%	20%
Support	0%	0%	50%	50%
Everyone	0%	8%	54%	38%

Figure 49. Diagram of how well each role estimate their trust in our internal daylight tool on a scale from 1-4, i.e. low to high.

Overall, the trust in the daylight too is good, shown in Figure 49. Since it is something created by the author this has been something important to focus on in the presentation. Although from the results from this survey as well as from replies from the interview this does not seem to be an issue for others. One comment from the support group stated how the writer speak regarding the daylight topic creates credibility for the work. Which creates the question, is the credibility of the tool interlinked with the credibility of the developer and in extension, the user of the tool.

Shown in Figure 47, the experience of the internal tool is very low, which makes sense since very few have used it. A few junior architects have stated that they can use the tool better, which most likely are the ones who have been given the course regarding the daylight tool. In Figure 48 experience from other tools was measured. One third of the responders had used Velux, but the credibility for that software was stated very low in the interviews with the representative from management, responsible architect, and Project architect. A “cowboy-style” software. Other tools which had been used by very few were IDA ICE and Forma.

4.2.2 *Evaluation of the presentation*

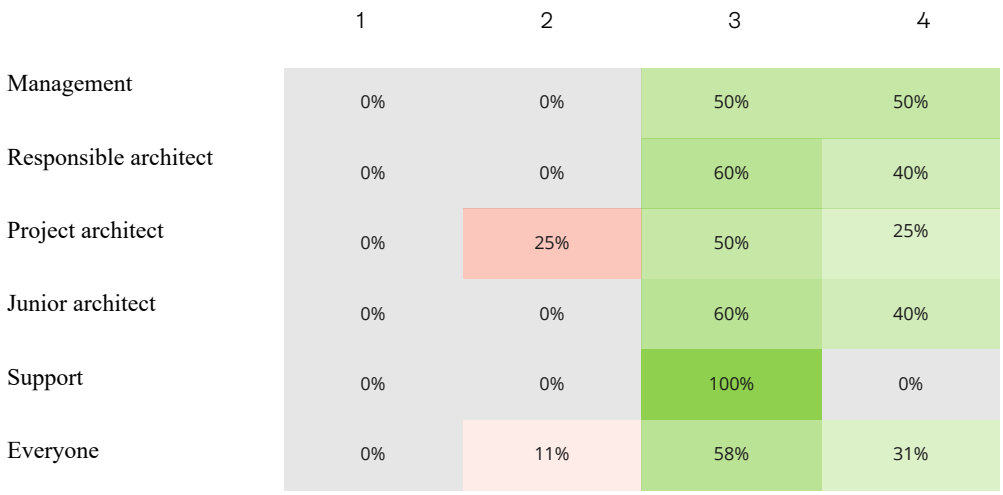


Figure 50. Diagram of how well each role estimate how their general daylight knowledge was affected by the presentation on a scale from 1-4, i.e. low to high.

Shown in Figure 50, almost everyone, 89% of the responders stated that their knowledge increased by the presentation, except for 25% of the project architect. Most of the responders stated that the presentation increased their knowledge of why daylight is important, but a few thought it did not, from the project architects and junior architects, visible in Figure 51.

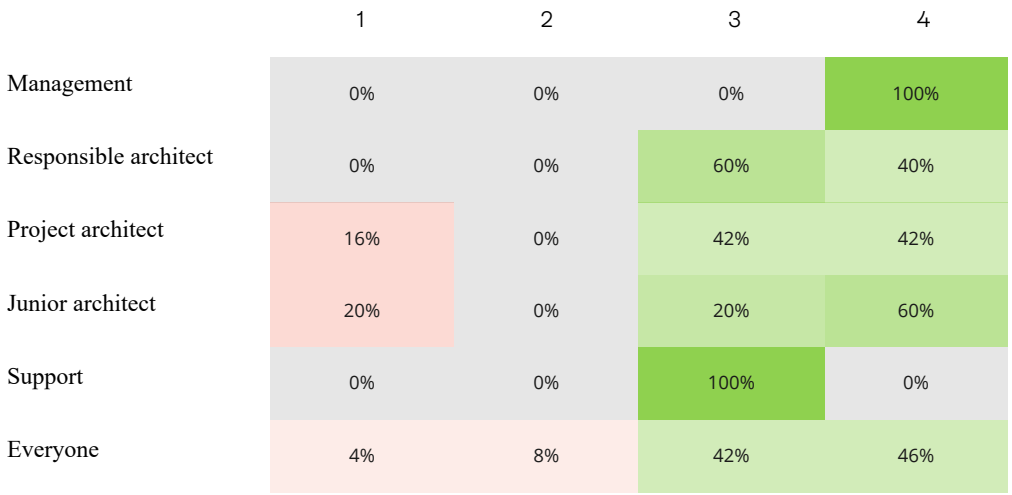


Figure 51. Diagram of how well each role estimate how their knowledge regarding the relevance of daylight were affected on a scale from 1-4, i.e. low to high.

	1	2	3	4
Management	0%	0%	0%	100%
Responsible architect	0%	0%	60%	40%
Project architect	0%	17%	50%	33%
Junior architect	0%	0%	40%	60%
Support	0%	0%	100%	0%
Everyone	0%	8%	50%	42%

Figure 52. Diagram of how well each role estimate how their motivation to work with daylight was affected by the presentation on a scale from 1-4, i.e. low to high.

As stated before, one goal with the presentation was to increase the motivation to work with daylight, which the Figure 52 shows. Almost everyone stated they were more motivated to work with daylight after the presentation, but according to the response how motivated they were to work with daylight the replies were 50/50 negative respectively positive.

Two thirds of the responders stated that the general relevance of the presentation was good shown in Figure 53. One representative of the support team felt the presentation was less relevant.

	1	2	3	4
Management	0%	0%	50%	50%
Responsible architect	0%	0%	20%	80%
Project architect	0%	0%	25%	75%
Junior architect	0%	0%	20%	80%
Support	0%	50%	50%	0%
Everyone	0%	4%	31%	65%

Figure 53. Diagram of how well each role estimate the general relevance of the presentation on a scale from 1-4, i.e. low to high.

Suggestions for improvements were also given and sorted into topics and by the role of the responders in Figure 54. The time aspect was mentioned, one representative of the management role wanted it to be a bit less detailed and faster whereas one of the junior architects wanted it more in depth. Several responders from junior architects and Project architects wanted more examples from realised projects in the presentation. Better graphics in the presentation was also asked for as well as a searchable document where you can find answers. One issue with such a document is that it is going to be a lot of work to keep it updated since the information continues to update. Responsible architects would like help with sell arguments for daylight in early stages.

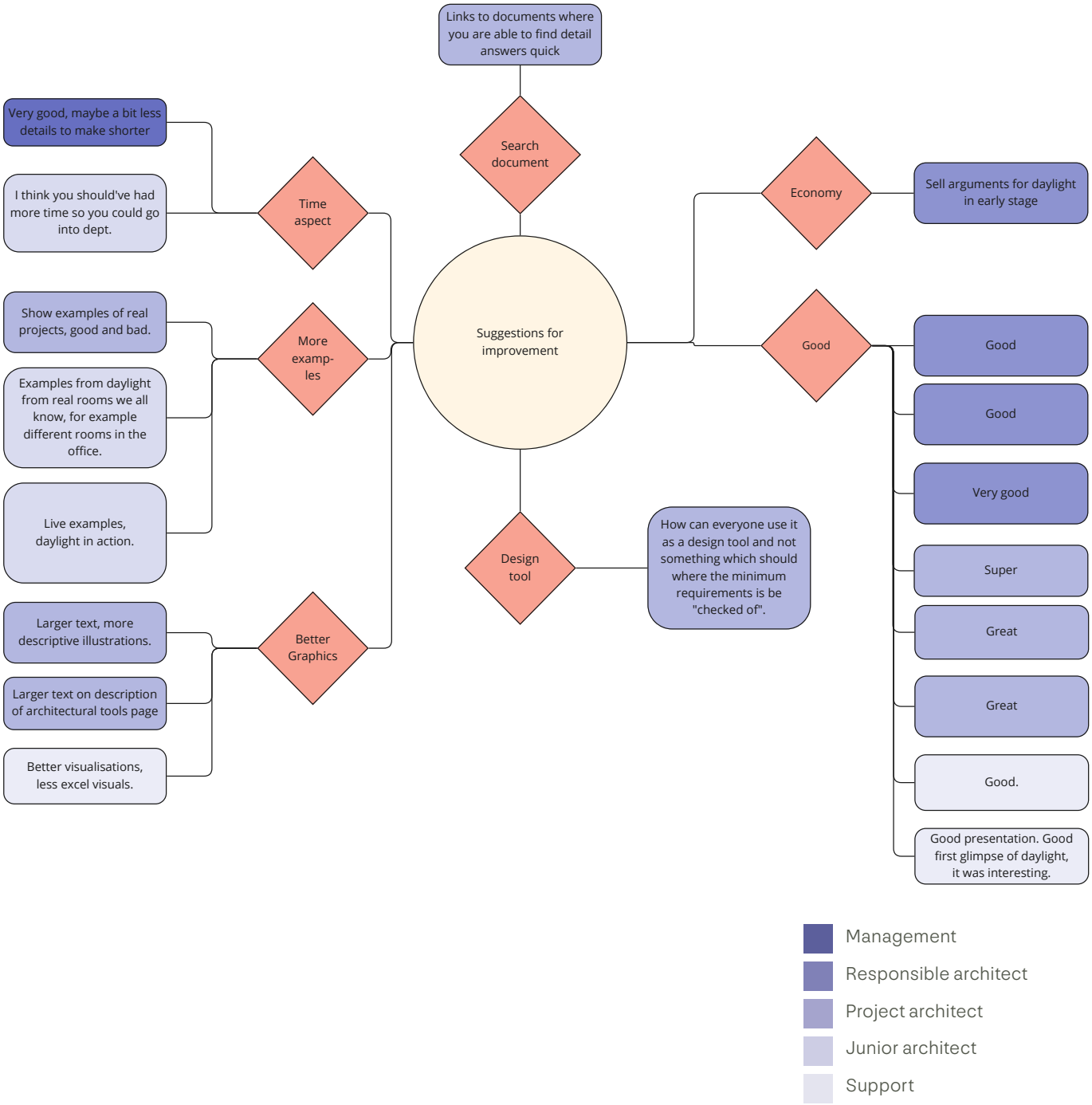


Figure 54. Diagram of suggestions for improvements after the presentation.

4.2.3 Presentation conclusions

The response was generally very good from the presentation for everyone who works at the office. Every role at the office has their own responsibility to get the tool used. The seniors need to know how to sell the service, when it is relevant to use it, and how to motivate more junior architects to learn the tool. The more junior architects have a higher demand on their motivation and interest to learn the new tool. The presentation did not cover how the software functions, but rather the parts surrounding it, why it's relevant, what users need to know and the credibility of the tool.

4.3 Course results

Two surveys were sent out during the course, before and after. There were six people attending the course. At the end of the course a home exam was held, with two people finishing it. Both surveys asked the same questions, to measure how the course affected their self-assessment of their competence.

4.3.1 Self-assessment after the course

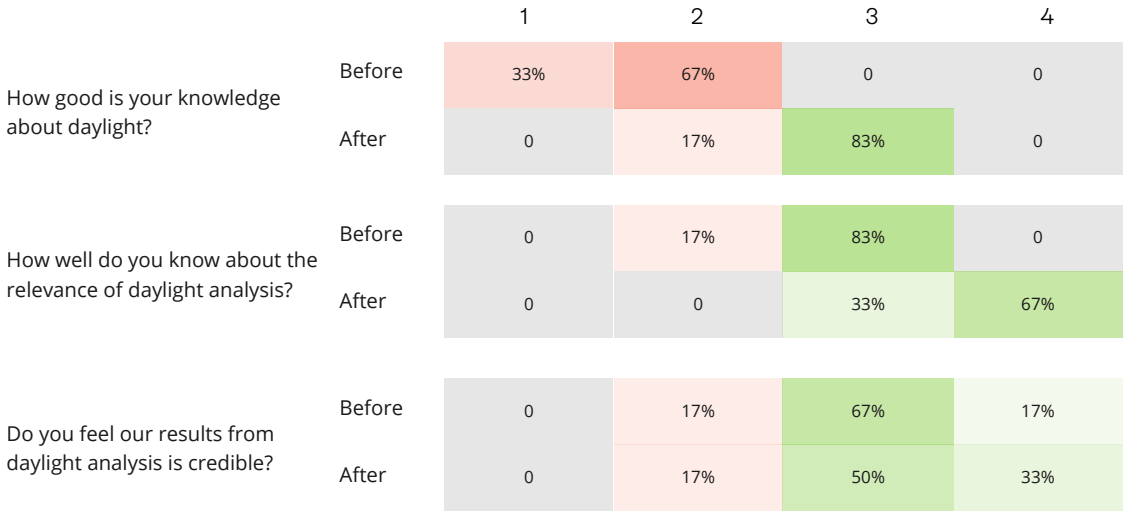


Figure 55. Diagram of knowledge metrics after the course on a scale from 1-4, i.e. low to high.

Visible in Figure 55 the course had a very positive effect on how well the attendee's knowledge regarding daylight was. From negative to majority positive. The understanding of the relevance of daylight increased as well from 3 to 4. The credibility of the daylight analysis was not affected as much, as only the correspondent of one person changed their opinion when summarising the totals. All these metrics were very considerable positive or good after the course, with only one person feeling their knowledge and credibility in the tool was worse after the course.

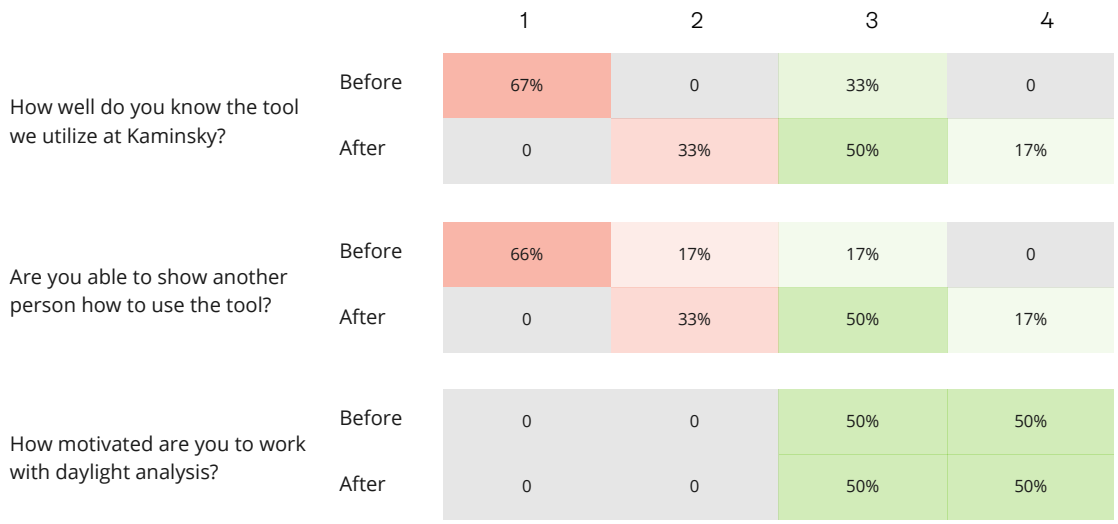


Figure 56. Diagram of tool experience metrics after the course on a scale from 1-4, i.e. low to high.

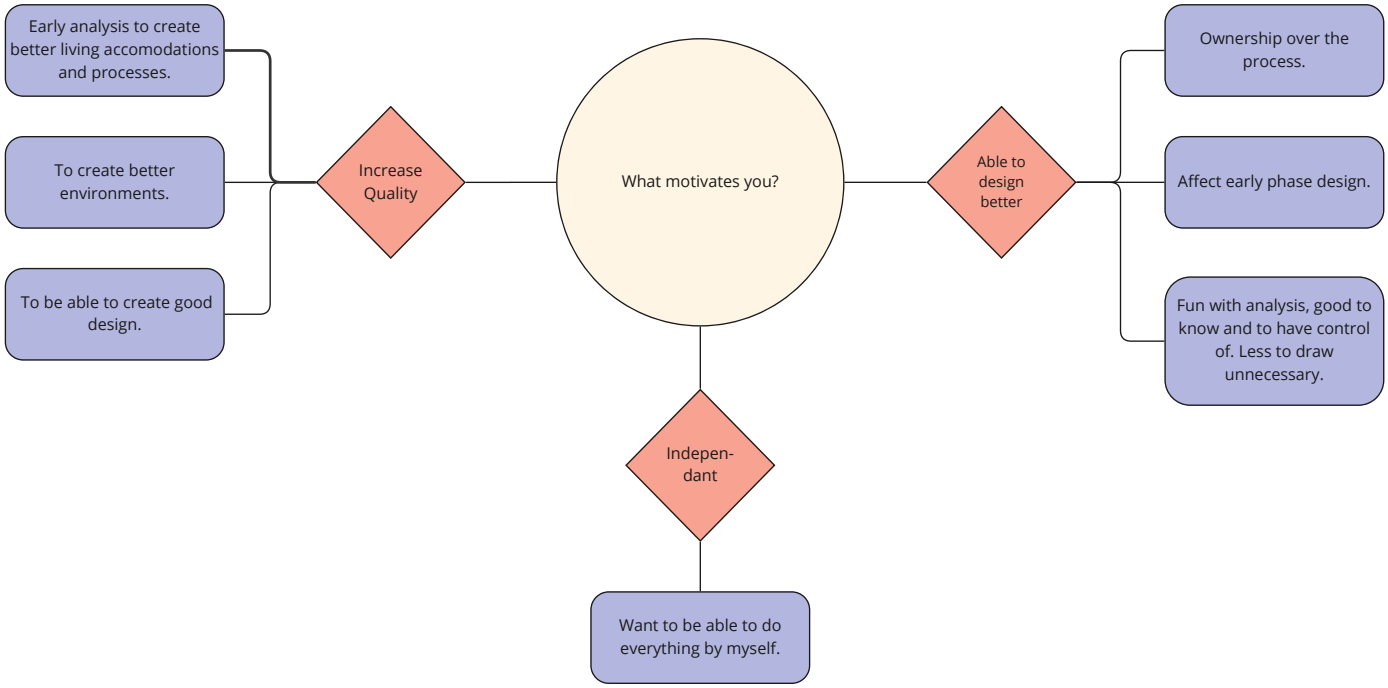


Figure 57. Diagram of what motivates the responders after the course.

Tool experience was as well measured as well if the attendees consider if they can show another person how to use the tool, visible in Figure 56. This was not the main aim with the course but was very fast shown at the end before their exam. Therefore it is a surprise how well the attendant felt they could use the tool. Two of the persons attending had used the tool before. As seen in the response for the question how well they knew of the tool, asked before the course.

An effort was made to increase the motivation to work with daylight. Both focus on how daylight is important for us humans physically and mentally but also how it is an important element to consider in the design of architecture with good qualities according to the author. Even though the effort the motivation was not affected for the better or the worse after the course.

When asked what motivates the attendees the answers are according to Figure 57. Most of the replies could be sorted into two main topics, to increase the quality of what we design and to be able to have a better design process. The expectations of how the course would affect the attendant's ability to affect the respective topic might have matched the result and therefore the result was left unaffected. It might have had a greater effect on the attendants who did not know about the tool and its purpose beforehand. Or motivation is not something affected by a course, but rather something which is the result of working with the tool and getting the response and satisfaction of the improvement to the design process and increased quality.

4.3.3 Exam response

The exam was responded to by two out of six attendees to the course even though several reminders which should be improved to the next time. The two who responded had succeeded in defining the room boundaries and the analysis. The exam could have been more extensive and control more task where it would have been a more complete check of daylight analysis, but the estimated time was set to two hours to do the exam where four of the attendees did not respond, likely due to lack of time. Figure 58 shown one of the exam results.

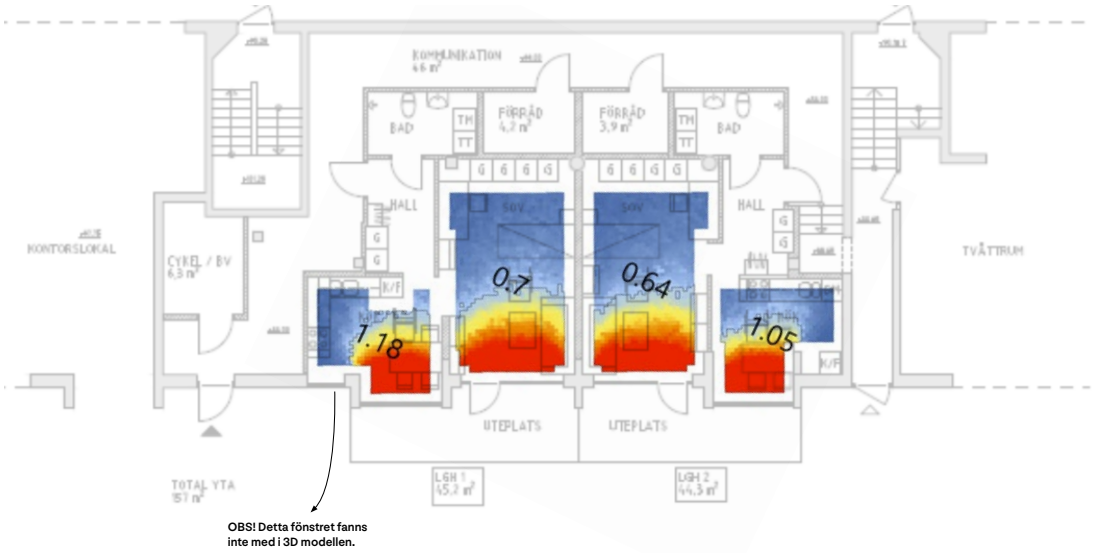


Figure 58. Image of the result from one of the users.

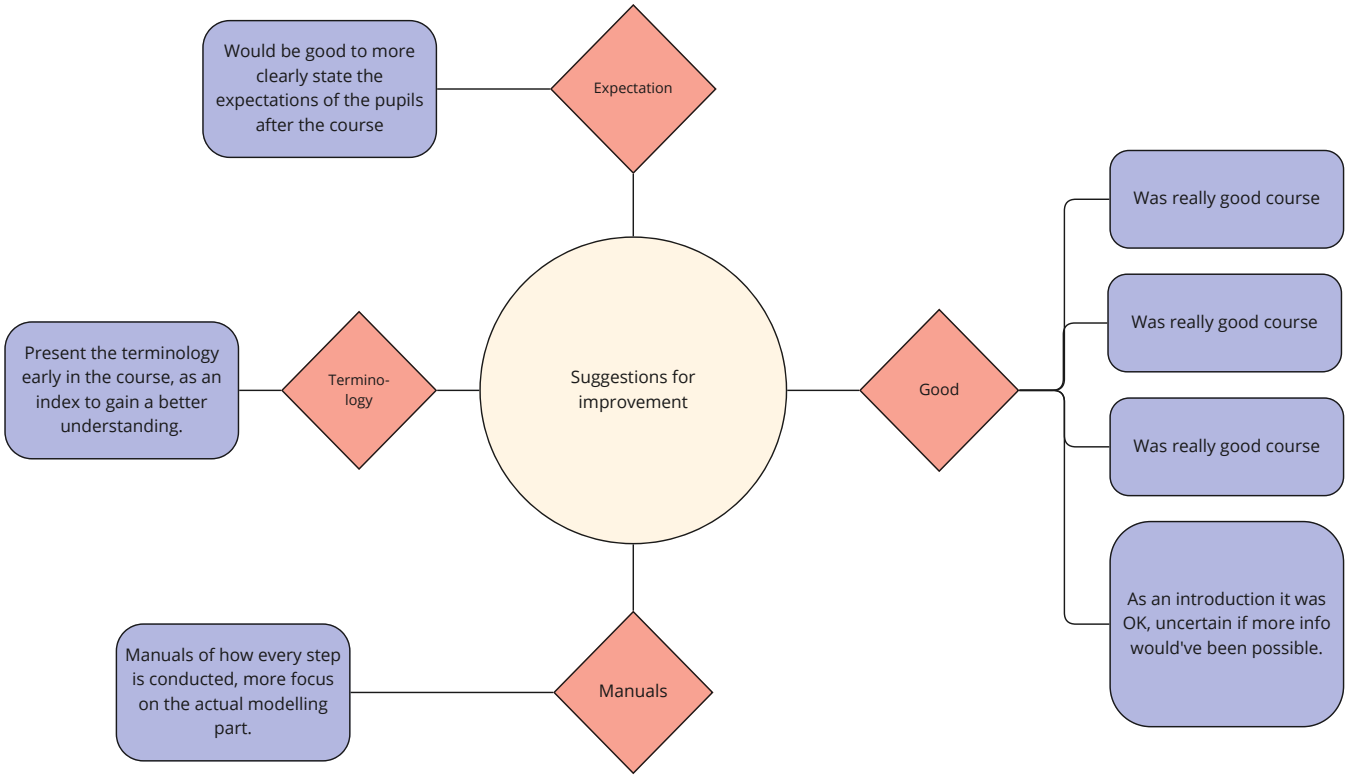


Figure 59. Diagram of suggestions for improvements after the course.

4.3.3 Course evaluation

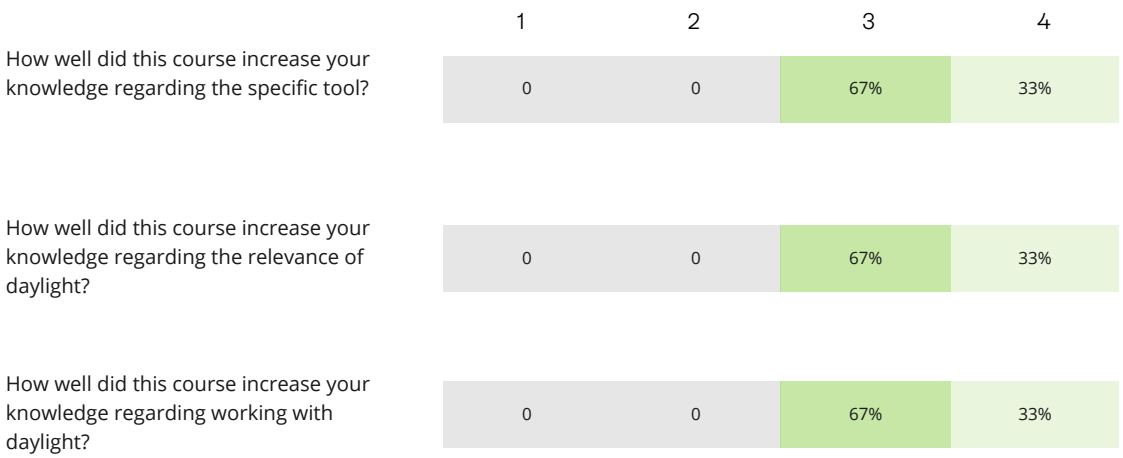


Figure 60. Diagram of result from course evaluation after the course on a scale from 1-4, i.e. low to high.

In all aspects, shown in Figure 60, the attendants to the course though the course helped them with getting better knowledge of daylight, understanding of the relevance of daylight and an understanding how to work with daylight in our profession.

In Figure 59 the suggestions to improve the course for next time is presented. Three suggestions were put forward, more clear expectations of the attendants to the course, more clearly present the terminology early in the presentation and manuals describing how to use the tool. The manual is not a suggestion of improvement to the course but an extra feature which would be good to have. Since daylight have a lot of different units a terminology as suggested would have been good to have to avoid confusion.

In the course the writer stated the expectations of the course, but not clearly the expectations of the pupils after the course, which of course would be good to do to assess how well the course succeeded with the goals.

4.3.4 Course conclusions

Based on the self-assessment from before and after the course, the course performed very well in its intended use. Regarding the self-assessment of how well the users know the tool the improvement between the two questions could be questioned, as the users did not try the tool themselves at that point.

The motivation was not affected by the course, which was an ambition by the author. As written replies indicate, the motivation for architect might come when the tool is used, and they see how it affects design.

The suggested improvements to the course, as the terminology at the beginning, clearer expectations of the pupil's level after the course, and a manual are good suggestions which should be implemented.

The lack of replies from the exam is not good but might indicate which of the new users are most motivated to work with these kinds of tools and in that way serves a purpose. The two replies were good, were both of the users have performed well in the one-to-one approaches.

4.4 One-to-one results

The One-to-one approach has been performed with six users during the work with this thesis, with an average of one project per user. Five of the users replied to this survey.

4.4.1 Self-assessment after the One-to-one

	1	2	3	4
How good is your knowledge about daylight?	0	17%	83%	0
How well do you know about the relevance of daylight analysis?	0	0	33%	67%
Do you feel our results from daylight analysis is credible?	0	17%	50%	33%

Figure 61. Diagram of knowledge metrics after the one-to-one on a scale from 1-4, i.e. low to high.

Figure 61 shows how the responders self-assessed their knowledge regarding daylight, credibility of the results and relevance of daylight analysis positively after the one-to-one. The assessment is comparable with the result from the course which implies the one-to-one have less effect on these factors. How well the users self-assess their knowledge of the specific tool is shown in Figure 63 and is also like the result after the course, which is surprising since the increase of the tool experience.

The motivation is shown in Figure 62 and 63 and is still regarded high, and comparable with the result of the course. From the reply option we learn that several users have replied to an increase of motivation since using the tool, where one has highlighted how the motivation increases when the design is affected by the analysis.

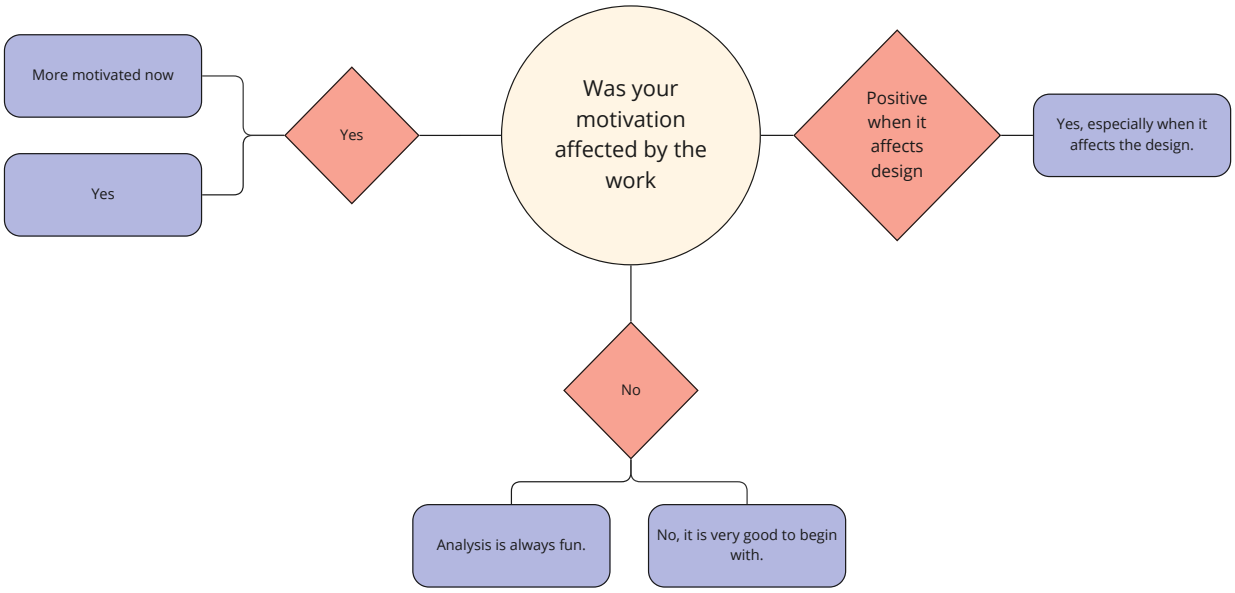


Figure 62. Diagram of what motivates the responders after the one-to-one.

	1	2	3	4
How well do you know the tool we utilize at Kaminsky?	0	33%	50%	17%
Are you able to show another person how to use the tool?	0	33%	50%	17%
How motivated are you to work with daylight analysis?	0	0	50%	50%

Figure 63. Diagram of tool experience metrics after the one-to-one on a scale from 1-4, i.e. low to high.

4.4.2 One-to-one evaluation

	1	2	3	4
How well did this method increase your knowledge regarding the specific tool?	0	0	0	100%
How well did this method increase your knowledge regarding the relevance of daylight?	0	20%	40%	40%
How well did this method increase your knowledge regarding working with daylight?	0	0	40%	60%
How well did this method increase your motivation to work with daylight?	0	0	60%	40%

Figure 64. Diagram of result from the one-to-one evaluation on a scale from 1-4, i.e. low to high.

It is apparent from Figure 64 that the approach was successful in increasing the user's competence in using the tool. The responders were as well positive in general regarding the increase in motivation, and knowledge regarding working in daylight. A bit less positive regarding how well the approach increased their knowledge regarding relevance of daylight.

Two suggestions for improvements were given and shown in Figure 65. One regards a suggestion for a general improvement the program and to increase the user-friendliness of the program. The other is regarding reduced thresholds, between the course and working on actual projects, where the responder suggests practice tasks with increasing difficulty.

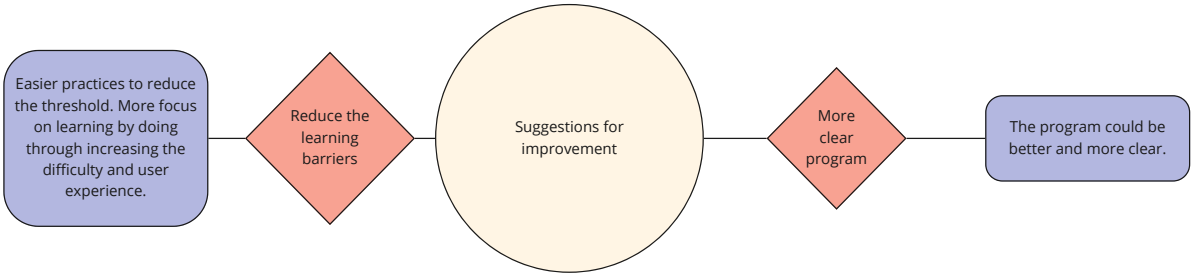


Figure 65. Diagram of suggestions of improvements from the responders after the one-to-one.

4.4.3 One-to-one conclusions

The one-to-one approach was successful in learning the program to the users, both from the new surveys from the users as well as the opinion of author. The effect on the users self-assessed knowledge regarding daylight does not differ from the self-assessment from the course, although it could be explained by other factors, such as a longer time between working with daylight and answering the survey.

It is a relief that the motivation to work with daylight was increased or maintained after working with the tool in a project, where one user highlighted the possibility to affect the design as a motivating reason. How motivation is connected to the tools' ability to affect design is recurring in several surveys and interviews.

Two suggestions were given, a general improvement to the program as well as a step between the course and one-to-one approach. As the learning curve and required time was very individual for each user, a decreased thresholds might improve the learning time.

4.4 The evolution of the framework

The framework of the tools need has been continuously developed throughout the work with this thesis. In this chapter the evolution of the framework is shown.

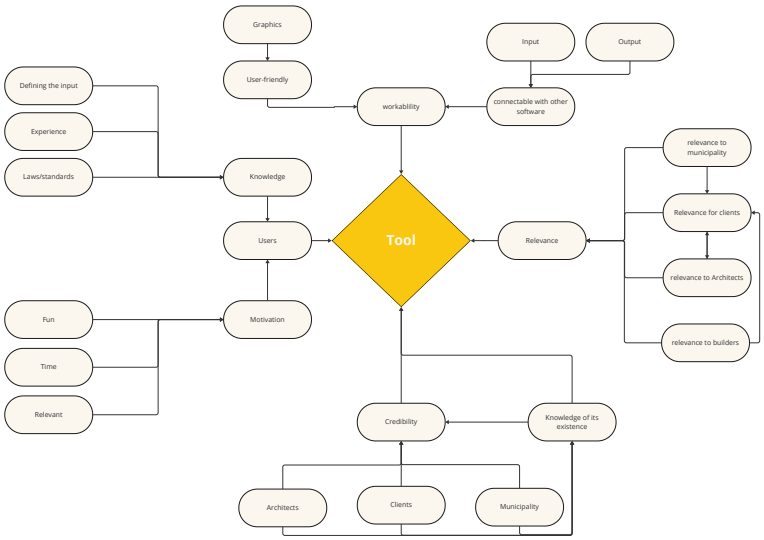


Figure 66. Initial framework in January, with the four categories users, functionality, relevance, and credibility.

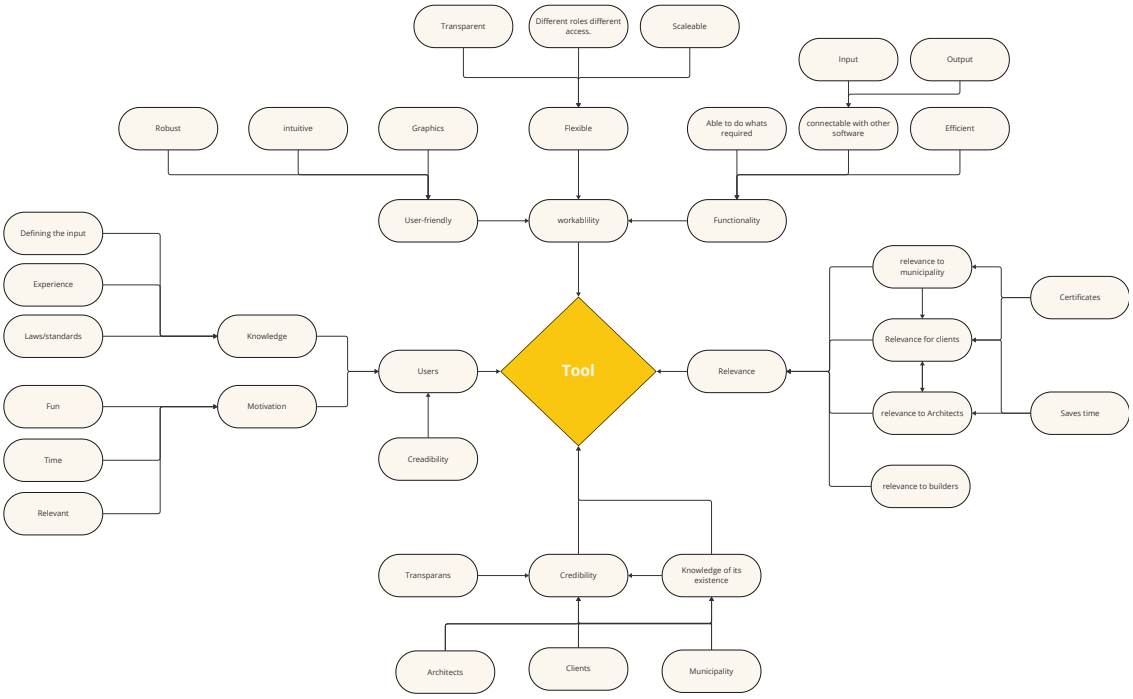


Figure 67. Framework in February. More topics have been added, especially in the functionality category.

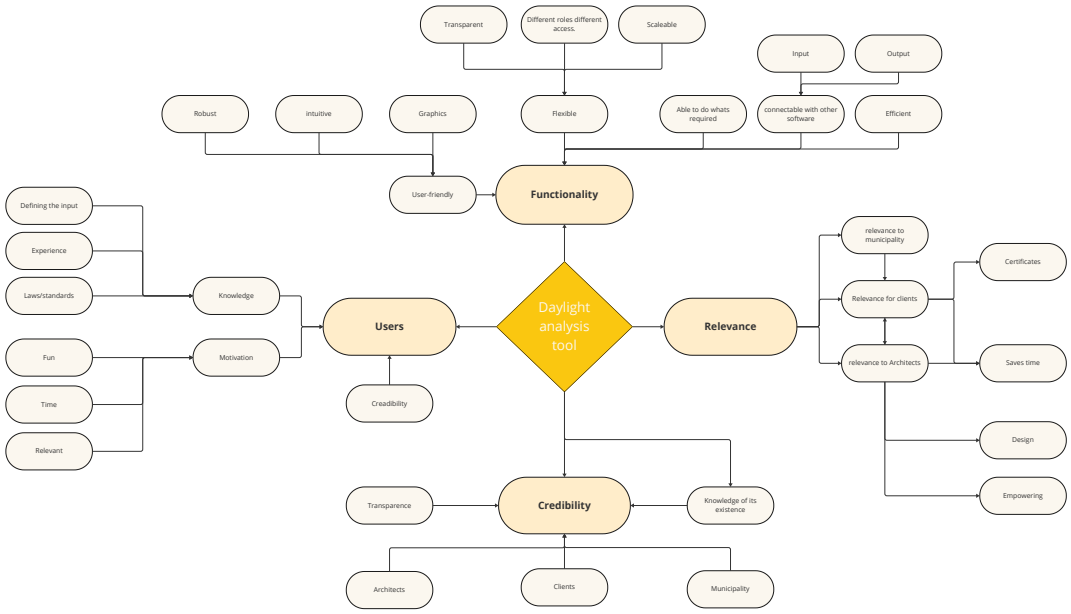


Figure 68. Framework in March. The readability has been slightly improved. From the interview with the management the following changes were made; The builders were removed from the category which influence relevance and design and empowering was added to topics which contributes for the tool's relevance for architects.

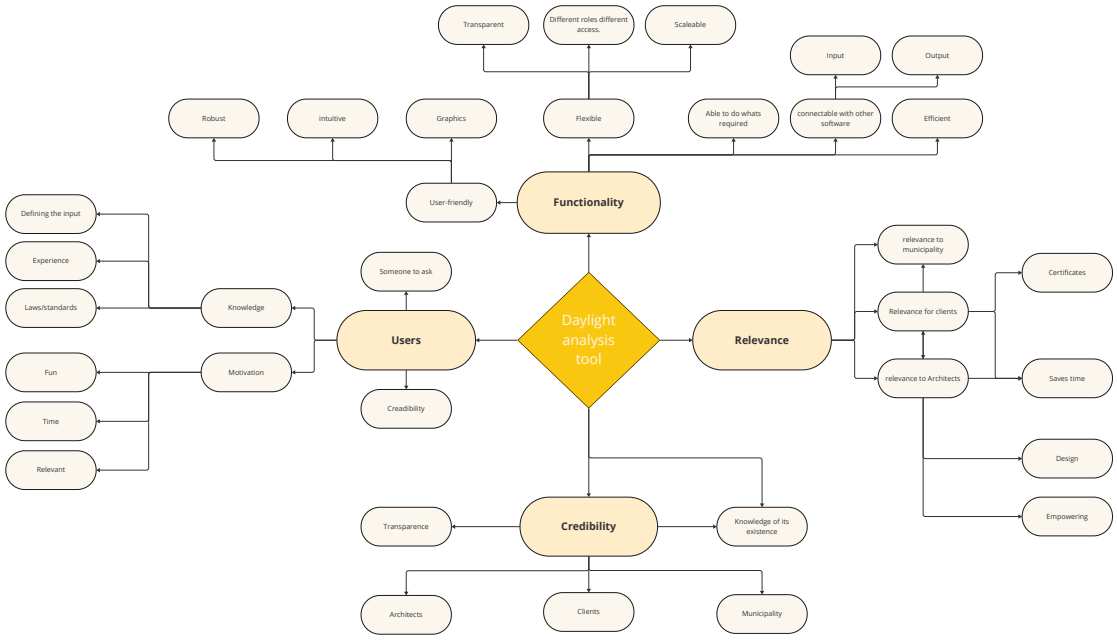


Figure 69. Framework in April. The project architect and junior architect expressed the need for users to have someone to ask.

4.5 Synthesis

The aim of the study has been to compare how different educational approaches can improve the integration of digital tools in architectural practices. The integration process has both focused on educating the potential users and other roles within the office, such as the support group, responsible architect, and management. A second aim is to better understand these groups' specific needs and how the tool can better fulfill these, or how the integration of the tool could better fulfill these needs. The tool which was integrated was an internally developed daylight analysis tool.

This has been investigated through an interview study with a representative for each of the different roles of the office. I.e. the management, responsible architect, Project architect, Junior architect, and support group. In addition, has different educational approaches been investigated experimentally such as a presentation for the office, a course with the new users, as well as one-to-one session on actual projects. The different approaches had different desired effects, the presentations aim was to give a general understanding, the course a more in depth understanding as well as a brief understanding of the tool, and the one-to-one sessions to teach the tool and how to work with daylight analysis tools.

The research study showed that different roles within the office had different needs of the tool, which highlights the importance of focusing on more than the end users of the tools when integrating a tool. An outcome of this thesis has been the framework of tool needs. This framework has evolved through the work with building performance analysis tool as well as in the different interview sessions, where different roles highlighted the importance of different aspects.

In the interview with the representative from the project architects, which has the role of the author, it occurred that even though the opinions might differ the general topics which was raised by the interviewee was the same as the topics which occupies the work of the author, i.e. how to keep everyone in the project happy and motivated and maintain a good working environment. Whilst the responsible architect highlighted topics such as budget and control as well as the importance of sale arguments for this type of work. The management raised topics such as the need for more services the practice can offer the clients. The junior architect in turn raised the importance of someone to ask for help with her task, as well as the importance of being able to continue to learn and develop. The support raised the importance of being able to install the software, the importance of having several people with the competence of how to use the tool for the robustness of the office, as well as having a general understanding of the different kinds of work to be able to connect employees.

The different educational approaches used experimentally were successful in their intended use and could be further improved by the suggestions of the replies to the surveys.

The importance of "champion user" was raised as an important concept. Champion users, or product champions are workers with a passion for the product which drives the development of the product (Markham & Aiman-Smith, 2001). In the office the author has the positions of "champion user", i.e. a user of the tool who has more in depth knowledge and is a person who users, responsible architects and management can ask when they need aid, either related to the tool, daylight in general or the relevance of daylight in different aspects. The junior architect highlighted in her interview the need for one more approach if this tool were to be integrated into another practice, where a second course would be needed for a local champion.

only one iteration is done with each role, i.e. one interview takes place with a representative for each role of the office. In the method used by Pil Brix Prup and Steffen Petersen (2020) they performed iterative interviews with different people but with the same role, in an ambition to get all possible information from that specific role. The method used is not as thorough as the reference but will give a glimpse of the needs and thoughts of different parts of the hierarchy. It is important to note that the interviewer has prior knowledge regarding these topics and intentionally or unintentionally guides the interview and discussions based on his experience. To get as correct information as possible it has been important to include the concept of the reflective researcher, to reflect on how the interviewer affects the interview to minimise any bias (Purup & Petersen, 2020).

In the effort to teach the tool to the junior architects several approaches were used, but one that was missing and expressed a need for was a manual on how to use the tool. Considering the very different issues expressed by the users who started to learn the tool it would be hard to cover everything, and to do so the document itself would be less useful. But a manual covering the essentials, in combination with good examples would be beneficial in helping the users with self-learning and reduce the need to ask for help.

Most of the effort in learning the new tool to the users has been conducted in a one-to-one approach where the new users work on actual projects, where the “extra time” it takes to learn the tool should be reduced from the time put on the projects. The idea of this approach is to learn on the fly, where the user can learn without too much training time. This approach is a problem-based learning approach described in the paper by Banerjee & Graaff (1996). As described by Hmelo-Silver (2004), a negative part of this approach is that it requires more time from the teacher, and the total time it takes for the project could in the end be double the intended. The course took 4 hours, but in retrospect it is possible that it would have been more efficient to spend more time on the course approach to reduce the time spent on the one-to-one approach.

Another aspect is that the work as consultants is measured in hours, but how fast someone learns a new tool, or the time required to do a certain task is very different. As Huitt (2004) describes, learning is interlinked with motivation along with other factors such as how fast the user learns the knowledge and how much pre-existing experience in similar tools the user has. In addition to this the tool is built in a very free environment, i.e. Grasshopper, without safety nets and warnings and where you can design in very different ways. It requires a high level of meticulousness of the user and high level of pride in getting the work to the appropriate level. The time going through someone’s work can require more time than doing the analysis itself for a more experienced user. Perhaps through a more defined control system approach, better defined expectations, and clearer reference projects the user could control their own work better.

Champion user was found to potentially be an important concept for the development of internal building performance analysis tools. As described by Markham & Aiman-Smith (2001), it is people with passion for the project who need to be managed in a particular way to be successful. If champions are key for internal tool development, it could be difficult to expand this into new practices without potential champion users.

The importance for architect that the tool is a design tool was highlighted in the feedback from several surveys as well as interviews. This is in line with the research by Banerjee & Graaff (1996). To more clearly integrate this in the tool and highlight it for the users early on might increase the motivation for new users to learn the tool. This is also in line with Stolterman & Pierce (2012), who argues about the importance of designer tools.

Säwén et al. (2024) found that the perspective of the tool users in design processes was lacking, where the research was focused on computational performance improvements. The research in this paper highlights that user's perspective should be expanded into the different roles within the practice, which requires different knowledge and have different needs of the building performance analysis tool.

In Figure 70 the criteria from Table 4, where three different papers with different frameworks, are co-relatedly mapped into the framework developed in this paper. These frameworks focus on Architect friendly criteria, learnability criteria and descriptive criteria of tools, where all of them are connected to the functionality of the tool, where the framework developed in this paper has a larger scope comparatively. Lacking criteria such as design support, reduced abstraction barriers and integrated knowledge-base can be added to this framework.

Table 4. Three different frameworks from other research papers with regards to tool criteria.

Attia et al. (2009)
Architect Friendly criteria

1. Usability and information management of interface
2. Integration of intelligent design knowledge-base (Comply with codes and rating systems)
3. Interoperability of building modeling (BIM)
4. Accuaracy of the tool and its ability to simulate complex and detailed building components

Aish and Hanna (2017)
Cognitive dimensions - different aspects which makes it easier to learn a tool

1. Abstraction barrier - Number of new abstractions which must be mastered.
2. Clear names - Easy to understand interface
3. Consistency between representations
4. Discoverability - Should be possible to be discovered by the user unaided.
5. Flexibility
6. Side effects - Example small changes to input has large unwanted changes somewhere else.
7. Work arounds
8. Convoluted workflow
9. Liveness - the tools spontaneity, responsivness

Säwén et al. (2024)
Characterisation criteria- Different descriptive aspects of the tool

1. User interface - How does the users interact with the analysis.
2. Information management - how is data related to the analysis stored and presented.
3. Analysis capabilities
4. Design support- How does the workflow support design judgement & workflows.
5. Practical integration - How can practices adopt the tool.

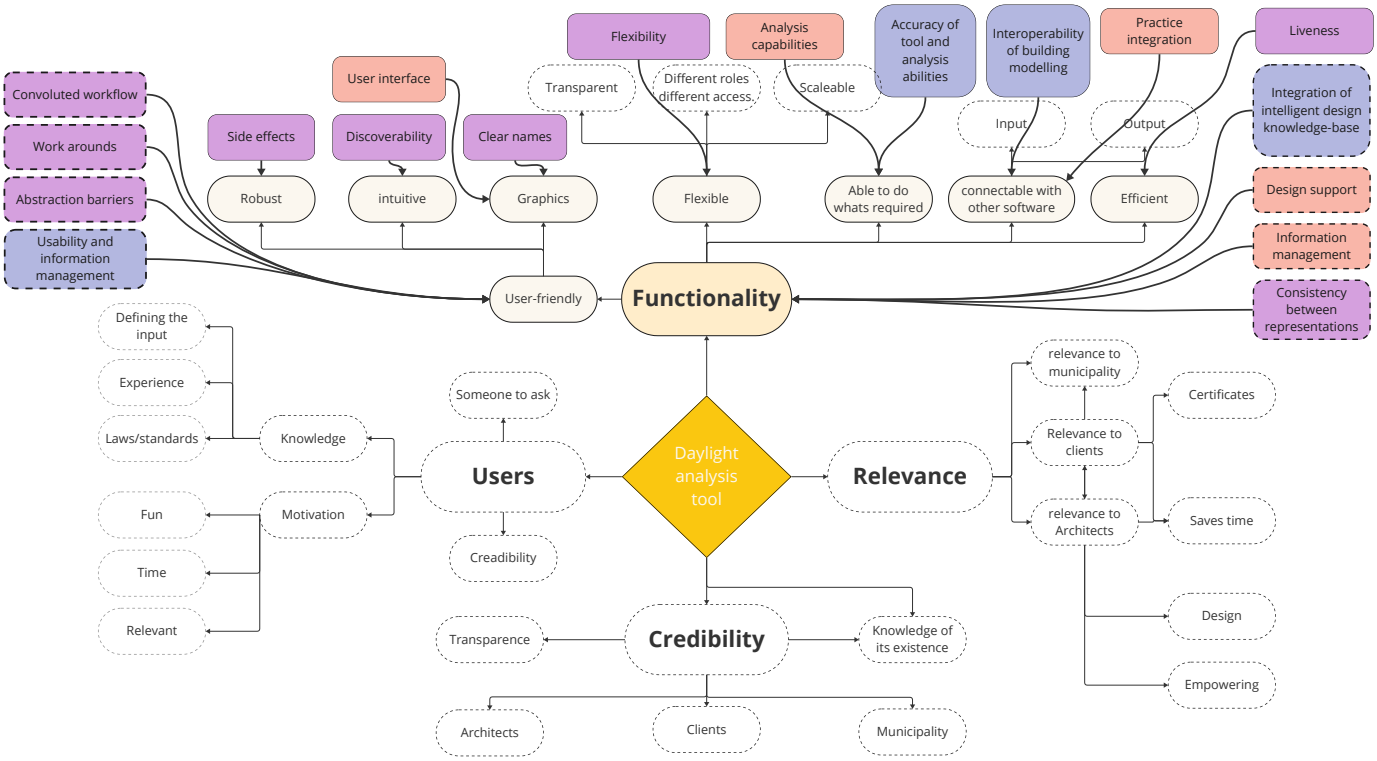


Figure 70. The framework from this paper with the criteria from Table 4 added and mapped corelated. Criteria from this papers framework not mentioned in others are shown as white surrounded with dashed lines. Unmentioned critera from other papers are shown surrounded by dashed lines.

6. Conclusion

The aim of the study has been to understand how the integration of digital tools in architectural practice can be improved. In order to get a founded understanding of the topic an interview study was performed with a representative for each of the different roles of the office; management, responsible architect, project architect, junior architect, and support group. In addition, this thesis explored experimentally how different educational approaches could improve the practical integration of an existing daylight analysis tool within one architecture practice. Feedback has been gained from the different approaches through surveys.

Key findings are listed below:

- Different roles within the office have different needs of the tool, which highlights the importance of focusing on more than the end users of the tools when integrating a tool.

- The educational approaches were successful in their intended use, but several more were requested; such as a presentation focusing on sales for more seniors. A manual on how to use the software for users.

- The importance of having product champions, who can develop the tool, support the users in their workflow and with the software, and assist project architects and management with questions regarding relevance, possible solutions and when the service is required. The credibility in the tool also resides in the these champions.

- The program is free and flexible in its possible use, which requires a high level of meticulousness of the user and in-house expertise who can verify the results.

- The needs of the tools have been organised in a framework in Figure 71. where the tools need is divided into the four categories, users, functionality, Relevance, and credibility.

In future works:

- In order to gain a more well based understanding more iterations of the educational methods have to be done in other practices, where a more elaborated evaluation method could be used.

- The framework is still a work in progress and needs to be further tested against other building performance analysis tools and evaluated.

- The proposed educational approaches could be tested to see what effect they have on the learning curve.

- A Control-system approach, better defined expectations, and clearer reference projects could be developed to increase the quality of the users' work.

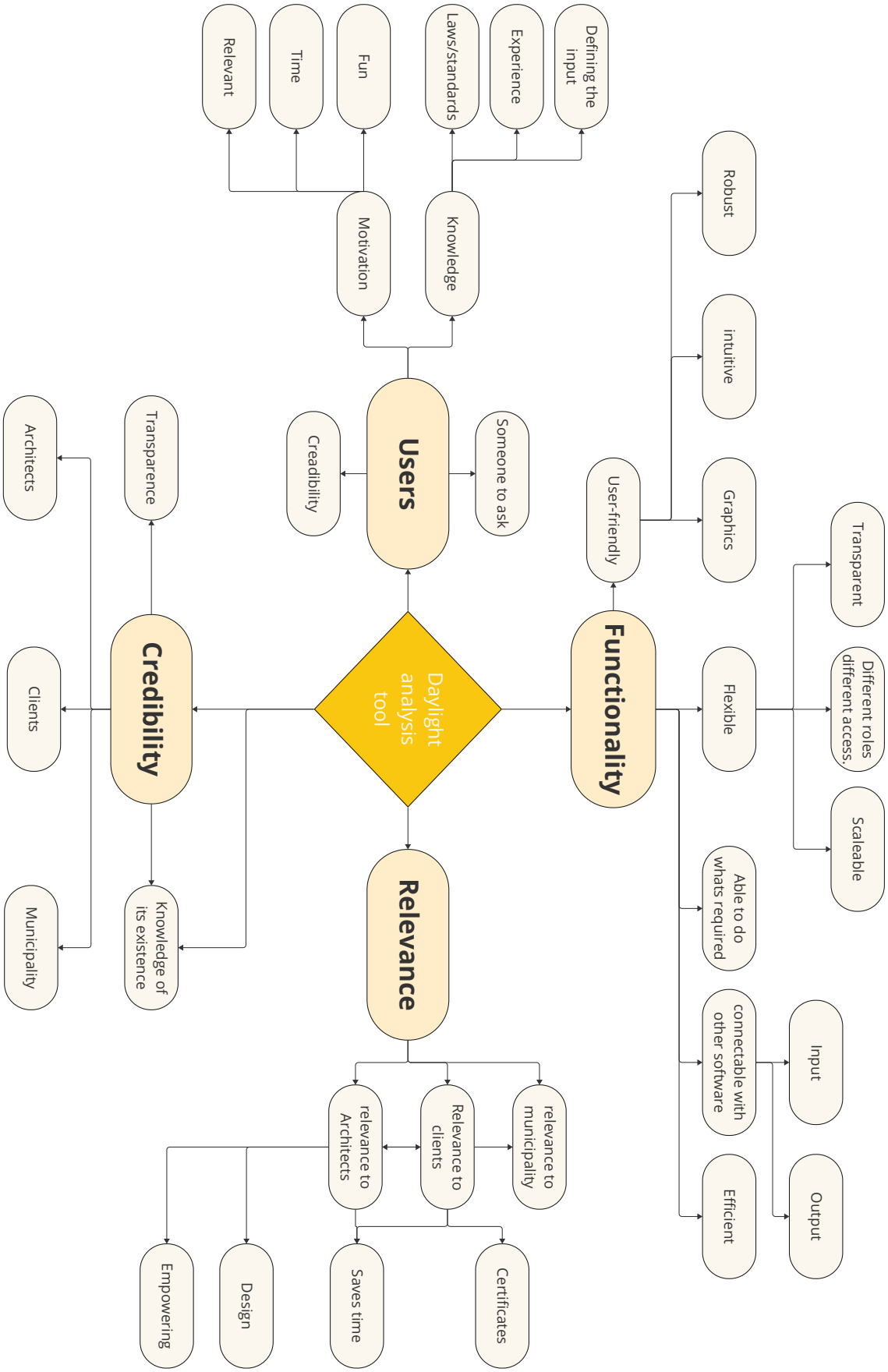


Figure 71.Framework of the tools needs.

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