

Att minska kognitiv belastning i säljutbildning: En experimentell studie om lärande i självstudier

Reducing Cognitive Load in Sales Training: An Experimental Study on Self-Directed Learning

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This thesis examines how insights from cognitive science can inform the design of self-study training materials to reduce cognitive load and enhance sales onboarding in complex technical domains. The study was conducted at a global company specializing in industrial sensor solutions, focusing on machine vision sales training.

The study was conducted in three phases. First, a pre-study mapped the sales current onboarding experience. High cognitive load, caused by the volume, structure, and content presentation emerged as a key challenge. Based on these findings, Cognitive Load Theory, Schema Theory, and Cognitive Theory of Multimedia Learning were selected as theoretical frameworks to guide the following phases.

In phase two, a machine vision overview training module was analyzed and redesigned into two e-learning versions: a control and an experimental version. The latter was optimized for extraneous cognitive load reduction and schema formation.

In phase three, an experiment ($N = 25$) tested the design intervention's impact on knowledge gain and perceived cognitive load. The experimental group reported significantly lower extraneous load and showed a trend toward greater knowledge gains, especially on difficult items. They also reported slightly higher motivation and confidence, though differences were not statistically significant.

The thesis further discusses broader cognitive challenges in the onboarding journey, including fragmented content, poor navigation, lack of overview modules, and non-situated learning. It also offers actionable recommendations to the company for improving the learning experience for new salespeople. The study aims to demonstrate the practical value of applying cognitive science to corporate training design.

1 Introduction

When thinking about learning, one might recall childhood scenes of sitting at a school desk, puzzling over math problems, or pulling all-nighters before university exams. Yet learning does not end when formal education does. It is a lifelong process that continues through everyday life; when starting a new job, assembling IKEA furniture, or simply watching the news.

At its core, learning involves selecting, processing, and integrating information into the brain's cognitive architecture (Neisser, 1967). This unfolds through a complex yet elegant interplay of perception, attention, memory, motivation, and the surrounding context (Sweller, van Merriënboer, & Paas, 2019). In the digital era, where individuals are constantly bombarded with information, cognitive processes are increasingly strained. When the volume or complexity of information exceeds the limits of working memory, learners experience *information overload*; a phenomenon that can

impair comprehension and performance (Eppler & Mengis, 2004; Sigolo & Casarin, 2024). In cognitive science, this is referred to as *cognitive overload* (Sweller et al., 2019).

One crucial arena of lifelong learning is the workplace. Starting a new job requires not only the rapid acquisition of complex, role-specific knowledge but also the ability to navigate an unfamiliar organizational environment. This dual demand makes onboarding both cognitively and emotionally challenging, especially in fast-paced, high-element interactivity domains, such as technical sales (Evanick, 2024). This thesis investigates such a context: onboarding salespeople at a company specializing in intelligent sensor solutions for industrial automation.

A significant portion of modern workplace training involves self-directed learning, where individuals independently manage their learning process, including setting goals, navigating content, and assessing their own progress (Garrison, 1997). While self-study promotes autonomy and flexibility, it also places increased cognitive demands on the learner, who must regulate attention, motivation, and comprehension without external instructional support.

The company in focus had voiced concerns about the difficulty of training new salespeople, especially in technical complex topics such as machine vision through self-study formats. In talks with the company, central questions emerged about how to present complex information in a user-centered way and how to design training materials that accommodate diverse levels of prior knowledge. The identified need to improve the user experience of their training materials to enhance knowledge transfer ultimately motivated this thesis.

However, the challenge of effectively communicating complex technical information is not unique to the company analyzed in this thesis. As technological fields continue to grow, products and systems become increasingly sophisticated; making the need to educate others about them more pressing than ever (Sokol & Flach, 2021; Wang, Huang & Yao, 2024). This complexity reflects what Norman (2013) describes as the *paradox of technology*: while advances bring greater functionality and flexibility, they often introduce complexity that undermines usability. The implications of this paradox extend beyond internal staff and sales teams to the general public, who are increasingly expected to interact with technologies they may not fully understand. In a world shaped by rapid innovation, the ability to clearly present and explain complex information has become a critical skill. As such, exploring how technical content can be structured and communicated to support user understanding is not only relevant but urgently needed in today's world.

Previous research, especially in the fields of human resources and healthcare (Lin, 2025; Sewell et al., 2019), has shown that cognitive overload in workplace training can be

reduced using theories such as Cognitive Load Theory (Sweller et al., 2019). Expansions like Mayer's Cognitive Theory of Multimedia Learning (Mayer & Fiorella, 2022) offer practical design principles to lower this load to support learning. While these theories have been widely validated empirically in academic settings, their application in corporate onboarding processes, especially for roles like sales, remains limited. This thesis addresses that gap by exploring how such theories can improve onboarding in technical sales, focusing on user-centered design and cognitive load reduction.

Purpose of the Study

The purpose of this study is twofold. First, it aims to map the broader learning journey of salespeople within the company and identify key challenges in their onboarding experience. Particular focus is placed on their perceptions of the company's self-study materials related to machine vision. This exploratory phase is guided by the following research questions:

1. How are the company's self-study e-learning materials constructed, used, and perceived among stakeholders and the salesforce?
 - a. What does the learning journey look like for a new salesperson at the company?
 - b. What specific challenges do salespeople face when learning about machine vision?

The second aim is to explore how cognitive science theories can be applied to address the challenges identified in the pre-study and how these principles can be demonstrated in the redesign of one selected training module. Thus, the pre-study is essential to ensure that the design intervention is grounded in actual user needs and organizational context, rather than based on assumed challenges. This phase focuses on improving the structure and presentation of information to manage cognitive load and enhance learning outcomes, guided by the following research questions:

2. How can cognitive theories be applied, to address the key onboarding challenge of cognitive load, within a selected training material?
 - a. Does restructuring the material according to cognitive principles lower perceived cognitive load and improve knowledge gain?

2 Theoretical Background

Cognition & Learning

In cognitive science, learning is defined as a relatively permanent change in knowledge or mental representations resulting from experience (Shuell, 1986; Anderson, 2010; National Research Council, 2000). This change occurs through internal processes in which information is perceived, attended to, encoded, stored, and retrieved (Neisser, 1967; Mayer, 2011; Baddeley, 2003). These processes depend on core components of human cognitive architecture; particularly perception, attention, and memory, which together transform sensory input into meaningful knowledge (Sweller, van Merriënboer, & Paas, 2019; Cowan, 2005).

Understanding these systems is essential, as they shape how learners integrate information.

From an evolutionary perspective, the human brain is both remarkable and constrained. While capable of abstract reasoning, language, and symbolic thought, these abilities emerged from neural systems that evolved to solve very different challenges. Our perceptual and attentional systems, for example, are optimized for detecting patterns, tracking movement, and responding to environmental threats; functions that were critical in ancestral environments (Cosmides & Tooby, 1994; Shepard, 1984). Yet evolution is slow, and the core architecture of human cognition has changed little over tens of thousands of years, even as cultural and educational demands have accelerated (Geary, 2008). This mismatch explains why we often struggle with biologically secondary tasks such as reading or algebra, which place heavy demands on working memory and abstract processing (Geary, 2008; Sweller et al., 2019).

As Dehaene (2009) explains, reading is not an evolved ability but a cultural invention that repurposes neural circuits originally designed for object and face recognition that makes us superior in pattern recognition. The brain's remarkable plasticity allows for such adaptations, but its evolved constraints still shape what can be learned easily and what requires structured support. Rather than functioning as a general-purpose processor, the brain consists of specialized systems; some of which can be redirected for new uses, while others set hard limits. Understanding these evolutionary foundations helps explain why learning is effortful, why overload occurs, and why instruction must be aligned with, rather than opposed to, our biological cognitive architecture.

Perception, Attention & Memory

Perception refers to how the brain selects, organizes, and interprets sensory input into coherent experience (Neisser, 1967; Goldstein & Brockmole, 2017). It is not passive but constructive, drawing on prior knowledge, expectations, and context to make sense of ambiguous input (Gregory, 1970; Anderson, 2010). This top-down influence means that perception is shaped as much by what we know as by what we sense (bottom-up influence), and these processes interact continuously to shape perception (Clark, 2016; Neisser, 1967). Perception is also fundamentally multimodal; different perceptual systems, such as the visual, auditory, and tactile systems, process specific types of sensory input, which are then integrated into a unified experience (Calvert, Spence, & Stein, 2004; Goldstein & Brockmole, 2017).

Given the continuous influx of sensory information we receive, attention plays a critical role in selecting which information is processed further and perceived. Attention functions as a filtering mechanism that prioritizes certain inputs for conscious awareness and deeper cognitive processing (Broadbent, 1958; Posner, 1980). Contemporary models distinguish between two main systems of attentional control: bottom-up (stimulus driven, such as bright colors) and top-down (goal-directed, shaped by e.g. prior knowledge) (Corbetta & Shulman, 2002). These systems interact dynamically to determine which information reaches working memory and in what order. Attention also supports the binding process, in which features such as color, shape, and location are integrated into a coherent perception of a single stimulus (Treisman, 1996). However, attention is a scarce resource. When it is misdirected, due to distraction or excessive cognitive demands, learners may fail to process

relevant input effectively, leading to reduced comprehension (Sweller et al., 2019; Lavie, 2005).

Information that is attended to enters the memory system; what we do not attend is not consciously perceived. Classic models describe memory as a sequence of stages: sensory memory, working memory, and long-term memory (Atkinson & Shiffrin, 1968) (see Fig. 1). Sensory memory briefly holds raw visual or auditory input for milliseconds to a few seconds, allowing the brain to detect continuity and begin selection. Attended and selected information moves into working memory, where conscious processing occurs. Baddeley's multi-component model (Baddeley & Hitch, 1974; Baddeley, 2000) describes working memory as consisting of three subsystems; an auditory loop for processing verbal information; an optical loop for processing visual and spatial input; and an integrative buffer that combines information from both systems and links working memory with long-term memory. These are coordinated by the central executive, a domain-general system responsible for managing attention, task switching, and inhibitory control (Baddeley & Hitch, 1974; Baddeley, 2000). Working memory is sharply limited in capacity (typically holding about four chunks of information) and in duration (unattended material fading after 10 to 20 seconds) (Cowan, 2005; Peterson & Peterson, 1959).

When information is meaningfully encoded, through rehearsal, elaboration, or association, it can be transferred into long-term memory in the form of structured mental representations (Craik & Lockhart, 1972; Anderson, 2010; Kintsch, 1998). Long-term memory has virtually unlimited capacity and stores information over extended periods, from minutes to decades (Squire, 2004). It includes declarative memory, which encompasses semantic memory (general facts and concepts) and episodic memory (personal experiences), as well as procedural memory, which stores unconscious skills, routines, and motor sequences (Squire, 2004; Tulving, 1985). Stored knowledge provides the conceptual frameworks and associative structures that support higher-level cognitive functions such as pattern recognition, reasoning, comprehension, and problem-solving (Anderson, 2010; Chi, Glaser, & Rees, 1982).

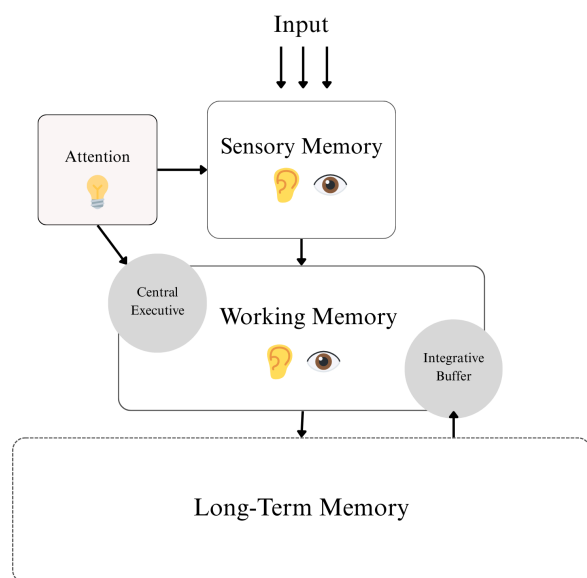


Figure 1. Simplified visualization of the human memory system

Importantly, encoding and retrieval are shaped by the physical, emotional, and cognitive context of learning (Baddeley, 1997). Studies of context-dependent memory (e.g., Godden & Baddeley, 1975) show that recall improves when the learning and retrieval environments match. When learners engage with material in abstract or unfamiliar ways, retrieval can be impaired. Therefore, meaningful, context-rich environments enhance learning transfer (Bransford, Brown, & Cocking, 2000).

Together, perception, attention, and memory form an integrated system that underlies all learning. Perception constructs incoming information into meaningful representations; attention filters and prioritizes what is processed; and memory encodes, stores, and retrieves what is learned.

Schema Theory

Schema Theory, originally introduced by Bartlett (1932) and later expanded by Anderson (1977, 1983, 1984), explains how information in long-term memory is organized into structured mental frameworks called *schemas*. Schemas represent generalized knowledge about concepts, events, situations, and procedures. They help learners make sense of the world by enabling them to recognize patterns, interpret new information, predict outcomes, and recall relevant information more efficiently. These frameworks guide top-down attention, perception, and the integration of new material into memory.

Anderson (1984) demonstrated how schema theory applies to comprehension and learning. He identified different types of schemas, such as conceptual schemas (knowledge about categories and definitions) and procedural schemas (knowledge of how to perform tasks or actions). According to Anderson, learning involves not only storing new facts but also constructing and modifying schemas. When learners encounter unfamiliar information, they either 1) assimilate it into existing schemas, or 2) accommodate it by creating new schemas. Thus, learning involves the activation, construction, and modification of schemas. These processes depend heavily on associative networks, where prior knowledge is linked to new inputs by meaning, context, and experience.

Schema theory highlights that learning is not just about acquiring isolated facts but about organizing knowledge into usable and transferable mental models. In the context of instructional design, schema theory emphasizes the importance of helping learners activate prior knowledge, organize new content logically, and connect new ideas to existing knowledge structures. Instructional materials that use examples, analogies, and visual organizers help guide this process by supporting schema construction. Anderson argued that such supports help learners build robust, flexible schemas; the kind needed for deep understanding and knowledge transfer to new situations.

Cognitive Load Theory

Before information can be integrated into long-term memory and stored as schemas, however, it must be actively processed in working memory (Baddeley, 2000). Cognitive Load Theory (CLT), first introduced by Sweller (1988), explains how the limited capacity of working memory constrains the retention of new information. If cognitive demands exceed these limits, learning is impaired. Over the decades, CLT has become a central and widely influential framework in instructional design and educational

psychology, offering a detailed account of how cognitive architecture constrains learning. The theory has been thoroughly expanded; in Sweller, van Merriënboer & Paas (1998), Sweller, Ayres, and Kalyuga (2011), and most recently in Sweller, van Merriënboer, and Paas (2019), which serves as the primary reference in this thesis.

CLT (Sweller et al., 2019) distinguishes between three types of cognitive load put on the working memory during the learning process (see Table 1.)

Table 1. Three types of cognitive load according to CLT

Load	Description
Intrinsic	The effort required to process the complexity of the material itself, which is determined by element interactivity (the number of elements and their interrelations that must be processed simultaneously), prior knowledge, motivation, and context.
Extraneous	The effort imposed by how information is presented, rather than by the topic itself. Poor instructional design that causes splitting of attention, redundancy, or unnecessary information can thus overload working memory without contributing to learning.
Germane	The effort dedicated to constructing, automating, and refining schemas that support deeper understanding. This effort thus supports the kind of deep and meaningful processing necessary for complex learning.

According to CTL, the goal of any educational design is to manage intrinsic load and minimize extraneous load to maximize germane load, through which effective learning occurs. CLT is primarily concerned with the acquisition of biologically *secondary* knowledge, which refers to culturally important skills, like reading and mathematics, that require explicit instruction and conscious effort to learn (Sweller et al., 2019).

Motivational and Affective Dimensions of Learning

While learning depends on internal mechanisms such as attention and memory, it is equally shaped by motivational and affective factors like self-beliefs (Bandura, 1997) and intrinsic motivation (Deci & Ryan, 1985). Cognition is, after all, performed by a brain embedded in a personal history, context, and social environment (Clark & Chalmers, 1998; Lave & Wenger, 1991; Suchman, 1987). From this perspective, learning is best understood as a meaning-making activity (Boekaerts, 2011).

In self-study and e-learning environments where learners must independently manage focus, pace, and persistence, motivation and self-regulation are especially critical. According to Zimmerman (2002), self-regulated learning involves setting learning goals, monitoring progress, managing effort, and adapting strategies. It also includes regulating one's emotional and motivational states; factors essential to sustaining engagement and resilience in the learning process.

A foundational framework for understanding learner motivation is Self-Determination Theory (SDT), which proposes that three basic psychological needs drive human motivation: autonomy (a sense of control over one's actions),

competence (a sense of effectiveness), and relatedness (feeling socially connected) (Deci & Ryan, 1985; 2020). When learning environments support these needs, learners are more likely to experience intrinsic motivation, which refers to the internal desire to accomplish a goal based on interest rather than external factors. This intrinsic motivation leads to deeper engagement and stronger learning outcomes (Deci & Ryan, 1985; 2020).

Closely related to SDT is the concept of perceived control, or the belief that one can influence outcomes through one's actions. Perceived control enhances both motivation and self-efficacy (Perry, Hladkyj, Pekrun, & Pelletier (2001). Self-efficacy, defined by Bandura (1997), refers to a person's belief in their capacity to succeed in a specific task and it strongly predicts learning behaviors; learners with high self-efficacy are more likely to invest effort, persist through challenges, and apply effective strategies (Pajares & Schunk, 2001).

Conversely, when learners experience low perceived control; often caused by overwhelming content, poor usability, or cognitive overload (Sweller et al., 2019; Norman, 2013; Deci & Ryan, 2020; Perry et al., 2001), they may enter a state of cognitive dissonance (Festinger, 1957). According to Cooper (2007), this psychological discomfort arises when learners' goals are misaligned with their perceived ability to reach them. If unresolved, this dissonance can undermine motivation, weaken self-efficacy, and reinforce negative self-beliefs; all of which are known to impair learning and reduce the likelihood of knowledge retention and transfer (Bandura, 1997; Deci & Ryan, 2020; Boekaerts, 2011).

Together, these dynamics show how motivational and emotional processes are tightly coupled with cognitive processes. When learning environments fail to support autonomy or perceived control, motivation, and competence or self-efficacy, learners not only struggle with engagement but also experience weaker learning outcomes; especially in cognitively demanding, self-directed contexts like e-learning.

Embodied, Extended, Distributed & Situated Cognition

What is important to understand about cognition is that it is not isolated within the skull, but is fundamentally *extended* (Clark & Chalmers, 1998), *distributed* (Hutchins, 1995), *situated* (Lave & Wenger, 1991; Suchman, 1987), and *embodied* (Kirsh, 1996; Kirsh & Maglio, 1994). This means that cognition is deeply influenced by the outer world and how we act in it, as cognition arises from our bodily experiences (Kirsch, 1996; Kirsch & Maglio, 1994). Evolutionarily, humans have not just simply adapted to environments but redesigned them to reduce mental workload, to ease living in them (i.e. superoptimization) (Kirsch, 1996). Furthermore, many of our physical actions in the world are not directly relevant to achieving a certain goal (pragmatic actions) but are made to understand it more efficiently (epistemic actions). Such actions simplify mental computation, reduce cognitive load, and support reasoning (Kirsch & Maglio, 1994). Thus, interaction and action support our cognition, which highlights the value of interactive learning environments that allow learners to manipulate and engage with content through action.

Therefore, cognition can be considered to be *extended* beyond the individual to include the environment but also tools and artifacts. For instance, notebooks or calculators, are used to offload memory and computation (Clark & Chalmers, 1988). From this perspective, learning is not just supported

by internal capacities, but by how learners use external resources to store, manipulate, or access information. Tools such as e-learning platforms, or other user interfaces, should therefore be designed to support these cognitive functions. It has also been argued that the environment and external tools and other people in it can even be considered a part of our cognitive system, as cognition is distributed across these (Hutchins, 1995). Cognitive processes can thus be considered as shared across these parts and not emerging from, or can be reduced to, the individual parts alone. Hutchins (1995) therefore emphasizes that cognition must be understood from a bigger perspective than solely the individual, but rather from a socio-technical system. Learning environments should similarly support shared representations, collaboration, and distributed memory, enabling learners to build understanding collectively rather than in isolation.

In line with this, thinking and learning are directly tied to the physical and social context in which they occur (Lave & Wenger, 1991, Suchman, 1987). This means that knowledge is inseparable from the context and activity in which it is developed and used. Lave (1991) describes cognition as a dialectical relation among people, their actions, and the context of those actions. Effective learning thus requires real-world relevance and social grounding. Decontextualized learning materials are ineffective because they lack the cues and constraints of real tasks (Lave & Wenger, 1991, Suchman, 1987).

These modern perspectives on cognition emerged as responses to classical views that emphasized isolated, brain-bound processing. Instead, they offer a richer view of learning as shaped by dynamic interaction with the body, tools, environments, and social context. For instructional design and learning research, this means understanding user experience not only in terms of internal cognition, but also in relation to learners' environments, contexts, and interactions.

Interaction & Instructional Design

The fields of interaction and instructional design are central to this thesis. Both rooted in cognitive science, these fields are concerned with shaping how people engage with systems. Interaction design stems from human-computer interaction (HCI) and focuses on the design of products, interfaces, and experiences that are effective, efficient, and meaningful to use (Preece, Rogers, & Sharp, 2015). Instructional design, in contrast, is concerned specifically with structuring educational experiences that support effective learning by promoting understanding and retention (Smith & Ragan, 2005).

While distinct in practice, these fields are theoretically deeply connected; especially when learning occurs through interactive systems such as e-learning platforms. They are both based on the understanding of human cognition, and as Sweller et al. (2011) put it, "without knowledge of human cognitive processes, instructional design is blind" (p. 5). This thesis treats both fields as cognitive concerns: design choices (whether interface-based or instructional) directly affect how learners attend to, process, and remember information.

Usability

A central concept in both interaction and instructional design is usability; how easily and effectively users can interact with a system to achieve their goals. In *The Design of Everyday Things*, Norman (2013) outlines principles of human-centered design, arguing that when users struggle, the

problem lies not with them but with design that fails to account for human cognitive limitations.

In his book, Norman introduces key cognitive concepts that are highly relevant for the design of learning environments, such as affordances (features of an object that suggest how it can be used), natural mapping (intuitive relationships between interactions and their meaning), and feedback (that users know the effects of their actions). These principles support the formation of conceptual models; the mental models users form to understand how a system works. Norman further identifies two important cognitive challenges in design; minimizing the gap between users' intentions and knowing how to carry it out (gulf of execution) and the gap between performing an action and understanding what happened as a result (gulf of evaluation).

Similarly to theories of embodied, extended, and situated cognition (Clark & Chalmers, 1998; Hutchins, 1995; Lave & Wenger, 1991; Suchman, 1987; Kirsh, 1996), Norman highlights that cognition is shaped both by internal knowledge and external structures. Learning environments should consequently be designed to balance and support these two. A particularly relevant insight for educational design is Norman's concept of the paradox of technology; while technological advances offer increased functionality and flexibility, they often introduce complexity that undermines usability. In learning contexts, this means that added functionality, if not carefully designed, can increase cognitive load and reduce usability. Ultimately, Norman's design principles are not just about convenience; they are grounded in how people think and learn. In educational contexts, particularly in self-study, supporting usability ultimately means supporting cognition.

Mayer's Cognitive Theory of Multimedia Learning

A central theory in instructional design for multimedia environments is Mayer's Cognitive Theory of Multimedia Learning (CTML). Multimedia learning refers to the use of materials that combine words (spoken or written) and visuals (e.g., illustrations, animations, videos) to enhance understanding (Mayer & Fiorella, 2022). This encompasses many different formats, including self-study formats such as e-learning modules, which are central to this thesis. Initially formalized by Mayer (2001) and extensively developed in subsequent editions (e.g. Mayer, 2005, 2009, 2011, 2014, 2021), the theory culminates in the third edition of *The Cambridge Handbook of Multimedia Learning* (Mayer & Fiorella, 2022).

CTML holds that meaningful learning involves three cognitive processes: selecting relevant information (attending), organizing it into mental structures (schemas), and integrating it with prior knowledge. These occur in working memory, which, as discussed, is limited in capacity (Sweller, 1988), making the design of multimedia content critical to avoid cognitive overload. CTML integrates several theories of cognition and learning, especially Cognitive Load Theory (Sweller et al., 2019) and Baddeley's multi-component model (Baddeley & Hitch, 1974; Baddeley, 2000), both discussed earlier in this section. It also draws on Dual Coding Theory (Clark & Paivio, 1991), which proposes that verbal and visual information are processed through two distinct but connected channels. Activating both channels helps learners form dual representations which improve comprehension and recall.

Additionally, CTML is highly influenced by gestalt psychology, a field that explores how people naturally

perceive and organize information (e.g. Wertheimer, 1959; Katona, 1940). Early gestalt psychologists, such as Wertheimer (1959) and Katona (1940), suggested that the human brain is wired to look for patterns, structure, and meaning. Instead of interpreting individual parts, we tend to group related elements together into a single, meaningful whole. They identified several gestalt principles, such as that we tend to group things that are close together (proximity), look similar (similarity), or appear to follow a continuous line (continuity). These principles help explain how attention and pattern recognition support an intuitive understanding of visuals. CTML is also informed by the work of developmentalists such as Piaget (1926) and Vygotsky (1978), who emphasized the active and socially embedded nature of learning.

A further theoretical foundation of CTML is the Integrated Model of Text and Picture Comprehension (Schnotz, 2022, in Mayer & Fiorella), stating that learners mentally coordinate verbal and pictorial representations into a coherent mental model. Additionally, CTML considers the role of motivation and affect in multimedia learning, as emotional engagement, interest, and perceived relevance influence how deeply learners process instructional material (Schrader, Kalyuga, & Plass, 2022, in Mayer & Fiorella). Finally, metacognition, referring to learners’ awareness and regulation of their own thinking, is essential in self-directed multimedia learning environments. Supporting metacognitive monitoring (e.g., through prompts or feedback) can enhance self-regulated learning and overall comprehension (Azevedo & Dever, 2022, in Mayer & Fiorella).

As shown in Fig. 2, CTML applies Baddeley’s model of memory to multimedia input. Visual sensory memory captures visual information and auditory sensory memory processes spoken input. Attended content enters working memory, where it is integrated with prior knowledge gathered from long-term memory. Since only a limited number of elements can be processed here at once, CTML stresses that instructional design must manage extraneous, intrinsic, and germane cognitive demands. Poor design increases extraneous processing, reducing the cognitive resources available for learning (essential and generative processing).

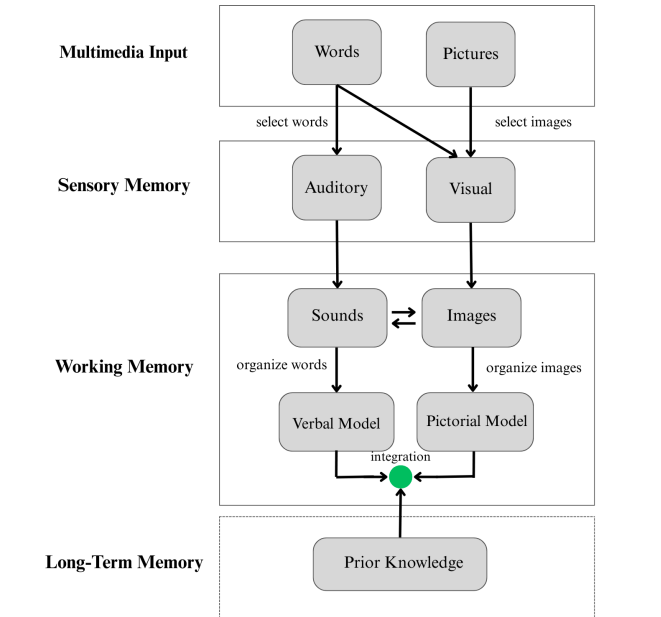


Figure 2. Cognitive Theory of Multimedia Learning (adapted from Mayer, 2024)

CTMLs main practical contribution is its set of empirically supported multimedia design principles. These principles aim to help instructional designers manage intrinsic load (essential processing), reduce extraneous load (extraneous processing), and promote germane load (generative processing). The most relevant design principles to this thesis are presented below under the types of processing they aid (see Tables 2, 3 & 4).

Table 2. CTML principles to manage essential processing

Principle	Description
Segmentation	Breaking content into smaller, meaningful parts supports chunking and prevents overload (Mayer & Fiorella, 2022, in Mayer & Fiorella).
Pre-training	Introducing key concepts and definitions before instruction facilitates schema construction (Mayer & Fiorella, 2022, in Mayer & Fiorella).
Modality	Spoken text paired with visuals avoids overloading the visual channel, enhancing dual-channel processing (Castro-Alonso & Sweller, 2022, in Mayer & Fiorella).

Table 3. CTML principles to reduce extraneous processing

Principle	Description
Coherence	Removing unnecessary or distracting elements minimizes irrelevant processing (Fiorella & Mayer, 2022, in Mayer & Fiorella).
Redundancy	Avoiding presenting the same information in more than one format in the same modality (verbal and visual) reduces overload (Kalyuga & Sweller, 2022, in Mayer & Fiorella).
Signaling	Using cues like arrows or highlighting guides attention to important content (van Gog, 2022, in Mayer & Fiorella).
Spatial & temporal contiguity	Presenting related visuals and text close in time and space facilitates integration and avoids split-attention effects (Ayres & Sweller, 2022, in Mayer & Fiorella).
Worked Example	Providing complete examples of tasks supports learning by modeling problem-solving strategies, especially for novices (Renkl, 2022, in Mayer & Fiorella).

Table 4. CTML principles to promote generative processing

Principle	Description
Multimedia	Combining words and images enhance learning more than words alone (Mayer, 2022, in Mayer & Fiorella).
Personalization	A conversational communication style increases learner engagement and improves retention (Mayer & Fiorella, 2022, in Mayer & Fiorella).

Collaboration	People learn better in groups than individually (Janssen, Kirschner & Kirschner, 2022, in Mayer & Fiorella).
Emotional Design	Warm colors, facial expressions, and human-like voices can enhance learning motivation by creating a social presence (Plass & Hovey, 2022, in Mayer & Fiorella).
Expertise Reversal	Instructional methods that are effective for novices may be ineffective for more experienced learners (Kalyuga, 2022, in Mayer & Fiorella).
Generative Activity	Learning improves as learners are instructed to engage in generative learning activities (such as creating conceptual maps, drawing, imagining, producing self-explanations, etc) (Fiorella & Mayer, 2022, in Mayer & Fiorella).

In summary, CTML provides a comprehensive and research-based framework for designing instructional materials that align with human cognition. While CTML is rooted in numerous aforementioned cognitive theories and developed by several authors, further references to these principles will be aligned under Mayer and Fiorella (2022).

Previous Research on CLT in the Workplace

Although CLT and CTML are grounded in robust cognitive science and are widely used in instructional design (Sweller et al., 2019; Mayer & Fiorella, 2022), much of the empirical validation has occurred in academic or simulated environments. Research on their application in workplace settings, particularly in onboarding, is still limited, despite the theories' relevance to any context involving human learning.

Few studies have examined how CLT, CTML, or schema theory apply to onboarding for salespeople. An exception is Bolander et al. (2019), who used CLT and Mental Models Theory (Johnson-Laird, 1983) (similar to schema theory) to compare the development of sales knowledge in newly hired salespeople with either prior experience or formal sales education during onboarding. Their findings showed that although experienced hires exhibited stronger initial performance, their mental models were often fragmented, formed under high extraneous load, and less conducive to long-term growth. In contrast, formally educated hires developed more coherent schemas and demonstrated greater improvement over time.

Evanick (2024) offers further insight through a comparative analysis of instructional design in higher education and corporate learning. His study emphasizes that effective corporate onboarding should leverage experiential, goal-oriented learning, supported by rapid, iterative instructional design and embedded performance support tools. These practices align with CLT by minimizing extraneous load and with CTML by enabling dual-channel processing through well-designed multimedia. Evanick concludes that onboarding is most effective when it embeds learning in realistic contexts, scaffolds schema formation, and applies evidence-based multimedia and cognitive principles to enhance transfer and retention.

In broader workplace research, Kiliç, Akdemir, and Sağbaş (2024) conducted a comprehensive review of 25

empirical studies applying CLT across organizational contexts. Their analysis revealed that digital tools, frequent interruptions, emotional stress, and unstructured communication significantly elevate employees' cognitive load, often hindering performance and well-being. They argue that managing cognitive load should be considered a core managerial responsibility, even though a standardized framework for cognitive load management (CLM) is still lacking. Among the studies reviewed, several highlight design interventions that successfully reduce extraneous load and improve performance. For instance, Blissett et al. (2021) applied CLT to the training of cardiology trainees and identified multiple sources of intrinsic load and extraneous load in workplace learning environments, such as task complexity, information search requirements, and interface design. Their findings show that reducing extraneous load through better instructional design and increasing germane load via peer guidance and accessible feedback loops improved learning outcomes. These types of studies provide concrete examples of how CLT-informed design can optimize both task performance and knowledge acquisition in professional settings.

In the field of healthcare, Sewell et al. (2019) provided one of the most comprehensive workplace-oriented CLT reviews to date, analyzing 116 empirical studies across simulated and actual professional environments. Their scoping review confirmed CLT's core claims: high cognitive load, especially among novices and in complex tasks, consistently degrades performance, while instructional and environmental design can either raise or lower that load. Although most studies focused on overall cognitive load, few distinguished between subtypes (intrinsic, extraneous, germane), underscoring a measurement challenge in applied settings. The authors highlighted practical strategies such as adjusting task complexity to learner expertise, simplifying information displays, using checklists, and teaching metacognitive strategies to help learners recognize and respond to overload. They emphasized the need for future research to integrate CLT with other frameworks, including sociocultural and motivational theories, to better reflect the realities of workplace learning.

Finally, insights from human resource development research further support the role of CLT in workplace training. Lin (2025) proposed an extended CLT framework emphasizing that effective performance depends on managing intrinsic, extraneous, and germane load while supporting schema construction. Lin identified modeling, scaffolding, and structured reflection as strategies that enhance understanding and reduce unnecessary mental effort. The study also emphasized that individual differences, such as cognitive ability, emotional intelligence, and self-directed learning, significantly influence how learners process and respond to complex training content.

User Experience

Both instructional and interaction design emphasize the importance of understanding users and how they perceive, interact with, and are affected by systems in specific contexts (Arvola, 2021). This aligns with modern views of cognition as embodied, situated, and extended - shaped by the tools we use, the environments we act in, and the social and physical contexts of activity (Suchman, 1987; Lave & Wenger, 1991; Hutchins, 1995; Clark & Chalmers, 1998).

User research must therefore consider not only cognitive factors, but also motivational and emotional ones; such as

intrinsic motivation and psychological needs (Deci & Ryan, 2020), self-efficacy (Bandura, 1997), self-regulation (Zimmerman, 2002), and perceived control (Cooper, 2007).

User Experience (UX) is thus central to learning design. According to Norman (2013), systems should be designed around human thinking and behavior. Arvola (2021) emphasizes that UX research must be grounded in empirical insight into users' goals and challenges. This thesis applies that approach through a comprehensive pre-study examining how salespeople engage with training materials, which directly informs the study's redesign of the self-study material.

While UX and cognitive science are distinct interdisciplinary fields, they overlap in critical ways. UX without cognitive science, in this thesis's view, risks becoming blind to the actual mechanics of learning and thinking. Cognitive science provides essential insight into attention, memory, processing limitations, and human reasoning; all of which are foundational to effective design. This thesis approaches UX not as a separate design layer, but as a cognitive and instructional concern, directly affecting how users process, understand, and retain information.

3 Pre-Study

The pre-study was conducted to address the thesis's first research question, investigating how the company's self-study materials are constructed, used, and perceived by stakeholders and the salesforce. This user research aimed to build a foundational understanding of the learning journey for new salespeople at the company and which challenges are experienced, particularly when learning MV.

An important goal of the pre-study was to identify usability challenges in the company's self-study materials and to inform the selection and redesign of a training module for the main study's experiment. This ensured that the design process was user-centered (Norman, 2013) and based on the actual needs and experiences of its users. The pre-study also provided necessary contextual insight into how these materials are developed, distributed, and used within the organization.

To understand the sales learning journey, it was essential to examine how training materials are introduced, how learners navigate them over time, and how they connect to other parts of onboarding. Cognition is, after all, not isolated, but extended, distributed, and situated in its social and physical environment (Clark & Chalmers, 1998; Hutchins, 1995; Lave & Wenger, 1991; Suchman, 1987). Therefore, understanding the context in which the materials are embedded was crucial, as learning does not occur in a vacuum but is shaped by organizational structures, tools, and social interaction (Lave & Wenger, 1991; Nardi, 1996).

Upon starting the pre-study, it became clear that insights from the local office alone would be insufficient to capture the diversity of experiences within the global organization. One purpose of this investigation of the thesis was therefore additionally to collect and spread knowledge of the usage and perceptions of self-study materials to the local office. The distributed nature of sales offices and the extensive volume of training materials made it impossible to review everything in detail or to rely on a single source of input. Therefore, the pre-study included multiple methods; interviews were conducted, a survey was sent out to individual salespeople, and company and material analyses were done.

Research Setting

As briefly mentioned in the introduction, the company is a large, global company that produces intelligent sensor solutions for industrial automation. With over 12,000 employees and a portfolio spanning more than 40,000 products, including sensors, safety systems, robot guidance systems, and machine vision technologies, the company faces the challenge of helping its international salesforce make sense of a highly complex product landscape. This study was conducted within one of the company's business units that develop industrial machine vision cameras.

Machine vision (MV) refers to systems that enable machines to "see" by using cameras and image processing algorithms to inspect, guide, and control processes automatically. The company targets customers in industrial settings, in which cameras with MV techniques are used to detect, measure, locate, and inspect objects. Teaching new salespeople to understand and sell such advanced systems, especially through self-directed e-learning modules, is no trivial task. Feedback from sales offices pointed to challenges not only in the complexity of the topic but also in how the information was structured and delivered. Thus, in a company of this scale, the challenge lies not only in explaining intricate content, but also in designing a coherent, accessible, and scalable learning experience across the onboarding journey.

Method

Material Analysis

To gain a comprehensive understanding of the company's training ecosystem, internal pages were reviewed, including those detailing the sales training program, global structure, and product portfolio. This included examining guidelines, templates, and an internal course for trainers. Exploring the tools and templates used to develop e-learning helped ensure a dual perspective: both user and creator.

The training portal, where all e-learning materials are published as self-study materials, was analyzed in depth. Several modules were completed, including sales, MV and other product families, to experience the self-study journey firsthand. Portal usage statistics were also reviewed to identify usage patterns. Given the size of the product portfolio (40,000+ items), full coverage was impossible; therefore, representative materials were sampled.

Additional resources reviewed included the training material bank (housing PowerPoints, videos, and e-learning links) and the company's graphic design guide. Although not an in-depth analysis, this phase was essential for identifying usability challenges and building confidence ahead of stakeholder interviews. One recent internal evaluation of the sales training concept was also reviewed. While broad in scope, it offered useful insights into perceived challenges.

Interviews

While internal pages and training modules provided some insights, they were insufficient for addressing the qualitative nature of the research questions. Interviews emerged as the most effective method to gather information on the usage and perceptions of the self-study materials. Consequently, 24 semi-structured interviews were conducted with relevant stakeholders across three categories: individuals involved in constructing the training material ($n = 10$), managers or trainers at sales offices ($n = 13$), and one new vision

specialist salesperson. This diverse selection was necessary to understand how the self-study materials are constructed, used, perceived, and the context in which they exist.

Participants were recruited internally from the local office, and mail contact was used to recruit participants from the training department and sales offices across Europe and America. Identifying the right participants was a complex process, but help was provided by the local office. Interviews were conducted online or in person, lasting between 30–60 minutes. All participants were informed about the study's purpose, gave verbal consent, and, when online, were asked for permission to record the conversation to support notetaking. Recordings were deleted after transcription.

Interviews followed flexible guides to balance consistency with the ability to explore emerging themes (Bryman, 2016). Guides were tailored to each group's role. For stakeholders involved in training material creation, the conversations focused on the processes, design rationale, and instructional goals behind the self-study modules. These discussions were often informal and open-ended, allowing participants to elaborate on constraints, priorities, and design practices. For the new vision salesperson, questions focused on their onboarding process and usage and experience of self-study materials.

For the interviews with managers and trainers at sales offices ($n = 13$), a more structured yet still flexible guide was used (see Appendix B), shaped around five core themes: the structure of their sales unit, onboarding and training practices, role and usage of self-study materials, perceptions of those materials, and specific challenges related to learning MV. While these themes helped ensure consistency across interviews, they were approached as entry points rather than fixed sequences, allowing participants to guide the flow and depth of discussion based on their own experiences.

Conversations typically began with open questions about the participant's role and their sales unit's structure. This not only served as a natural starting point but also allowed questions to be tailored depending on their involvement in sales training. When discussing perceptions of the training materials, personas and scenarios were used to encourage reflection; for example, by asking participants to imagine themselves as a new salesperson navigating the onboarding journey. This method supported imagination and perspective-taking, helping participants articulate insights that might otherwise have been difficult to express (Arvola, 2021).

The final theme focused on how salespeople learn about MV, with particular attention to recurring difficulties. Early in the process, participants were asked what salespeople found most difficult to learn, but responses were often hesitant or vague. Reframing the question as "What do you get asked about the most?" proved more effective, prompting concrete, relatable examples. This iterative refinement of the questioning approach is highly recommended in user research practices (Arvola, 2021).

Given the international scope of the company, the interviews reflected varied communication styles and organizational practices. Adopting a semi-structured and conversational format allowed each interview to develop its own rhythm and accommodate these cultural differences. A secondary goal of the sales office interviews was to seek permission to distribute a survey to their salesforce and to obtain contact information for doing so. This request was made at the end of each interview.

Survey

To complement the interviews and gain insight into individual user experiences, an anonymous survey targeting salespeople was constructed and distributed with the support of local office contacts and sales managers. The goal was to collect background information on the salesforce, map their learning journey, assess the use and perception of self-study materials, and identify specific challenges in learning MV.

The construction of the survey was iterative and informed by findings from the interviews and feedback from internal experts at the local office, ensuring relevance and clarity. The Slido platform (Cisco Systems, 2025) was used to construct the survey, as it was the only external tool permitted by the company. Its limitations, such as the lack of conditional logic, embedded media, and custom formatting, restricted design flexibility. To compensate, free-text questions were included for richer responses.

The final version (see Appendix C) consisted of 17 questions and began with a consent item outlining the study's purpose. Demographic questions included role, sales unit, age, and education. Respondents also reported on how long they had worked in the company and prior technical experience to assess their entry-level knowledge. This was followed by multiple-choice items identifying the types of training materials provided during onboarding and asking respondents to rank the most valuable informational resources. Questions then focused on self-study materials; usage frequency, perceived challenges, and overall evaluation. Predefined challenge categories, informed by analysis and interviews were used to standardize responses and facilitate analysis. Categories included aspects such as navigation difficulty, language issues, visual design concerns, and technical complexity. A free-text field allowed participants to elaborate on their experiences.

A separate section asked about experience with MV training, including completion level and specific difficulties encountered. Finally, participants were invited to share additional feedback, positive or negative, about the self-study materials. At the end of the survey, participants were thanked for their time and those interested were invited to participate in the main experiment, by providing their email in a separate Slido form to ensure anonymity.

Distribution of the survey relied on internal mailing lists provided by sales managers, primarily through group emails to sales teams. Certain sales managers preferred to send out the survey themselves, so the number of recipients was unknown; the estimated reach was between 300 and 400 salespeople across 13 countries. The invitation email was brief, personal, and deliberately framed as a call for help with a master's thesis to increase engagement (Cialdini, 2021). It included information such as estimated time (5–10 minutes), anonymity assurance, the survey link and password, and a deadline. The survey remained open for 1.5 weeks.

Analysis

A version of thematic analysis was conducted on all qualitative data gathered during the pre-study to identify, analyze, and organize recurring patterns (Braun & Clark, 2006). For each interview, key points were extracted and grouped under a set of predefined themes in a separate analysis document:

- Company Structure
- Salesforce
- Training Material Construction

- The Learning Journey
- Usage of Self-Study Material
- Perceptions of Self-Study Material
- Perceptions of Learning Machine Vision

Relevant statements were copied under these headings in bullet-point form to summarize and structure the large volume of information. This approach enabled the identification of recurring patterns and the development of categories and sub-themes, particularly regarding user perceptions and learning challenges. Free-text survey responses and observations from the material analysis were integrated into the same framework to form a cohesive understanding across data sources.

Quantitative survey data was analyzed using Slido's built-in analytics tools, which provided descriptive statistics such as response percentages. No further statistical analysis was carried out, as the survey's purpose was only to generate indicative insights. The results from all three data sources; material analysis, interviews, and survey, are presented in an integrated manner in the following section.

Results

Organizational Learning Context

Understanding how training materials are created, managed, and used requires a clear grasp of the company's structure and sales training system. As outlined, the company is large; it operates in over 40 countries and is organized into five business clusters, each responsible for a group of product families (see Fig. 3). Each cluster consists of several business units, including one focused on MV: the domain of this thesis.

Product development, marketing, and training material construction occur at the business unit level, while global sales and customer operations are handled by regional sales units. A central management function oversees competence development across the organization, including the sales training concept, training materials, and the training portal. Each cluster is supported by a dedicated Training & Education (T&E) team, which ensures that product knowledge is effectively transferred from development to sales.

These T&E teams play a key role in transforming raw content, often in PowerPoint format, into structured e-learning modules using Articulate Rise 360 (Articulate Global, 2025). They follow company-wide instructional guidelines and design models, such as ADDIE (Branch, 2009), and ensure content is goal-driven, interactive, and accessible in five languages. Modules are then published in the company's internal training portal and distributed to sales offices, where local managers assign training via structured profiles.

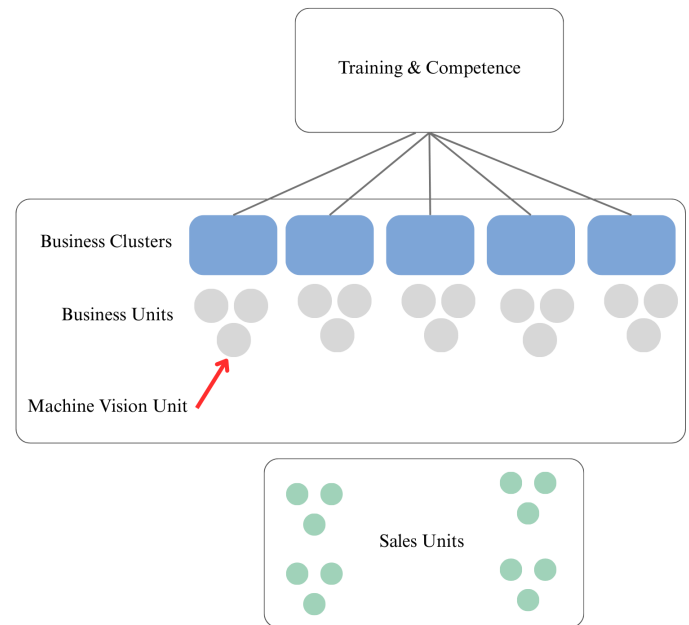


Figure 3. The company's organizational structure at a glance

Training Material Construction & Distribution

The company's sales training concept, launched a few years ago, provides a standardized framework for onboarding and continued learning throughout an employee's time at the company. It categorizes training for each product into three levels; basic, advanced, and expert, each covering five core areas: market, industry, technology, application, and product information. Each module is guided by templates with defined learning objectives and instructional structure.

Basic-level training, which is the focus of this thesis, delivers concise, entry-level product knowledge suitable for short sales pitches. These modules are distributed as self-paced e-learnings in the training portal, while more technical or practical content is delivered through advance-level PowerPoints in face-to-face training sessions. The training approach is informed by the 70-20-10 model (Lombardo & Eichinger, 1996), acknowledging the importance of learning by doing (70%), from others (20%), and self-study (10%).

Material creation is a collaborative effort. Product managers at the business unit level are responsible for content and knowledge transfer for their product lines. They are supported by application engineers, who contribute expert insights and often lead training for complex systems. Marketing specialists help shape the basic content, particularly for market-facing materials. Once drafted, the T&E team transforms these materials into e-learnings, ensuring consistency and instructional quality.

Despite this structure, the large number of contributors leads to some variation in quality, format, and update frequency. If the content is not converted into e-learnings, it is uploaded to a centralized internal material bank. In practice, product information may also be distributed across several internal platforms, leading to perceived fragmentation. This structural complexity presents challenges for both content creators and learners, particularly in locating and navigating relevant training.

The Training Portal

The training portal serves as the company's primary platform for managing sales training. It offers interactive e-learning modules, booking pages for trainer-led sessions, and administrative tools for assigning, tracking, and evaluating learning progress. Content is organized into roles, profiles, skills, and lessons. Sales managers at the local sales units assign roles to their salesforce, which link to structured profiles with collections of skill modules that reflect the knowledge needed for specific sales responsibilities. Completing all lessons and quizzes in a module earns a "skill," signaling readiness to sell a product. From a user perspective, the portal's interface includes dashboards for assigned skills, recommended content, and searchable training catalogs (see Fig. 4)

During this thesis, a major restructuring of the training portal was underway. Based on feedback from sales offices, the aim was to optimize overly large training profiles and improve usability. Profiles were condensed, with a greater focus on relevant and manageable content. For MV, new profiles were introduced: one for 2D and four dedicated to 3D technologies, each supposed to contain an overview module and selected product and software training modules. The shift also involved making sure all training in the portal is in interactive e-learning format and not PowerPoint.

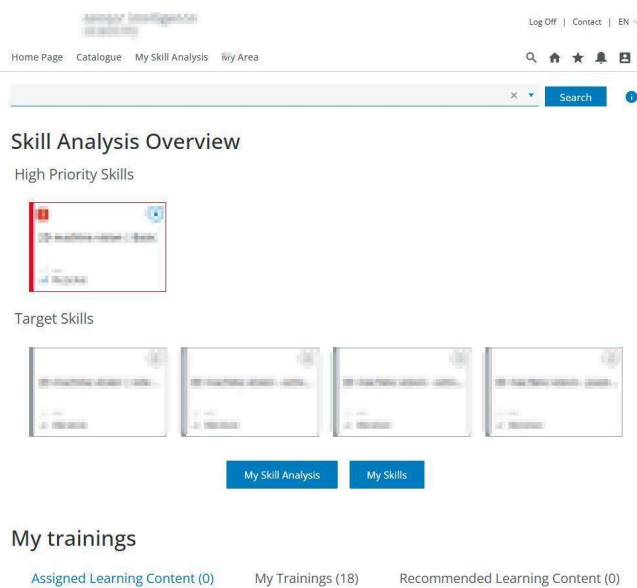


Figure 4. Overview of the start page of the company training portal

The Salesforce

The global salesforce spans approximately 30 sales offices and is central to the company's business operations. It includes general salespeople, who manage the full product portfolio within assigned regions, and specialists focused on specific markets, industries, customers, or technologies like MV.

The survey conducted for this thesis received 37 responses from 11 countries. Respondents included general salespeople ($n = 15$), industry specialists ($n = 12$), customer specialists ($n = 4$), vision specialists ($n = 5$), and other roles such as sales engineers ($n = 5$). Despite a modest response rate, the sample was diverse and reasonably representative. About 30% of respondents had worked at the company for over 10 years, 22% for 5–7 years, and 48% were relatively new (0–4 years). Additionally, 57% were between 44 and 65

years old, confirming interview insights that the salesforce includes both long-standing employees and recent hires, many of whom joined after the pandemic.

Survey data revealed that 75% held a university degree, and only 6% lacked prior technical education or work experience. Nearly half had both, which aligns with interviews suggesting that most salespeople are technically skilled, many with backgrounds in engineering or technical sales. However, regional variations exist, with some offices emphasizing general sales capabilities over technical depth.

One recurring challenge is the scope of the company's product portfolio (40,000+ items), which makes comprehensive product knowledge difficult to achieve. Interviews highlighted that this scope makes the onboarding process particularly demanding for new hires; a challenge that will be explored further in upcoming sections.

During the thesis period, the company launched an initiative to prioritize MV, responding to internal feedback about its technical complexity and rising market importance. Vision Specialist teams were formalized in local sales offices to take over responsibility for solution design and sales in this domain. General salespeople are now expected to have only a basic awareness of MV to identify customer opportunities for the Vision Specialist teams to proceed with.

The Learning Journey

With different sales offices and roles, there is no single unified learning journey for a general salesperson within the company. New salespeople generally begin with onboarding activities, including introductory meetings with managers and sessions with product managers. This is followed by self-paced, basic-level training in the company's training portal. Introductory modules on company guidelines and communication are usually completed early. Sales managers then assign training profiles, which include basic-level modules on specific products, applications, or industries. These assignments vary: some managers assign comprehensive profiles, while others tailor selections to salespeople's backgrounds or local market needs. Some salespeople are left to explore the portal independently. It was evident that MV modules were rarely assigned to generalists unless relevant to their customer base or prior interest.

Face-to-face sessions with product managers or dedicated engineers located at sales offices are often part of onboarding and typically occur before self-study is completed, despite being designed as more advanced-level follow-ups. Local onboarding practices vary, including shadowing or participation in training courses abroad. During the COVID-19 pandemic, face-to-face training was postponed or converted into self-paced modules. This shift toward self-study persisted even after restrictions eased, as it offered greater flexibility and scalability.

A consistent finding was that the amount of self-study material is overwhelming. Stakeholders described the training workload as excessive; one manager estimated it would take a full year of dedicated study to complete. This is unrealistic given that salespeople typically start with customer visits within two weeks of onboarding. Some stakeholders believed that most self-study occurs within the first six months, while others felt it is never fully completed.

Important to mention is that self-study in the training portal is only one part of a diverse learning landscape. There are six major platforms where training content can be found, underscoring the complexity of the learning environment.

Survey respondents reported on their use of different available informational sources in their learning journey at the company (see Fig. 5). Respondents reported using the company website (76%), self-study modules in the portal (68%), and attending advanced trainer-led sessions (66%). Other frequently used resources included user manuals (58%), local materials (55%), and the training material bank (50%).

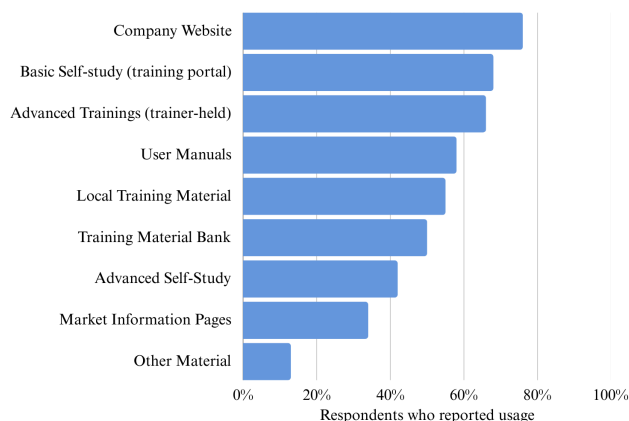


Figure 5. Informational resources in order of usage (%)

When ranking these by informational value, respondents prioritized face-to-face training with trainers, product managers (PM), and colleagues, followed by video tutorials and company websites (see Fig. 6). Self-study materials ranked seventh. This highlights a clear preference for interactive and social learning formats over independent study.

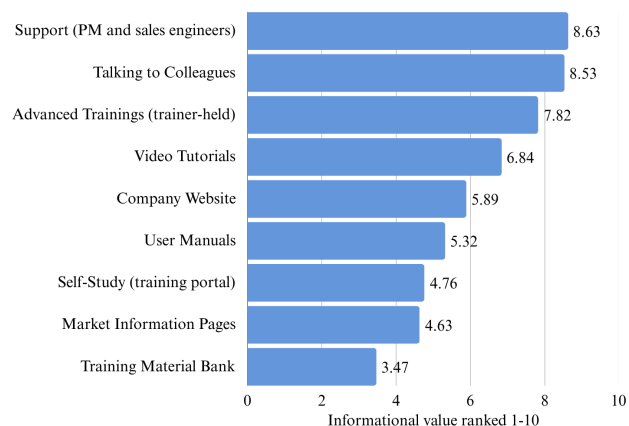


Figure 6. Ranking of resources in terms of informational value

Despite this, 95% of survey respondents reported having completed basic modules, though only 39% said they continued using the portal regularly. Around 58% had completed advanced training independently (via the portal or PowerPoints), while 37% had done so with a trainer.

However, there was general uncertainty around how and when self-study materials were used. Many creators of training content had little to no direct contact with the end users. Portal statistics were seen as uninformative; they tracked completions but not participation or progress. Most completions occurred shortly after the training portal's launch, likely due to organizational mandates. There was, thus, little insight into ongoing use.

Interviewed sales managers expressed mixed views. Some believed introductory modules were widely used,

while others thought basic product modules were ignored. About 30% of managers believed that self-study materials were not used at all, citing time constraints and competing training formats. Many believed advanced modules in PowerPoint form, intended for trainer-led sessions, were instead being used as self-study.

In general, self-study materials were seen as a supplement to more valued resources like face-to-face sessions or local materials. While their importance was acknowledged, there was no consensus on their actual integration into the learning journey. Some managers actively monitored completion; others did not. Concerns about quiz quality, learner engagement, and passive participation were frequently mentioned.

One example helps illustrate these dynamics. In the interview with a newly hired MV specialist, their onboarding process was described. Although highly experienced in the field, he reviewed the company's product training to understand portfolio positioning. He did not use the portal's e-learning but relied on PowerPoints from the training bank, product manager-led sessions, and colleague support. He also attended a week-long in-person session at the local business unit. While he appreciated the quality of videos and presentations, he found internal navigation difficult and reported needing direct links to access content. He summarized the challenge as that "You have to give things a name, and then they fall under a certain category. If you don't know what the category is, you won't find it". The challenges in navigation were also expressed by several stakeholders.

Perceptions of self-study materials

Survey responses and stakeholder interviews revealed a wide range of perceptions regarding the company's self-study materials. The most frequently reported challenges were related to information overload, poor navigation, limited engagement, and difficulty in applying content to sales contexts. Eight themes (see Fig. 7) emerging from the interview and survey findings are presented below.

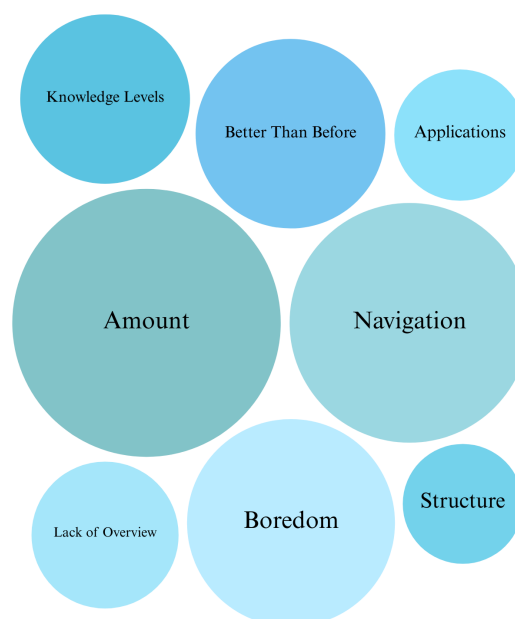


Figure 7. Themes of perceptions of self-study materials

The most common criticism was the overwhelming amount of material, scattered across multiple platforms. This was particularly problematic for new employees, who found it unrealistic to complete the training within the limited time

available for self-study. While some stakeholders appreciated the distribution across platforms for broader reach, most noted it contributed to confusion, even among experienced staff.

Navigation was a frequent pain point. Both the internal pages and training portal were often described as difficult to use. The training portal's search function was reported as ineffective, largely because modules are not tagged clearly. As a result, managers and trainers often directed employees to other internal pages; but these were perceived as even harder to navigate due to the amount of pages and further poor search capability. Nearly half (49%) reported that self-study materials were hard to find and that there were too many modules to go through.

Many stakeholders raised concerns about disengagement during self-study, describing the experience of salespeople finding it boring and hard to focus. The phrase "death by PowerPoint" was repeatedly used, highlighting frustration with passive content formats. Although the newer e-learning format was seen as an improvement, thanks to its interactive content, users noted that "clicking through" lessons did not guarantee actual learning. 22% of survey respondents reported that there was too much information to take in and that it was difficult to stay focused and alert during self-study. A demand for more engaging formats, particularly videos and animations, was clear; 51% of survey respondents expressed a request for more visuals in self-study materials.

While the training portal was often used to get a general overview, respondents noted a lack of structured overview modules that help them understand how different technologies and products relate to each other. Several managers mentioned that new salespeople frequently asked for such training, indicating both demand and a gap in the current offering. 27% of survey respondents reported struggling to get a clear overview of the company portfolio, and 22% reported difficulties initially understanding how products relate to applications.

Stakeholders also emphasized that training should better support and be situated in real sales contexts. Many expressed a need for more application-based training and practical, hands-on sessions. Without seeing how products are used to solve customer problems, it was perceived as hard to translate technical knowledge into sales value. 22% of survey respondents reported difficulties understanding how the products are applied in real contexts.

Some structural issues were also raised. The standardized five-area format for each training module (market, industry, technology, application, product) was not always a good fit; especially for complex software or advanced products. Quality and consistency varied across modules, and there was significant overlap between marketing and training materials. A frequent question was why materials were still created in PowerPoint before being converted into e-learning, rather than developed directly in the training platform.

Designing training for such a broad target group posed another challenge. Because knowledge levels vary widely across general and specialist sales roles, it was difficult to ensure relevance and accessibility for all. While the basic modules were designed to provide broad awareness and identify sales opportunities, several respondents felt they were too technical. Others pointed out that subject-matter experts were developing and reviewing content not intended for them, which risked inflating the knowledge level.

Overall, the general attitude toward the basic training modules was cautiously positive. Most described them as "good" or "fine," and many appreciated the more interactive elements and growing use of video tutorials. It is important to note that 24% of survey respondents reported no experienced challenges with self-study materials. Longer-tenured employees tended to express more support for the current system, having experienced less structured formats before. The transition to the new training concept, however, required a heavy workload to migrate and complete content, which some perceived as forced. Still, several respondents mentioned that the company's training was better than what they had experienced at previous employers.

Learning Machine Vision

MV emerged as one of the most cognitively demanding areas for the salesforce to learn. Although 85% of survey respondents reported completing some form of vision training, stakeholder interviews indicated that general salespeople often avoid engaging deeply with the topic. Many believed self-study was not sufficient for this area and that salespeople relied instead on in-person introductions or guidance from colleagues. Six themes emerged from survey and interview findings as typical challenges involved in learning MV (see Fig. 8).

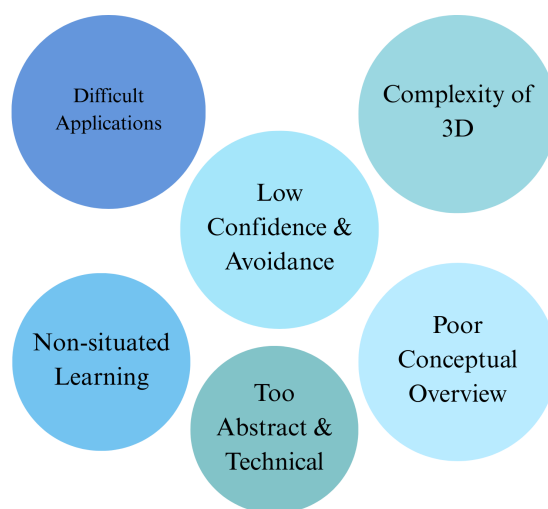


Figure 8. Themes of challenges learning Machine Vision

A recurring issue was stakeholders perceived general salespeople to often avoid engaging with MV due to low confidence and a sense of fear. Sales managers described the topic as intimidating and noted that many salespeople hesitated to speak about vision solutions with customers. One stakeholder summarized this sentiment with the remark, "Vision has always been the problem child." This reluctance seemed paradoxical given that the company markets its MV systems as intuitive and user-friendly. The contradiction highlights a disconnect between how the products are designed and how they are perceived internally.

A key reason for the lack of confidence is the technical and abstract nature of MV, which spans optics, electronics, programming, and image processing. Salespeople are expected to grasp camera settings like resolution and exposure; knowledge that typically requires hands-on experience. This is made harder by expert-centric language in self-study materials, where product descriptions often reflect an engineer's view rather than practical customer benefits. Stakeholders also noted a lack of conceptual knowledge

transfer, with many salespeople unclear on what MV is, what problems it solves, and how to communicate this to customers.

Another common challenge was the lack of a clear overview of the MV portfolio. Salespeople struggled to understand product relationships, differences between 2D and 3D technologies, and how vision tools vary. Although only basic awareness is expected for general salespeople, recognizing opportunities still requires understanding what's inside a camera system; something many found difficult without an overarching framework.

Stakeholders also pointed out that some parts of the portfolio were especially difficult to learn, particularly the 3D cameras, and software. While the software's interface was designed to be user-friendly and no one reported difficulty using it, understanding what it actually does and how it fits into the MV system was challenging. The software uses AI-based tools and the continuous addition of new tools also made it difficult to keep up. Salespeople often lacked clarity on which products included the software, how it should be configured, and how to describe its functionality in customer conversations. To make sense of this, stakeholders emphasized the need to "step back" and provide a higher-level model of how cameras and software work together as a system.

Another key challenge was understanding how MV products apply to real customer problems. Salespeople struggled to match products with use cases and found camera selection especially difficult. Stakeholders stressed that this knowledge is best gained through real-world observation, not abstract instruction. While some self-study and advanced modules include hands-on tasks, most salespeople lacked access to cameras, making it hard to follow instructions or apply what they learned. Without situated, experiential learning, much of the training was perceived to lose its impact.

Discussion & Analysis

This section discusses the central challenges identified in the pre-study of the sales onboarding journey, with a specific focus on MV; the domain of this thesis. It explores how these challenges impact cognitive processing, motivation, and user experience, and it motivates the selection of one central issue for intervention. While expert teams are dedicated to managing the most complex aspects of MV in company sales, general sales people without expertise backgrounds are still expected to develop a working understanding of the portfolio. This group is the focus of analysis, as their learning experience reflects broader usability and cognitive challenges across the company. It is important to note that many positive practices were identified in the company's training materials and concept, although this thesis will focus on the identified challenges.

Survey results revealed that although 68% of respondents used the internal training portal, it was only ranked seventh in perceived value. This low ranking, despite widespread use, indicates a mismatch between the structure of self-study materials and the learning needs of salespeople. A dominant theme in interviews and surveys was a sense of overwhelm; not only due to content complexity, but also due to how information is presented, structured, and accessed. These patterns point to cognitive load as a core barrier to effective learning.

CLT, CTML & Schema Theory as Analytical Lens

To interpret these challenges, the analysis applies cognitive load theory (CLT; Sweller et al., 2019), supported by schema theory (Anderson, 1984) and the cognitive theory of multimedia learning (CTML; Mayer & Fiorella, 2022). As outlined in the theoretical background, these frameworks describe how learning depends on the limits of perception, attention, and memory, and how instructional design can support or hinder schema formation. CLT distinguishes three types of cognitive load: intrinsic (complexity of content), extraneous (inefficient presentation), and germane (schema-building effort). Several factors were deemed to introduce a high cognitive load in the learning journey of a new general salesperson at the company:

Information Complexity: During onboarding, salespeople are required to learn a wide range of unfamiliar content, including products, technologies, internal tools, and sales processes. This information is especially complex within the MV portfolio, where topics like 2D and 3D imaging, lighting, optics, and image processing must be understood in relation to one another. Such high-element interactivity imposes a substantial intrinsic load (Sweller et al., 2019). For generalist salespeople, who must cover multiple product families, this complexity is further magnified. Even with some prior technical knowledge, the onboarding experience remains cognitively demanding.

Volume and Fragmentation of Material: Salespeople must navigate a large number of training materials and internal pages to learn about various product families. These resources are organized modularly (across levels, areas, profiles, roles, and skills) which often gives the impression that there is more content to complete than there actually is. Combined with poor content prioritization, this can contribute to both intrinsic and extraneous load (Sweller et al., 2019). Additionally, frequent switching between platforms and tools imposes further extraneous load, as learners must constantly integrate scattered information and redirect their attention across systems; a process known to impair learning through the split-attention effect (Ayres & Sweller, 2022).

Navigation and Usability: From the start, the learning journey is marked by poor navigation. Finding the right content within the internal platform and the training portal was reported as extremely difficult. The lack of clear affordances, natural mapping, and visibility in the interface minimizes the gap between users' intentions and knowing how to carry them out (Norman, 2013). These navigation challenges impair usability and create frustration (Norman, 2013), pose extraneous load (Sweller et al., 2019), and lead to a reduced sense of control; a key factor in sustaining intrinsic motivation (Deci & Ryan, 2020).

Lack of Overviews and Schema Support: A major challenge identified in the pre-study was the lack of materials that establish mental models or schemas early in the learning process. This gap impairs learning throughout onboarding by increasing extraneous load and limiting schema construction (Anderson, 1984; Sweller et al., 2019; Norman, 2013). Most modules begin at the product level, excluding higher-level explanations about how technologies and products relate to the broader portfolio. Without these conceptual scaffolds, learners may struggle to organize new information and build lasting understanding.

The issue is especially evident in the MV portfolio, where both interviews and surveys revealed that salespeople often lacked a clear understanding of how products differ or when to use them. Managers reported frequent requests for portfolio overviews, underscoring the practical impact of missing schema support. One reason for this can be that materials are typically developed and reviewed by subject-matter experts, who may overlook the needs of novices: known as the expert blind spot (Koedinger & Nathan, 2000). This often results in an overemphasis on advanced or application-oriented content at the expense of foundational overviews.

Additionally, a strong emphasis from sales offices on application training has shaped even basic modules. While understanding real-world use is important, presenting applications before learners have grasped the underlying technology creates premature integration demands. It forces learners to process unfamiliar content and its use simultaneously, increasing extraneous load (Sweller et al., 2019). There is also uncertainty about when self-study materials are used. While some engage with them before hands-on sessions, many reportedly complete them afterward to meet requirements. This practice undermines their intended role in building a conceptual foundation.

Presentation of Self-Study Materials: Many self-study materials impose unnecessary extraneous load due to poor presentation. Although some content is adapted into e-learning formats, the original PowerPoint slides, especially those on the training material bank pages, are still widely used and frequently shared with sales teams. These slides are typically overloaded with text that's poorly integrated with visuals and lacks clear segmentation or signaling. This design violates several core CTML principles, such as spatial contiguity, coherence, and dual-channel integration (Mayer & Fiorella, 2022). Even in e-learning formats, attempts to simplify content sometimes fall short. Long paragraphs are replaced with excessive bullet points, and visuals remain poorly integrated with corresponding text; maintaining a high extraneous load rather than reducing it (Sweller et al., 2019). Furthermore, advanced training materials originally designed for instructor-led sessions are often repurposed for self-study without adaptation. These materials lack the necessary guidance and scaffolding for independent learning, further undermining usability and increasing cognitive demands.

Cognitive-Psychological Consequences

Together, these challenges create a consistently high cognitive load from the start of the onboarding process which can indeed impair learning outcomes. As CLT shows, excessive load impairs working memory and learning (Sweller et al., 2019). Furthermore, when salespeople feel overwhelmed by fragmented systems, poor navigation, and unclear content structure, their perceived control over the learning process diminishes (Norman, 2013). According to the Self-Determination Theory (Deci & Ryan, 2020), this perceived control is critical for sustaining intrinsic motivation.

Low perceived control can also reduce self-efficacy; the belief in one's capacity to succeed in a specific task (Bandura, 1997; Perry et al., 2001). Learners with low self-efficacy are less likely to persist, invest effort, or apply effective strategies (Pajares & Schunk, 2001). Thus, apart from that cognitive overload itself impairs learning, it can trigger a negative motivational chain, as visualized in Fig. 9.

This chain was reflected in interviews, where managers reported that many salespeople, particularly those new to MV, showed signs of hesitation and low confidence, or specifically self-efficacy. Additionally, the widespread feeling of disengagement and unenjoyment of going through self-study materials also reflects this. Ultimately, these motivational consequences impair not only learning outcomes but also downstream performance in customer-facing roles where self-efficacy and knowledge are essential.

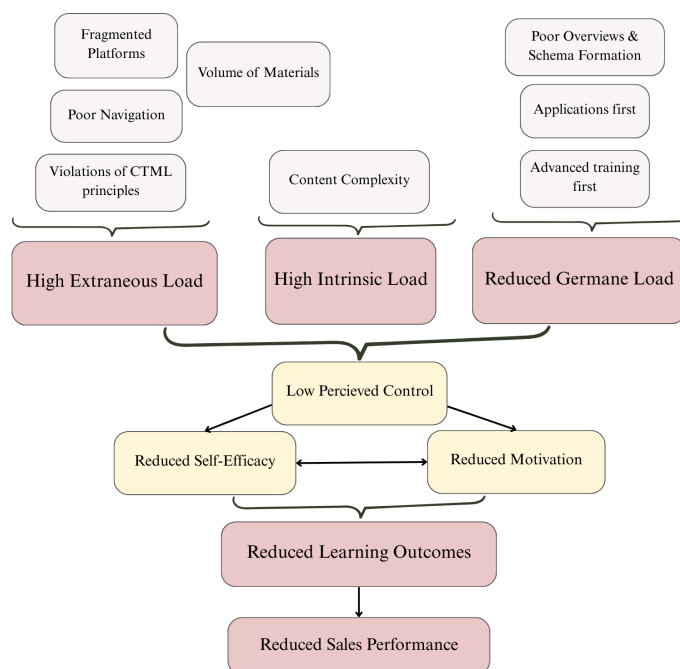


Figure 9. Visualization of identified challenges and outcomes affecting the learning journey

Informing the Main Study

Based on the pre-study findings, cognitive load emerged as the central challenge influencing the effectiveness of the onboarding journey, particularly for salespeople learning MV. While intrinsic load is unavoidable due to the portfolio's complexity, extraneous load - caused by poor instructional design, fragmentation, and lack of conceptual scaffolding - could be reduced to support germane processing and schema formation (Sweller et al., 2019; Anderson, 1984). The most actionable area was the self-study materials, where the absence of overview content stood out as a specific and addressable gap hindering schema development. Improving this aspect became the focus of the design process.

With the theoretical framework and analytical lens established, the next step was to identify a suitable training module for redesign and testing. A MV overview was selected, as the thesis was premised on the idea that MV is especially challenging for new salespeople. Interview and survey data confirmed a need for clearer conceptual overviews, particularly regarding how products relate to one another within the broader portfolio. 3D vision was also seen as especially difficult, further justifying the focus on the overview module addressing 3D.

4 Design process

This section outlines the design process behind the training materials used in the experiment, involving three steps:

1. Selecting an appropriate training module based on insights from the pre-study
2. Evaluating the original material to identify cognitive load challenges
3. Designing two new versions of the material; a revised one for the control group, and a redesigned experimental version

Material Selection

Based on insights from the pre-study, a Machine Vision Overview module was selected for the study, as it reflected many of the learning challenges identified. The selected module was launched earlier in the same year and covers both 2D and 3D vision. The module was available in PowerPoint format, which, as noted in the pre-study, is the standard starting point for internal training materials before conversion into the company's e-learning platform. It is intended as an entry-level introduction to the company's MV offerings and is planned to be placed at the beginning of all training programs involving MV; to provide foundational knowledge before more in-depth product- or industry-specific modules.

The module introduces foundational concepts such as what MV is, key technologies, relevant product families, and application examples. It is primarily designed for new general salespeople with little or no prior experience in MV. This is in line with the CTML principle of pre-training, stating that introducing key concepts before further training facilitates schema construction (Mayer & Fiorella, 2022).

Expert Review

To validate the original PowerPoint module, the material was reviewed by two application engineers specializing in 2D and 3D MV. They were specifically asked to assess content relevance, accuracy, and structure. Feedback indicated that some product references were outdated, and application examples were generally relevant, but that explanations of 2D technology were unclear and insufficient.

One expert noted that the structure, introducing applications before technologies and products, lacked coherence, while the other suggested that introducing technologies first might cause confusion. Both reviewers agreed that the material seemed intended for instructor-led sessions rather than self-study and that it would benefit from adding more information. One also noted that clearer distinctions between general company products and MV-specific products were needed. Minor issues, such as distracting background noise and abrupt endings in the videos, were also expressed.

The review sessions provided additional insight into how the cameras function, their use cases, and the distinctions between different models. It was noted that these differences were not apparent in the module, which could lead to confusion for learners. Overall, the experts found the overview lacking in depth and identified significant potential for improvement.

Material Evaluation

Building on the expert feedback, the original PowerPoint module was further analyzed through the lens of cognitive load theory (CLT; Sweller et al., 2019), cognitive theory of multimedia learning (CTML; Mayer, 2022), and schema theory (Anderson, 1983). These frameworks were used to identify design flaws likely to impose extraneous load, amplify intrinsic load, and limit germane load; all essential for schema formation and effective learning.

The MV overview module consists of 23 slides. Detailed slide-level evaluation was conducted, but the key findings are presented below organized thematically under core CTML principles and schema development. A full slide-by-slide reference of the original material is provided in Appendix D.

Schema Formation and Germane Processing

Instructional materials should provide clear conceptual anchors, progressive organization, and sufficient explanation to support schema formation or integration (Anderson, 1983). The purpose of an overview model specifically is thus to construct new schemas for entry-level learners to support the organization and integration of new information. Given the inherently high intrinsic load of MV concepts, supporting germane processing early is especially critical. However, the overview module provides limited support for these processes. While the module does state learning goals at the beginning, which is a recommended practice for guiding novices in unfamiliar content (Fiorella & Mayer, 2022), this is not followed up with sufficient scaffolding to support schema development throughout.

The introduction of the module lacks a clear definition of what MV *is* or why it matters in industrial automation, failing to establish an early mental framework critical for integrating subsequent information. For example, slides 1–3 contain minimal explanatory text, overly broad titles, and decorative images with low instructional value, leaving learners without a coherent starting point. Similarly, the 2D technology slide (see Fig. 10) merely labels camera components without explaining how 2D technology functions.

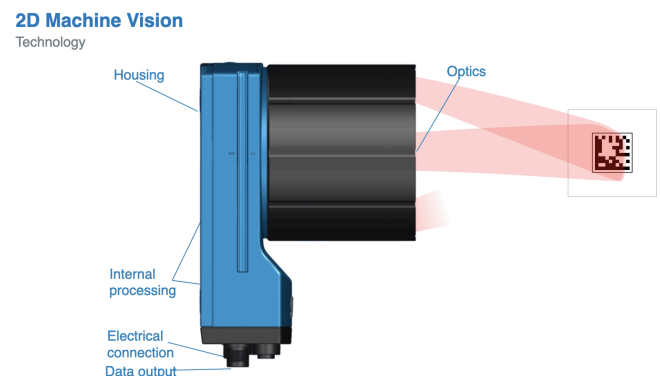


Figure 10. Slide 13: 2D Technology

In addition to lacking informational value, the sequencing of content might undermine schema development. Learners are introduced to applications (slides 6–11) before being familiar with the products (slides 19–23) and technologies (slides 12–18) that enable them. Although this reflects the company's prioritization of application training, it does not

align with how learners best organize and integrate information (Anderson, 1984; Mayer, 2022).

Introducing applications first prevents learners from understanding how products and technologies are connected and how they support specific applications. Additionally, in the application section, a specific product is introduced as a solution to that application (see Fig. 11). Encountering applications first thus forces learners to interpret unfamiliar content without context or conceptual understanding, increasing extraneous load and disrupting opportunities for germane processing and schema formation (Sweller et al., 2019; Mayer, 2022). It is worth noting that CTML recommends using worked examples to model step-by-step problem-solving processes for novices, as this supports schema acquisition through guided application of knowledge (Renkl, 2022). However, the application slides in this module do not function as worked examples; they are not procedural or instructional in nature but rather illustrate use cases that should serve to build conceptual understanding.

Additionally, schema formation is hindered at slide level on several occasions. For instance, the 3D technology section (slides 14–18) presents the benefits and limitations of each technology before explaining their functional principles, making it harder for learners to meaningfully interpret advantages without a foundational understanding. The module further misses opportunities to activate prior knowledge that could reduce intrinsic load (Sweller et al., 2019; Mayer, 2022). For instance, no analogies are used, which could help learners map new concepts onto existing schemas (Richland & Simms, 2015). Nor is the MV portfolio contextualized within the broader company offering, making it harder for learners to situate new information.

Finally, while the pre-study revealed that many salespeople struggle to understand product relationships, no structural overview or concept map is provided to support schema construction. Additionally, the interleaving of 2D and 3D content prevents learners from forming separate mental models for each area and obstructs progressive complexity building (Anderson, 1984). The absence of this organization further constrains germane processing and might hinder the formation of coherent, transferable knowledge structures (Anderson, 1984; Sweller et al., 2019; Mayer, 2022).

Spatial & Temporal Contiguity Principles

Spatial contiguity (placing related text and visuals close together) and temporal contiguity (presenting them simultaneously) are essential for reducing extraneous load and supporting the integration of information (Ayres & Sweller, 2022). Several slides in the original material violate these principles. For instance, in slides 8–11 (3D applications; see Fig. 11), images are arranged horizontally while the text flows vertically, forcing learners to zig-zag their gaze across the screen. This disrupts bottom-up attention, which relies on spatial cues to guide visual processing (Corbetta & Shulman, 2002), and imposes unnecessary cognitive effort (Ayres & Sweller, 2022). The problem is aggravated when the sequence of images does not match the order of the text, making it difficult for learners to connect visual examples to explanations. Similarly, in the 3D technology section (e.g., Fig. 13), videos, images, and text are physically and temporally separated.

The general structure of presenting applications before technology and products, and not separating 2D and 3D content, does not either align with the temporal contiguity principle (Ayres & Sweller, 2022). Learners must recall

earlier content and mentally link it to new material which places strain on working memory, which is limited in both capacity and duration (Baddeley, 2000; Cowan, 2005; Sweller et al., 2019).

These design issues also violate basic gestalt principles of proximity and common region, which help the brain intuitively group related elements into coherent wholes (Wertheimer, 1959). When text and visuals are visually disjointed, learners cannot easily perceive their connection and must instead bind the elements mentally which adds cognitive load. This impairs not only moment-to-moment comprehension but also the construction of coherent schemas over time (Anderson, 1984; Mayer, 2022).

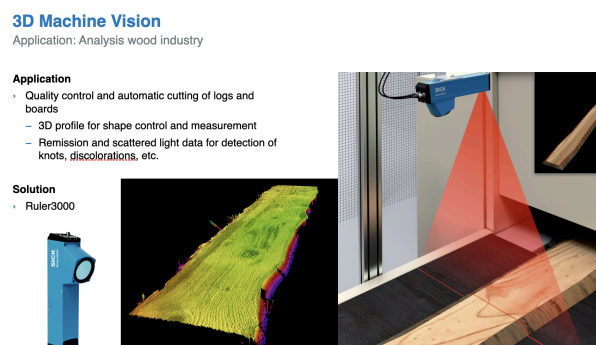


Figure 11. Slide 10: 3D Application

Multimedia & Coherence Principles

According to the multimedia principle, learning is more effective when words are combined with relevant visuals, as this engages both the verbal and visual processing systems to form dual representations (Mayer & Fiorella, 2022; Clark & Paivio, 1991). However, this principle assumes that the visuals meaningfully support the text. In the original material, visuals are frequently used, but their pedagogical value is inconsistent. For instance, an image showing a 2D and a 3D camera (see Fig. 12) offers no explanation of their functional differences. Instead of supporting understanding, such images force learners to infer meaning without guidance, which causes extraneous load (Sweller et al., 2019).

The coherence principle states that learning is hindered by the inclusion of irrelevant or decorative content, which draws attention away from essential information (Mayer & Fiorella, 2022). Several images in the module are dark, cluttered, or chosen for visual appeal rather than clarity. These violate top-down attentional guidance, as learners must work harder to identify what is important (Desimone & Duncan, 1995). This diverts cognitive resources away from germane processing and undermines schema construction (Sweller et al., 2019).

From a perceptual standpoint, uninformative or ambiguous visuals also fail to support pattern recognition and intuitive interpretation (Goldstein & Brockmole, 2017). Since learners tend to group and interpret visual information based on familiarity and context (Wertheimer, 1959), the lack of clear visual cues weakens the ability to form coherent mental models (Schnotz, 2022).



Figure 12. Slide 5: Difference between 2D and 3D sensors

Signaling principle

The signaling principle holds that learning improves when key information is highlighted to direct attention (van Gog, 2022). In the original material, signaling is inconsistently applied; particularly on slides with dense text (e.g., Fig. 13), where the absence of cues forces learners to search for relevant content on their own. This places demands on top-down attentional control, which is effortful and limited; especially in unfamiliar material (Corbetta & Shulman, 2002; Desimone & Duncan, 1995). Without guidance, attention may be misdirected, increasing extraneous load and reducing working memory efficiency (Baddeley, 2000; Sweller et al., 2019; van Gog, 2022).

3D Machine Vision Laser Triangulation

- Very high resolution and accuracy
- Light source: laser line
- No need for ambient light
- Relatively short measuring range
- Shadowing possible if the laser is hidden behind an object
- Movement required

Functional principle

- A laser line is projected onto an object to be measured
- The reflection/scattering is projected onto a light-sensitive element
- Depending on the position of the light spot and the known geometry of the sensor optics, the distance is calculated

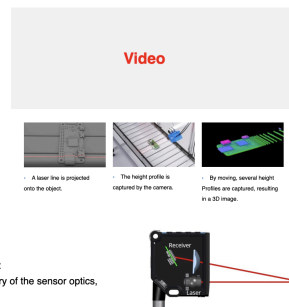


Figure 13. Slide 16: 3D Laser Triangulation Technology

Redundancy & Segmenting Principle

Perception is multimodal, meaning the brain integrates information across sensory channels such as vision and hearing (Calvert, Spence, & Stein, 2004). While this allows for rich learning experiences, each channel has limited processing capacity. According to the redundancy principle, learning is hindered when the same information is presented in multiple unintegrated forms, such as text, video, and images, without clear coordination (Mayer & Fiorella, 2022). This occurs in the 3D technology slides (15-18), where key concepts are shown through videos with audio, screenshots, and separate text blocks. For example, slide 16 (see Fig. 13) introduces a feature list, followed by a video, then screenshots, and finally an additional explanation. This can overload the visual channel and increase extraneous load (Mayer & Fiorella, 2022).

Further, the segmenting principle recommends breaking complex content into smaller, meaningful units to support intrinsic processing and reduce extraneous load (Mayer & Fiorella, 2022). In the module, 2D and 3D content is interviewed, and in several slides, dense visuals and text are presented all at once. This forces learners to self-organize the material, which is demanding given that working memory can only hold about four chunks of information for a limited

time (Cowan, 2005; Peterson & Peterson, 1959). Without clear segmentation, reduced capacity remains for comprehension or schema formation (Mayer & Fiorella, 2022).

Personalization Principle

The tone across the overview module is overly formal and includes unexplained technical terms such as "remission data" and "amplitude-modulated IR light." This increases intrinsic load and may hinder comprehension; especially for novices with limited prior knowledge. According to the personalization principle, people learn better from conversational language, which promotes engagement and supports germane processing (Mayer & Fiorella, 2022). Even if a formal tone aligns with marketing communication standards, applying it to internal training materials can reduce learning effectiveness by making content less accessible and harder to process.

Conclusion of Evaluation

Although the original PowerPoint material includes core content related to MV products, applications, and technologies, it imposes significant cognitive challenges that can hinder effective learning.

- The material fails to support early schema formation, as it introduces applications before foundational concepts, and presents 2D and 3D content simultaneously, which limits opportunities for germane processing.
- It violates multiple CTML principles, particularly those of spatial and temporal contiguity and coherence, increasing extraneous load.
- It lacks clear explanations and uses overly formal and technical language, increasing intrinsic load.

Collectively, these issues can overload working memory, limit schema construction, and impair the potential for meaningful knowledge transfer. The identified shortcomings directly informed the instructional design strategies used in developing the materials used in the experiment, which are described in the following sections.

Material Design

The first step of the design process involved transforming the original PowerPoint module into an e-learning format using Articulate Rise 360, as this had not been done yet by the company. The e-learning format was chosen to reflect real-world usage and to ensure experimental control. Presenting the material in the same format for both groups eliminated potential confounds related to delivery methods (e.g., PowerPoint vs. Articulate Rise 360), enhancing comparability between conditions. This design process resulted in a revised version of the original material, used for the control group in the experiment.

During the transfer to the e-learning format, however, a number of necessary updates were made to the material to create a valid baseline. While these updates inevitably improved the control group's material compared to the original PowerPoint overview module, they were deemed necessary to ensure relevance and to establish a functional overview model. The following sections detail the specific design decisions and modifications made to the control and experimental conditions, guided by the theoretical

frameworks of CLT (Sweller et al., 2019), CTML (Mayer & Fiorella, 2022), and schema theory (Anderson, 1983).

Control Condition Design

Several content changes were necessary when converting the original PowerPoint module into a functional e-learning overview. While these revisions were not part of the experimental manipulation, they were essential to ensure that the material was informative, technically accurate, and coherent. The need for these changes was identified during the material analysis, which revealed that the original overview lacked several key elements required for it to serve as an effective entry-level learning resource. Presenting these changes here is important for two reasons. First, they provide the necessary context for understanding the additional design modifications introduced in the experimental condition. Second, they illustrate how instructional materials can be strengthened through evidence-based improvements, serving as a critical first step toward reducing cognitive load and supporting learning.

By incorporating all necessary content changes into the control design, it was ensured that the only difference between the conditions was *how* the information was presented, while the content remained consistent across both versions. A summary of the core updates is provided below. The full control group material is available in Appendix E.

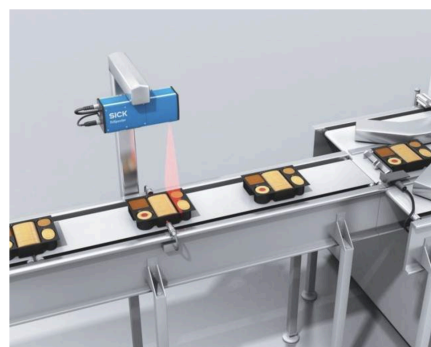
Structural and Format Changes: Redundant elements such as slide titles, page numbers, subtitles, and transitional slides were removed, as the e-learning format in Rise 360 provides a built-in side menu for tracking progress and navigation. This aligns with the coherence principle, which suggests that eliminating non-essential elements can reduce extraneous load and enhance learning (Fiorella & Mayer, 2022). The overall sequence and placement of content (images and text) were preserved as closely as possible to the original PowerPoint format. However, due to Rise 360's block-based structure, exact replication was not always feasible. In such cases, the layout was kept similar to the company's standard presentation of information in e-learning.

Additionally, the e-learning format inherently introduces more interactive navigation, requiring learners to actively engage with the material by clicking through sections via "Continue" or "Explore" buttons rather than passively scrolling. This design supports the segmenting principle, which helps manage intrinsic load by breaking content into manageable chunks and allowing learners to progress at their own pace (Fiorella & Mayer, 2022). Rise 360 also introduces more visually engaging transitions, such as fading in text and images.

Content and Clarity Enhancements: Explanatory text was widely added to clarify key concepts; especially in the introductory section, where foundational distinctions between 2D and 3D MV were underspecified. Although more text can increase the extraneous load (Sweller et al., 2019; Fiorella & Mayer, 2022), it was deemed necessary, in this case, to support germane load and facilitate schema formation (Anderson, 1984). The minimal text in the original module was found to increase the intrinsic load, as learners were left to infer critical information without guidance. This aligns with research suggesting that novices benefit from explicit instruction when forming new mental models (Kalyuga, 2022). Added content to the baseline design included:

- Added an introductory section explaining what MV is and why it is useful, with an informative image (see Fig. 14).
- Added text clarifying distinctions between 2D and 3D vision using informative images. To applications sections, text was added in the beginning to clarify in general terms what 2D vs 3D technology is used for, prior to going into specific examples.
- Updated outdated product references and added brief product descriptions.
- Clarified slide titles (e.g., "2D Applications" → "What can 2D cameras be used for?").
- Expanded the use of bold-marked keywords to better guide attention.

What is Machine Vision?



Machine Vision is a technology that enables systems to **see**, **understand** and **act** based on visual information from the environment.

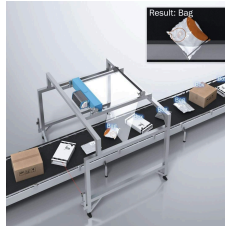
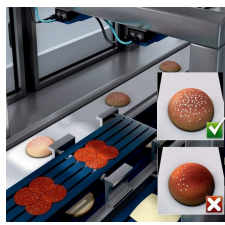
It refers to the entire process of **capturing** an image, **processing** and **analyzing** that image and using the results to **perform** specific tasks.

Figure 14. Added introductory section in Control Design

Language Improvements: All text was revised to follow the personalization principle, using simpler and more conversational language to reduce intrinsic load (Mayer & Fiorella, 2022). Everyday analogies, such as comparing 2D cameras to regular cameras, were added to activate prior knowledge and support schema integration (Anderson, 1984). Learning goals were shortened and clarified at the beginning of the module to better reflect the training content, providing learners with a clear sense of purpose and structure.

Enhanced Visual Support: Non-informative or decorative images were replaced with visuals that directly support the accompanying text, in line with spatial contiguity and multimedia principles (Mayer & Fiorella, 2022). For instance, relevant application images were added (e.g. see Table 5.) Image selection was limited to the company's media archive and customer presentations.

Table 5. Updated 2D application images in the Control Design

Application	Original Image	New Image
Identify & Classify		
Quality Control		
Robot Guidance		

New 2D Technology Section: The 2D technology section was completely redesigned, replacing the original static image with labeled components, which failed to explain how 2D cameras work or differentiate between the company's product types. The new section includes a clear description of 2D vision, a four-step simplified explanation of basic optical principles supported by informative visuals, a breakdown of the company's 2D product categories (streaming vs. smart cameras), and a visual workflow illustrating how a smart camera operates within an automated system.

Revised 3D technologies section: The original content was expanded to provide clearer explanations of the different 3D technologies, while also being simplified to suit novice learners. Key steps were broken down into smaller units and supported by more informative visuals to reduce intrinsic load. A summary comparison table was added to highlight the main differences between technologies, directly addressing a common source of confusion identified in the pre-study.

Improved Application Sections: Examples of 2D and 3D applications were updated to be more representative of real-world use and easier to understand for entry-level learners. The selection of applications was informed by expert input.

Although content was added to the control design, it was deliberately kept basic to align with the pedagogical purpose of an overview model; to introduce core concepts and support schema formation without overwhelming novice learners (Anderson, 1984). Overly detailed or abstract instruction risks overloading learners who lack well-developed schemas, making it essential to keep content simplified and strongly guided (Kalyuga, 2022; Mayer &

Fiorella, 2022). It is also important to note that several CTML principles were not incorporated into the overview module, such as the modality principle (Castro-Alonso & Sweller, 2022) and the pre-training principle (Mayer & Fiorella, 2022). However, the module functions as a pre-training step within the broader program, preceding more in-depth, product-specific training. While these principles were beyond the scope of the current experiment, they represent valuable opportunities for future developments of the company's training materials.

Experimental Condition Design

In the experimental condition, the content remained identical to the control design, but the *presentation* of it was systematically manipulated. The independent variable tested was thus how information was presented; through changes in content order, layout, and text-image integration. The goal was to investigate whether improving presentation would reduce extraneous load, ease schema construction, and promote germane processing (Sweller et al., 2019; Mayer & Fiorella, 2022; Anderson, 1984), hypothesized to be reflected in participants' increased knowledge gain. In addition, certain layout and interaction changes were informed by human-centered design principles (Norman, 2013), aiming to improve usability by aligning with users' perceptual and cognitive expectations.

The experimental design was guided by the findings from the material evaluation, directly addressing issues such as poor schema support, fragmented presentation, and high extraneous load. Changes were organized into two main categories:

1. The order of content
2. How information was presented on each page

A summary of the changes is presented below, with the complete experimental material available in Appendix F. A table comparing key design differences between control and experimental conditions is provided in Appendix G.

Reordering of Content for Schema Support

In the control material, applications were introduced before technologies and products, reflecting business priorities but conflicting with cognitive principles for effective schema formation (Anderson, 1984). In the experimental condition, the content order was reorganized (see Table 6).

Table 6. Order of content in the Experimental Design

Original & Control Order	Experimental Order
1. Introduction	1. Introduction + Context Overview
2. 2D Applications	2. 2D Technology
3. 3D Applications	3. 2D Products
4. 2D Technology	4. 2D Applications
5. 3D Technology	5. 3D Technology
6. Portfolio Overview	6. 3D Products
	7. 3D Applications
	8. Portfolio Overview

Presenting technologies and products *before* applications allow learners to first understand core operational principles and then apply them to real-world contexts, reducing the need to guess product functions during application examples.

This reordering aims to lower extraneous load, progressively build knowledge, and support germane processing by facilitating schema organization (Sweller et al., 2019; Mayer, 2022). To maintain consistency, the learning goals presented at the beginning of the material were also reordered to match the new instructional flow.

The 2D and 3D sections, previously interwoven, were separated to reduce element interactivity by allowing learners to focus on one coherent set of concepts at a time, rather than managing two domains simultaneously, aligning with the segmentation principle (Mayer & Fiorella, 2022). This separation aims to lower working memory demands, supports progressive complexity building (2D → 3D), and helps establish distinct 2D and 3D schemas.

Portfolio Separation & Visual Hierarchies

In the original and control material, the product portfolio was presented only at the end, showing product families together, with images and bullet points underneath listing product names and descriptions (see Fig. 15). However, this structure made it unclear which image corresponded to which product, adding unnecessary extraneous load.



Figure 15. 2D portfolio in Control Design

In the experimental condition, the portfolio information was separated and contextualized, with 2D products introduced immediately after the 2D technology section and 3D products following the 3D technology section. Each portfolio section used a visual hierarchy structure, logically grouping products into distinct categories (e.g., streaming cameras and smart cameras) (see Fig. 16). Separate, background-free images were used and text was placed close to them, where users could click an "i" icon for additional information about each product. This format aligns with the segmenting, coherence, spatial, and temporal contiguity principles (Mayer & Fiorella, 2022).



Figure 16. 2D portfolio in Experimental Design

A final portfolio overview remained at the end of the material but was redesigned into a visual hierarchy format (See Fig. 17). This contextualized summary showed how MV fits within the company's broader product portfolio, divided into 2D and 3D products and their respective technologies. Additionally, a similar visual hierarchy was added to the introductory section to provide early contextual framing. The purpose of these changes was to support schema construction by making relationships between categories explicit, organizing new information meaningfully, and aiding integration into broader existing frameworks.



Figure 17. Visual Hierarchy of Portfolio in Experimental Design

Reducing Extraneous Load on Page-Level

Beyond reordering content, the experimental material included systematic changes to how text, images, and navigation were organized within each page.

Image-Text Integration

Images and text were throughout the material placed close to each other, aligning with temporal and spatial contiguity principles to reduce split-attention effects (Mayer & Fiorella, 2022). For instance, see Fig. 18. Moreover, images were placed horizontally across the page, with explanatory text located directly underneath each image, aligning with users' culturally developed expectations for left-to-right reading flow; a principle that supports natural mapping in interface design (Norman, 2013). This structure was particularly important when describing sequential processes, where a horizontal arrangement supports a more intuitive understanding than a vertical list (Lübke, Ahrens, & Schneider, 2021).

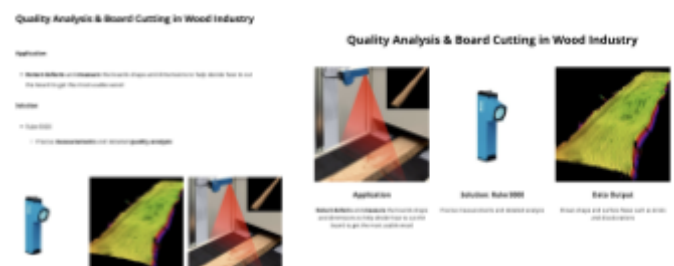


Figure 18. 3D application in Control vs Experimental Design

Additionally, under titles were also placed between images and text to explicitly state what each image represents, supporting the signaling principle and guiding learner attention (Mayer & Fiorella, 2022). In line with this principle, clear titles were added to each major content block and visuals to reduce the need for learners to infer the meaning from surrounding text. Text was also added to

previously unexplained visuals, such as the data output images in the applications section (see Fig. 18).

Order of Information on Page-Level

On certain pages, the internal order of content was refined for better logical flow. For instance, when introducing MV applications in the introductory section, the original headings ("Where?", "OK?", "Size?", "What?") were reorganized into a more natural sequence: "Where?" → "What?" → "Size?" → "OK?". Another example is the 3D technology section, where technology descriptions were instead presented before listing features, to ensure that learners understand functional principles before evaluating their advantages or limitations. Additionally, the video was positioned after textual explanations of the technology, allowing it to act as a complementary visual reinforcement rather than a primary instructional source. This ordering decision was made because the video did not fully explain the technology independently and was deemed more effective when used to consolidate prior understanding.

Segmentations Enhancements

To reduce extraneous load and manage intrinsic load, longer sections were broken into smaller parts by introducing more "Continue" buttons. This required learners to actively click through sections, rather than being presented with all information at once, applying the segmenting principle (Mayer & Fiorella, 2022) and facilitating learner-paced progression. Additionally, longer paragraphs were replaced with short (!) bullet points or numbered lists to help segment information into manageable pieces.

Multimedia Enhancements

Additional improvements were made to enhance multimedia integration. Subtle use of text coloring was used to visually group related elements, while technology features were color-coded with green for advantages and orange for limitations. Simple emojis were added alongside certain technology names (e.g., a clock emoji for Time-of-Flight) to strengthen conceptual associations using natural mapping (Norman, 2013). Although the addition of colors and emojis may introduce minor extraneous load by slightly increasing visual complexity, these elements were deemed beneficial as they helped organize information more effectively and guide learner attention, while also making the material more engaging and visually pleasing.

Videos that previously caused redundancy and possibly overload were selectively removed, in line with the redundancy principle (Kalyuga & Sweller, 2022). Two poorly produced videos covering 3D technologies were excluded, as they involved high-element interactivity and poorly integrated voice and text narration. The video on laser triangulation was retained but trimmed to show only relevant sections and background music was removed to minimize the extraneous auditory load. The modality principle states that learning is generally enhanced when visual materials are combined with complementary auditory information, supporting dual-channel processing (Castro-Alonso & Sweller, 2022). However, this principle applies only when the auditory input adds meaningful information. Finally, aligning with the redundancy principle (Kalyuga & Sweller, 2022), product overview images were cleaned, removing background clutter and non-mentioned products, and

reorganized by product category to further enhance clarity and reduce unnecessary cognitive effort.

Expert & Entry-level Reviews

Three company experts, one specializing in 2D and two in different 3D MV technologies, reviewed the designed materials for technical accuracy. Feedback was generally positive. A few factual inaccuracies were identified and corrected, including updated application examples and refined product descriptions.

In addition, both materials were user-tested with three entry-level participants during the pilot phase, which is detailed in the experiment section. The order of presentation (control vs. experimental material) varied across participants. Feedback on the experimental material was consistently positive, with participants highlighting its clear structure and effective visual hierarchies. All participants reported that the experimental material was easier to follow and understand than the control version. It should be noted that this may partly reflect social desirability bias; participants' tendency to respond favorably to the researcher (Fisher, 1993).

Based on the user tests, however, certain adjustments were made to the experimental design prior to finalization. These refinements are already incorporated in the experimental material presented in the preceding section. Adjustments included simplifying technical language further (in both conditions), further labeling sections for clarity (e.g. "Video Demonstration" before the video), and aligning content order across sections for coherence. Interactive markers were changed from "+" to "i" icons to improve intuitiveness, and brief instructions clarified their function. Participants appreciated the use of video and deemed it better to be presented at the end of the section (as done in experimental condition). Additional videos were requested but not added due to resource limitations.

5 Experiment

Method

The study employed a quasi-experimental, between-groups research design, consisting of a control group and an experimental group. The control group received the improved material, while the experimental group received the redesigned version. The independent variable was, as discussed, the *presentation* of information (specifically, content order and layout). The content remained consistent across both versions to isolate the effect of presentation on learning outcomes. Pre and post-surveys were used to measure knowledge and other relevant aspects such as perceived cognitive load. This section will discuss participant recruitment, the experiment procedure, instruments used in the pre and post-tests, as well as pilot testing.

Participant Recruitment

While the initial goal was to recruit new general salespeople within the company for the experiment, this was not feasible due to their limited availability and global dispersion. Instead, participants with little or no prior experience in MV were recruited, as the training was designed for entry-level learners.

In total, 28 participants were recruited across two rounds. In the first round, participants were recruited internally from the local office where the thesis was conducted. Although many employees worked with MV, 11 individuals (thesis

students, administrative staff, and HR personnel) were identified through informal outreach as having minimal background in the topic.

To increase the sample size while maintaining balance in participant backgrounds, a second round of recruitment was carried out externally. 17 students from Lund University were recruited through convenience sampling (Bryman, 2016), following confirmation that the training could be tested outside the company. Slight oversampling accounted for potential attrition, ensuring that at least 11 participants completed the study from each group. All 28 participants were pseudo-randomly assigned to either the baseline or experimental condition ($n = 14$ each), with internal and external participants balanced across groups to reduce background-related confounds.

Ethical Considerations

Several ethical precautions were taken to protect participants. The study clearly communicated that the focus was on evaluating the material, not individual performance, to prevent confusion from being perceived as personal failure (Bateson & Martin, 2021). As participants were accustomed to processing complex information in their work or studies, the study was assessed as involving minimal risk.

Company-internal participants were explicitly told that their performance would remain confidential and not be shared with their employer. Participation was voluntary, with no impact on work evaluations, and results were anonymized to ensure integrity. These steps were taken to promote psychological safety (Bateson & Martin, 2021) and prevent perceived pressure in the workplace context.

The study followed Vetenskapsrådet's (2024) four ethical principles: doing good (contributing to research and company learning), avoiding harm (ensuring a safe environment), respecting autonomy (voluntary participation), and ensuring justice (fair and informed treatment). As no major risks were identified, formal ethical approval was not required under the Swedish Ethical Review Act.

Experiment Procedure

The experiment was delivered as a web-based course published through Articulate Rise 360 (Articulate Global, 2025). Participants received a link directing them to the course, which consisted of four sequential sections:

1. Experiment Information
2. Pre-Survey
3. Self-Study Material
4. Post-Survey

Only Section 3 differed between conditions, where participants received either the control (see Appendix E) or redesigned (see Appendix F) version of the training material.

The introductory section (see Fig. 19) introduced the purpose of the experiment; evaluating whether selected cognitive design principles improve knowledge gain in self-study training. Participants were informed about the procedure, expected duration (~30 minutes), anonymity, and voluntary participation. They were instructed to complete the training in one uninterrupted session at home or in a quiet work environment. Informed consent was obtained both by

proceeding through the course and via consent items in the surveys. Contact information was provided for any questions.

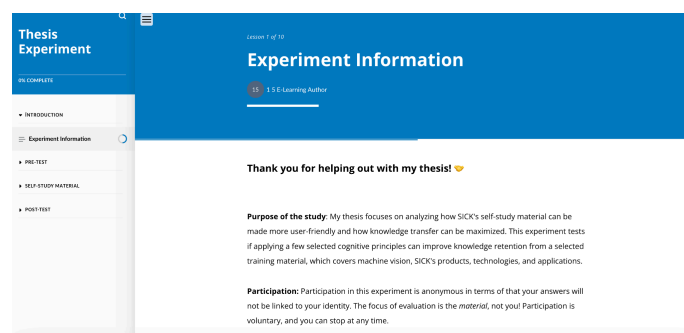


Figure 19. Interface of the introductory section of the course

In the second section, participants completed the pre-survey (see Appendix H) on an external Slido page, which was used due to performance tracking limitations in Rise 360. To maintain anonymity while allowing for pre-post matching, participants were asked to enter a randomly chosen, memorable word that would later be reused in the post-survey. The survey included participant information, including a reminder about anonymity and information about data storage and data deletion practices. Informed consent was confirmed by selecting "Yes" to have understood the purpose of the test and to participate in it. The remaining 18 questions of the survey included three demographic questions (affiliation with the company, age, gender), 12 multiple-choice knowledge questions, a self-efficacy rating, and a time-entry field for logging the session start to track time consumption. Once complete, participants submitted the survey and were asked to return to the previous page.

The third section contained the self-study material, presented in either its control or experimental format. Participants were instructed to go through the content at their own pace.

In the fourth section, participants were redirected to a second Slido page to complete a post-survey, again using the same self-generated word. The post-survey (see Appendix I) included 21 questions, starting with the same participant information and consent as the pre-test and a time log to measure the duration spent on the material. This was followed by a post-training self-efficacy rating and the same 12 knowledge multiple-choice questions. Additionally, one question about motivation was included and finally, participants completed four questions regarding perceived cognitive load. After submitting the post-survey, they returned to the experiment page, where they were thanked for their participation and again provided with contact details for any questions or concerns. Furthermore, two participants from each condition were randomly selected for post-experiment interviews.

Post-Experiment Interviews

As part of a multimethod approach, semi-structured interviews were conducted immediately after the experiment to gain deeper insights into participants' subjective experiences with the training material, particularly related to the different types of cognitive load. Enriching quantitative findings with qualitative insights is a recommended practice to gain a deeper understanding of complex internal constructs (Bateson & Martin, 2021), such as cognitive load, that are difficult to fully capture through single-item or subjective rating scales alone (Klepsch et al., 2017).

Two participants were randomly selected from each condition. All four interviews took place directly after the experiment, either via video call or in person. They lasted around 30 minutes and were conducted in a casual, conversational format to promote openness and reduce participant stress (Bateson & Martin, 2021). With participants' consent and a guarantee of later deletion, the interviews were recorded to facilitate note-taking.

A semi-structured interview guide was used to ensure consistency across participants while allowing room to explore emerging insights (Bryman, 2016). The guide (see Appendix J) covered seven thematic areas, each addressed through a few open-ended, non-leading questions. Interviews began with participants' general impressions of the training, serving as a warm-up to elicit spontaneous reflections. This was followed by questions on perceived intrinsic load, including how difficult the material felt and which knowledge test items were most challenging. Schema construction was explored by asking whether the training helped participants understand the relationships between concepts and see the bigger picture. Participants were encouraged to reopen the material if needed for better recall. Perceived extraneous load was investigated focusing on the clarity and structure of the content, identifying any confusing or redundant elements. Mental effort was discussed to assess overall cognitive demand and any sense of overload. Questions about germane load probed whether the training supported deeper understanding and integration of concepts. The interview concluded with a reflective prompt inviting suggestions for improvement and any additional feedback.

To address the risk of social desirability bias, where participants may respond in a way they believe is expected or favorable to the researcher (Fisher, 1993), participants were reminded that they had received either the control or the improved training material. They were explicitly encouraged to provide honest and critical feedback, regardless of whether their experience was positive or negative. It was emphasized that all responses were equally valuable and would contribute meaningfully to the evaluation of the training.

Instrument Construction

Knowledge Test

To measure knowledge gain, identical knowledge tests were constructed and administered before and after the training intervention. The same set of multiple-choice questions was thus used in the pre-survey (see Appendix H) and in the post-survey (see Appendix I) in both conditions. This enabled within-in-subject comparisons of knowledge change and between-group comparisons across conditions. Using identical knowledge questions before and after training is a well-established approach to detect learning effects (Jarodzka, 2022).

Participant response and performance could not be tracked in the Rise 360 platform where the experiment was administered. Therefore, surveys were administered through Slido (Cisco Systems, 2025) which format primarily supports multiple-choice questions, which limited the depth of response types. Ideally, matching exercises or open-ended self-explanation questions would have been included, as such formats are better suited for assessing deeper conceptual understanding and higher-order cognitive processes (Anderson & Krathwohl, 2001). However, given the practical limitations, multiple-choice items were used, as they are still widely regarded as an efficient and reliable method for

assessing knowledge recall and application when carefully constructed (Jarodzka, 2022).

The knowledge questions were deliberately designed to reflect not only basic knowledge retrieval but also schema formation and conceptual understanding, consistent with CLT (Sweller et al., 2019) and schema theory (Anderson, 1983). Several items required multi-step reasoning, forcing participants to integrate concepts and apply them to unfamiliar scenarios, as these aspects are good indicators of germane load and schema abstraction (Anderson, 1984; Sweller et al., 2019). Distractors were intentionally used in the non-correct items to increase intrinsic load, to ensure that performance reflected genuine understanding rather than guesswork. Participants were not expected to know the answers beforehand; rather, the test was designed to measure retention and transfer after the training.

The knowledge test consisted of 12 multiple-choice questions and 1 self-efficacy rating. The first two questions addressed conceptual understanding such as "What is machine vision?" and "What is it best used for?". These aimed to test whether participants have internalized the core purpose and function of MV systems, which is important to build a top-down conceptual schema that supports future knowledge integration. Another question required the identification of company-specific products, such as "Which camera is *not* part of the product portfolio?", to test recognition and product schemas.

Technical comprehension of 2D was assessed through two questions: "What makes a 2D camera smart?" and "What is the best explanation of how a 2D camera operates?". These targeted understanding of how different parts of a system work together and component interactions require procedural schema construction and mental models for how something works or how to do a task (Anderson, 1983).

Two questions focused on understanding and distinguishing between 3D imaging technologies (laser triangulation and stereo vision), by using distractors closely related to the different technologies presented in the material. This aimed to test deep conceptual differentiation within a shared domain, characterizing advanced schema acquisition (Anderson, 1984; Sweller et al., 2019). A subsequent scenario-based question required participants to evaluate whether 3D imaging was appropriate for a given use case, demanding the application of abstract knowledge to practical contexts. It required participants to separate between 2D and 3D technology, as well as connect product names to the correct technology.

Finally, four scenario-based items assessed participants' ability to select the most appropriate camera for a given situation based on the conditions described. The scenarios were similar, but not identical, to the applications introduced during training, enabling evaluation of knowledge generalization. Participants needed to (1) classify the situation as involving 2D or 3D vision, (2) identify the appropriate technology, and (3) select the relevant product. These items were designed to simulate real-world decision-making and assess the ability to transfer knowledge across contexts, as this is a recognized indicator of deep learning and robust schema construction (Anderson, 1984; Sweller et al., 2019).

Self-Efficacy Measurement

Additionally, one question was included in the post-survey to assess perceived self-efficacy, a factor shown to correlate positively with both motivation and learning outcomes (Pajares & Schunk, 2001). Given that the pre-study identified low confidence when discussing MV as a common barrier among salespeople, perceived knowledge self-efficacy was included to assess potential shifts linked to training effectiveness and to explore whether such changes differed across conditions. Self-efficacy refers to an individual's belief in their ability to succeed in a specific task (Bandura, 1997) and was presented to participants as a measure of confidence. It was also included as an indicator of perceived knowledge related to the training content.

Participants were asked to rate how confident they would feel, after completing the training, in explaining MV and the company's portfolio to a friend. Framing the question around explaining to a friend rather than in a professional setting was intended to minimize social pressure and reduce anxiety, helping to elicit more authentic self-assessments of perceived competence. Responses were collected on a 5-point Likert scale, ranging from 1 ("Not confident at all") to 5 ("Extremely confident").

In the pre-survey, participants rated their self-efficacy level in a hypothetical everyday scenario (calling tech support for a malfunctioning home security camera) to get a baseline for general confidence when talking about a technical topic. The self-efficacy measurement in the post-survey could then be interpreted relative to this baseline measurement.

The knowledge questions were reviewed by subject matter experts and tested on entry-level participants during pilot testing (see Pilot Testing) to ensure clarity, relevance, and appropriate difficulty. Based on the feedback, several questions were revised, and language was simplified to better align with participants' prior knowledge and to reduce unnecessary cognitive load.

Cognitive Load Measurement

Since the design intervention was hypothesized to improve knowledge gain by decreasing cognitive load, four questions measuring perceived cognitive load during the training were included in the post-surveys. Although several methods exist for measuring cognitive load, subjective rating scales remain the most widely used approach (Sweller et al., 2019; Klepsch et al., 2017). Their effectiveness is particularly enhanced when combined with objective performance measures (Sweller et al., 2019), which is in line with the current experiment.

The first question was constructed to measure overall cognitive load using the classic Paas scale (Paas, 1992), a widely used and validated single-item assessment (Sweller et al., 2019). The original formulation of the Paas scale was designed for problem-solving contexts, so its wording was slightly adapted to better fit the present study's context of going through self-study material. Participants were therefore asked how much mental effort the training required from them on a 9-point Likert scale, ranging from 1 (Very, very low mental effort) to 9 (Very, very high mental effort). To enhance clarity for participants unfamiliar with the term, a short explanation was added where mental effort was described in the current context as how hard one had to concentrate and think to understand the training material. While the Paas scale does not distinguish between different

types of cognitive load, it was included to provide a general indication of perceived cognitive demand (Paas, 1992; Sweller et al., 2019).

As a single load measurement does not identify which instructional elements contribute to general cognitive load, Klepsch et al. (2017) proposed a multi-dimensional measurement model to assess each type of cognitive load outlined by Sweller et al. (2019) separately. Building on this and other multidimensional frameworks (e.g., Leppink et al., 2013), the current study included an additional three questions, each targeting specific load types. Although several questions were used for each cognitive load type in the mentioned frameworks, only one question per type was included in the current study, to manage the length of the survey. The formulations were also adapted to be easily understandable and directly relevant to the self-study training context, with the final questions being as follows:

- *Intrinsic load*: The content and topic of the training were very complex.
- *Extraneous load*: The way the content was presented was confusing and difficult to follow.
- *Germane load*: I actively tried to make sense of the content and understand it.

Each load was rated on a 7-point Likert scale ranging from 1 (I strongly disagree) to 7 (I strongly agree). The 7-point scale was chosen to balance sensitivity and participant usability and is consistent with previous studies using similar constructs (see Klepsch et al., 2017; Leppink et al., 2013). By including both a general and a differentiated measurement approach, the study aimed to capture broad trends in overall cognitive demand as well as specific insights into which aspects of the instructional design might contribute to perceived cognitive load. This combination allows for a more nuanced interpretation of learners' experiences and cognitive processing.

Motivation Measurement

In the post-surveys, participants were also asked to rate how motivated they felt to learn about MV and the company's products during the training. This was measured on a Likert scale from 1 (not at all motivated) to 5 (extremely motivated). This question was included to assess differences in motivation across conditions and to control for it as a potential confounding variable. It also served an exploratory function, as motivation is, as discussed, known to positively correlate with learning outcomes (Ryan & Deci, 2000).

Pilot Testing

Pilot tests of the experimental setup were conducted with six participants. Three were external to both the company and the university (non-students), selected to represent entry-level users unfamiliar with experimental contexts. The remaining three were expert reviewers who had provided feedback during the design phase. The aim of the pilot was to evaluate clarity, usability, and functionality before the main data collection (see Bryman, 2016; Arvola, 2021).

The external participants completed the experimental condition. A think-aloud protocol (Arvola, 2021) was used to gain deeper insight into participants' thought processes and navigation behavior. Participants were asked to verbalize their thoughts in real-time as they progressed through the

experiment, read instructions, and answered questions. Sessions were conducted via video calls with screen sharing, allowing direct observation of user interactions and moments of uncertainty. Particular focus was placed on identifying whether any interface elements or instructions imposed unnecessary cognitive load that could compromise the validity of the study.

Overall, participants reported that the experiment was easy to follow and that the interface was intuitive. However, based on verbalized feedback and behavioral observations, several minor revisions were made, such as simplifying technical terminology (particularly in the surveys) and refining language formulations for clarity. Additionally, two participants expressed feeling discouraged by the pre-survey, not realizing they were not expected to know the answers beforehand. In response, the pre-survey introduction was updated to clearly explain that the purpose was to measure learning gain, not prior knowledge. Post-survey results from the pilot confirmed substantial learning gains compared to pre-test scores, indicating that the training materials effectively supported knowledge acquisition. The expected time requirement of 30–45 minutes was also confirmed. No major technical issues occurred.

Results

All data were exported from the four Slido surveys (pre-test control, post-test experimental, pre-test control, post-test experimental) as Excel files that were then merged into a single dataset. Participants were matched across tests using the unique word or code they had entered at the start of each survey. The final dataset included paired knowledge test results and survey responses from the participants, along with group assignment (baseline vs. experimental). Multiple-choice knowledge questions were recoded into binary format. A total score of correct responses was calculated per participant for 1) the sum of the pre-test, 2) the sum of the post-test, and 3) knowledge gain. Likert-scale responses (used for self-efficacy, motivation, and cognitive load) were numerically coded, and time spent on the training material was calculated by subtracting pre- and post-test submission timestamps, creating a new time variable in minutes. All following statistical analyses were conducted using the Jamovi 2.6.26 software (Navarro & Foxcroft, 2022).

14 participants were initially recruited for each condition (N = 28). In the baseline condition, one participant did not complete the training, and one was excluded due to missing post-test data (n = 12). In the experimental condition, one participant was excluded for missing post-test data (n = 13).

Participant Demographics

Participants in the control condition (n = 12) consisted of 58% females and 42% males, with 42% working within the company and 58% being external (students). In the experimental condition, participants (n = 13) were 77% females and 23% males, with 30% working within the company and 70% did not. Most participants in both the control (50%) and experimental (62%) conditions were aged 25–34. The remaining participants were rather equally distributed across the age groups 18–24, 35–44, 45–54, and 55–64 in both conditions.

Knowledge Scores

Knowledge was assessed pre- and post-training in 12 questions. Pre-test scores were approximately 1 point higher in the experimental group (M = 6.62, SD = 1.66) than in the control group (M = 5.75, SD = 1.76). Both groups improved at post-test; the control group achieved a mean score of 8.42 (SD = 2.11), while the experimental group reached a slightly higher mean of 9.38 (SD = 2.10). Knowledge gain, calculated as the difference between post-test and pre-test, was similar across groups (control: M = 2.67, SD = 2.42; experimental: M = 2.77, SD = 2.01) (see Fig. 20).

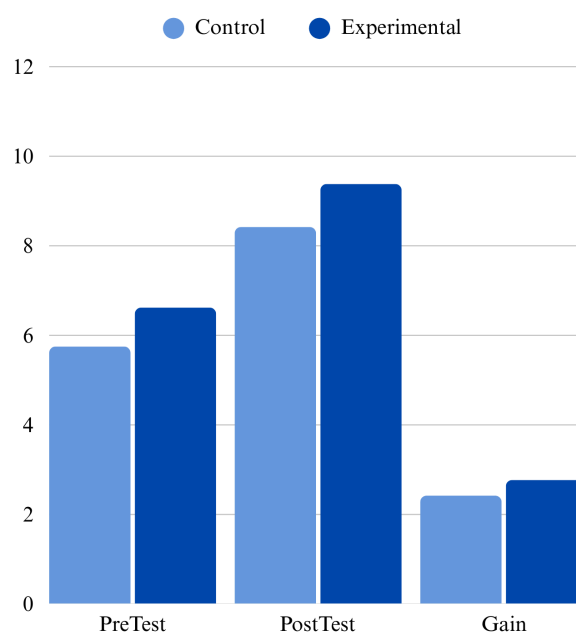


Figure 20. Knowledge scores and gain across conditions

A paired sample t-test confirmed that all participants' knowledge scores significantly increased from pre-test to post-test ($t(24) = -6.27$, $p < .001$). Cohen's d was 1.25, which exceeds the standard threshold for a large effect ($d \geq 0.8$) (Navarro & Foxcroft, 2022). A Shapiro-Wilk test was not significant ($p > 0.05$), confirming that the assumption of normality was met ($W = 0.93$, $p = 0.09$).

However, independent t-tests on pre-tests scores ($t(23) = -1.26$, $p = 0.22$), post-tests scores ($t(23) = -1.148$, $p = 0.26$), and knowledge gain ($t(23) = 0.12$, $p = 0.91$) revealed no significant between-group differences. Similarly, individual post-test question scores did not differ significantly across conditions. Given that the experimental group had slightly higher knowledge scores, an ANCOVA was conducted to control for pre-test scores. Results showed no significant difference in knowledge gain between conditions after controlling for pre-test scores ($F(1, 22) = 0.52$, $p = 0.48$).

Refined Knowledge Gain

Given the modest knowledge gain (2.77 and 2.67) across 12 questions, it was reasoned that some pre-test questions might have been too simple. This could have caused a ceiling effect, which limited room for further improvement (Taylor, 2010). A skewness check showed that the pre-test data was approximately normal (skewness values close to zero). Although, questions 1 (-3.46) and 2 (-0.81) showed negative skewness. Examining the mean pre-test scores, 7 questions had mean values above 0.5 (correct = 1, incorrect = 0) which

indicates that a significant portion of participants scored correctly on these questions.

Furthermore, pre-test scores and knowledge gain were moderately negatively correlated ($r = -0.43$, $p = 0.03$), indicating participants with higher prior knowledge gained less which supports the presence of a ceiling effect. A linear regression confirmed that pre-test scores significantly predicted knowledge gain ($\beta = -0.54$, $p = 0.03$), explaining 18% of the variance ($R^2 = 0.18$). To account for this, a refined gain score was calculated using only the five most difficult questions (mean < 0.5 in the pre-test): Q3 (product recognition), Q7 (laser triangulation), and Q10–Q12 (application-based scenarios). For these questions, the experimental group showed a slightly higher gain ($M = 1.92$, $SD = 1.32$) than the control group ($M = 1.17$, $SD = 1.53$) (see Fig. 21). However, the difference was not statistically significant ($t(23) = -1.33$, $p = 0.19$). An ANCOVA showed pre-test scores again significantly influenced knowledge gain ($F(1, 22) = 7.47$, $p = 0.01$). The control group had slightly higher pre-test scores ($M = 1.83$, $SD = 0.94$), than the experimental group ($M = 1.54$, $SD = 0.78$).

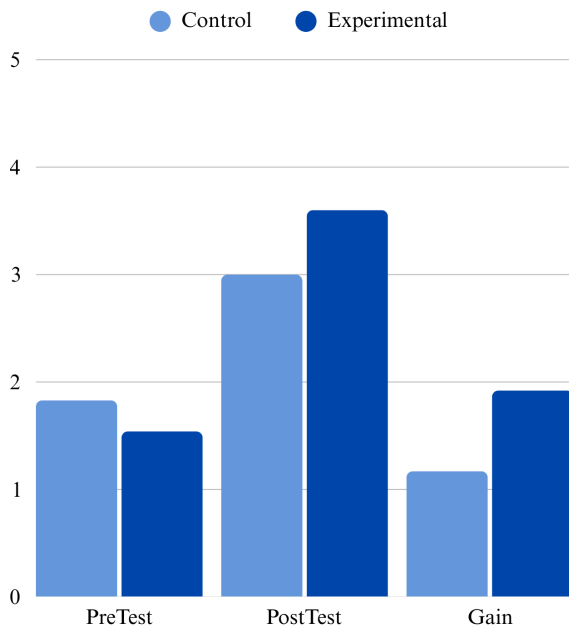


Figure 21. Knowledge scores and gain for more difficult questions

Cognitive Load

Three types of cognitive load (intrinsic, extraneous, germane) were measured in the post-test on a 7-point scale and general load on a 9-point scale. As shown in Fig. 22, the control group reported a slightly lower general cognitive load ($M = 5.08$, $SD = 1.78$) than the experimental group ($M = 5.69$, $SD = 2.02$). This may be explained by the experimental groups' slightly higher germane load ($M = 5.69$, $SD = 1.75$), than the control group ($M = 5.17$, $SD = 1.27$). Intrinsic load was nearly identical (control: $M = 3.75$, $SD = 1.60$; experimental: $M = 3.69$, $SD = 1.55$). Interestingly, extraneous load was notably lower and varied less in the experimental group ($M = 1.54$, $SD = 0.88$), compared to the control group ($M = 3.00$, $SD = 2.00$).

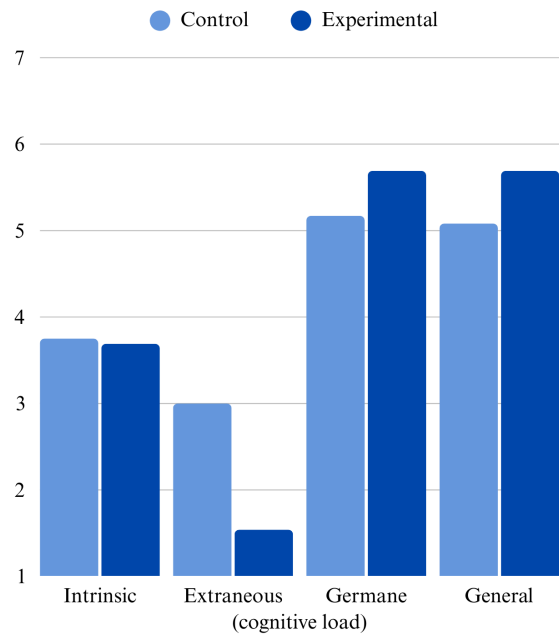


Figure 22. Cognitive load reports across conditions

However, a Shapiro-Wilk test informed that data was not normally distributed in intrinsic, extraneous, and germane load measures ($W = p < .05$). Consequently, non-parametric tests (Mann-Whitney U) were used to compare the conditions in terms of cognitive load (Navarro & Foxcroft, 2022). Extraneous load was the *only* measure that showed a significant difference between the two conditions ($U = 36.5$, $p = .017$), with a rank biserial correlation of -0.53 . Rank biserial correlations above 0.50 are considered large effect sizes (Navarro & Foxcroft, 2022). The difference remained significant in ANCOVA controlling for pre-test scores and intrinsic load ($F(1, 22) = 7.75$, $p = 0.01$), where intrinsic load also influenced extraneous load ($F(1, 22) = 10.34$, $p = 0.004$), but pre-test scores did not ($F(1, 22) = 0.333$, $p = 0.57$). Due to non-normality, ANCOVA findings should be interpreted cautiously (Navarro & Foxcroft, 2022).

Significant correlations were found between intrinsic and general cognitive load ($r = 0.64$, $p < .001$), and between intrinsic and extraneous load ($r = 0.51$, $p = 0.009$). This multicollinearity prevented multiple regression. Knowledge gain was not significantly correlated with any cognitive load type overall. However, when looking only at the difficult questions, intrinsic ($r = -0.43$, $p = 0.03$) and extraneous load ($r = -0.37$, $p = 0.048$) were negatively correlated with gain, while germane load was positively correlated ($r = 0.43$, $p = 0.03$). General load was not significantly related to gain ($r = -0.27$, $p = 0.2$). An ANCOVA controlling for pre-test scores and intrinsic load showed no significant difference in gain between groups in gain for the difficult questions either ($F(1, 22) = 1.14$, $p = 0.3$), but both pre-test scores ($F(1, 22) = 13$, $p = 0.002$) and intrinsic load ($F(1, 22) = 10.56$, $p = 0.004$) influenced knowledge gain.

Motivation, Self-Efficacy & Time Consumption

Motivation was measured post-training using a 5-point scale. The control group reported slightly lower motivation ($M = 3.25$, $SD = 0.62$) than the experimental group ($M = 3.62$, $SD = 0.77$) (see Fig. 23). Motivation scores were not normally distributed in either condition according to a Shapiro-Wilk test ($W = p < 0.05$), and a Mann-Whitney U test showed no

significant group difference ($p > 0.05$). However, motivation was moderate and significantly positively correlated with germane load ($r = 0.47$, $p = 0.02$).

Perceived self-efficacy (SE) was measured before and after training on a 5-point scale. In the control group, post-SE ($M = 2.67$, $SD = 0.65$) was lower than pre-SE ($M = 3.17$, $SD = 1.19$). In contrast, the experimental group reported higher post-SE ($M = 3$, $SD = 0.91$) compared to pre-SE ($M = 2.77$, $SD = 0.92$) (see Fig. 23). A paired t-test with all participants showed no significant difference in self-efficacy levels before and after training ($t(24) = 0.59$, $p = 0.56$). The scores were not normally distributed (Shapiro-Wilk $W = p < 0.05$), and Mann-Whitney U tests revealed no significant pre-SE ($U = 65.5$, $p = 0.47$) or post-SE ($U = 57$, $p = 0.23$) differences between groups. Change in self-efficacy was also not significantly different between conditions ($U = 49.0$, $p = 0.1$). However, post-SE was negatively correlated with intrinsic load ($r = -0.41$, $p = 0.04$) and positively correlated with pre-SE ($r = 0.43$, $p = 0.03$). Additionally, pre-SE was negatively correlated with general cognitive load ($r = -0.615$, $p = 0.001$).

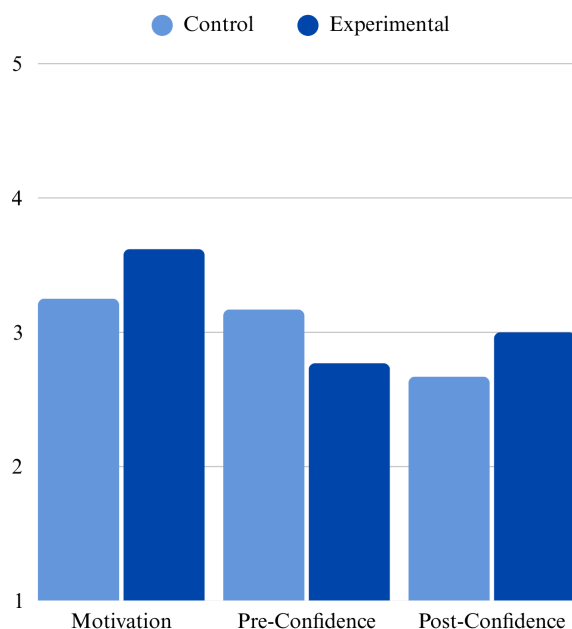


Figure 23. Motivation and confidence (SE) scores across conditions

The control group spent slightly more time on the training ($M = 15.7$ min, $SD = 7.7$, Range = 8–31) than the experimental group ($M = 14.2$ min, $SD = 4.14$, Range = 8–21). Data was normally distributed (Shapiro-Wilk $W = p > 0.05$), and a t-test showed no significant difference in time consumption ($t(23) = 0.62$, $p = 0.54$). However, time was significantly and negatively correlated with motivation ($r = -0.5$, $p = 0.01$).

Effects of Role, Age, and Gender

It was assumed that internal participants (employees), although entry-level, might have shown higher prior knowledge due to interest and general exposure to the domain. Indeed, they had higher pre-test scores ($M = 7.67$, $SD = 1.22$) and lower knowledge gain ($M = 1.67$, $SD = 1.58$) than external participants (students), whose pre-test scores were lower ($M = 5.38$, $SD = 1.44$) and knowledge gain higher ($M = 3.31$, $SD = 2.27$). The only statistically significant difference between internal and external

participants was found in pre-test scores ($t(23) = 4.08$, $p < .001$), with a large effect size (Cohen's $d = 1.7$). Specifically, internal participants significantly outperformed the pre-test questions 7 ($t(23) = 2.85$, $p = 0.009$, $d = 1.19$) and 8 ($t(23) = 2.37$, $p = 0.027$, $d = 0.99$). By analyzing mean values, no notable or significant differences were found in cognitive load, time, self-efficacy, or motivation between internal and external participants.

The only significant difference found between genders was that females reported significantly lower pre-SE ($M = 2.59$, $SD = 0.87$) than males ($M = 3.75$, $SD = 1.04$) ($t(23) = -2.93$, $p = 0.007$), with a large effect size (Cohen's $d = -1.26$). A one-way ANOVA found no significant age-group effect on knowledge gain ($F(4, 4.21) = 1.25$, $p = 0.413$). However, a linear regression revealed that participants aged 45–54 showed significantly lower knowledge gain ($M = 0.67$, $SD = 2.08$) compared to the youngest group (18–24; $M = 4.33$, $SD = 1.53$) ($B = -3.67$, $p = 0.04$).

Multiple Regression Analysis

To investigate which factors best predicted knowledge gain, a multiple regression analysis was conducted, including all measured variables as predictors:

$$\text{Knowledge Gain} = \beta_0 + \beta_1(\text{SumPretest}) + \beta_2(\text{Time}) + \beta_3(\text{Intrinsic Load}) + \beta_4(\text{Extraneous Load}) + \beta_5(\text{Germane Load}) + \beta_6(\text{General Cognitive Load}) + \beta_7(\text{Motivation}) + \beta_8(\text{Pre-SelfEfficacy}) + \beta_9(\text{Pre-elfEfficacy}) + \beta_{10}(\text{Condition}) + \beta_{11}(\text{Role}) + \beta_{12}(\text{Gender}) + \beta_{13-16}(\text{Age groups}) + \epsilon$$

None of the predictors in the full model reached statistical significance (all $p > .05$), although the model explained 61% of the variance in knowledge gain ($R^2 = 0.61$). This likely reflects overfitting and model instability due to the small sample size ($N = 25$) relative to the large number of predictors, including categorical variables with multiple levels (Navarro & Foxcroft, 2022). No significant interaction effects were found (all $p > .05$). To improve clarity and statistical reliability, a reduced model was estimated by excluding demographic variables (age, role, and gender) which were deemed as less relevant in the study. In this simplified model, pre-test scores emerged as a statistically significant negative predictor of knowledge gain ($\beta = -0.72$, $p = 0.009$), with the model accounting for 53% of the variance ($R^2 = 0.53$). This result suggests that participants with higher prior knowledge improved less, possibly due to ceiling effects. No significant interaction effects were found (all $p > .05$).

Simulating a Larger Sample

Given the small sample size in the current study (control: $n = 12$, experimental: $n = 13$), the observed difference in knowledge gain between conditions was not statistically significant. A post hoc power analysis indicated that the design had only 5.1% power to detect the observed effect size ($d = 0.045$), far below the conventional threshold of 80% (Navarro & Foxcroft, 2022).

To explore how this trend in knowledge gain might behave in a larger sample, a simulation using synthetic data was conducted in Jamovi's Rj Editor (cf. Mooney, 1997). Specifically, data were generated using the *rnorm()* function to simulate normally distributed values based on the observed means and standard deviations for each group. An independent samples t-test was then applied to the simulated dataset to test for a statistically significant difference.

The simulation showed that if the experimental group's mean knowledge gain increased modestly (from 2.77 to 3.2), a reasonable expectation in a larger sample given the observed trend, while standard deviations remained constant, the difference would become statistically significant with 135 participants per group ($p = 0.004$). (See Fig. 24). In this scenario, the experimental group would demonstrate significantly higher knowledge gain. These findings suggest that the study was underpowered to detect small to moderate effects and that scaling up the sample size could reveal meaningful differences in learning outcomes.

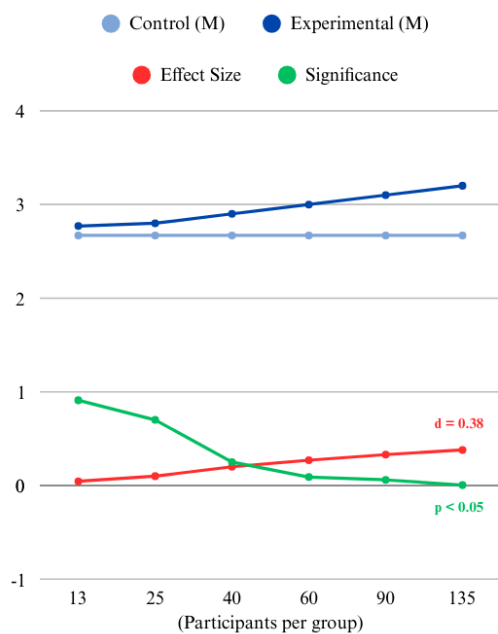


Figure 24. A significant difference in knowledge gain was found at 135 participants per group

Increasing the sample size to 90 participants per group, while keeping means and standard deviations fixed, would also reveal a significant difference in germane load ($p = 0.03$), with higher values in the experimental group. However, to detect a statistically significant reduction in intrinsic load ($p = 0.05$), a much larger sample, approximately 1,600 participants per group, would be required. This indicates that intrinsic load differences were minimal compared to within-group variability and were likely not meaningfully affected by the intervention.

Post Experiment Interviews

To gain deeper insight into participants' subjective experiences, four post-experiment interviews were conducted: two with participants from the control group and two from the experimental group. Each interview was transcribed, summarized, and thematically analyzed. This section presents common themes across participants, followed by a comparison of the two training conditions (Table 7). Full interview summaries are available in Appendix K.

All participants were students with no prior experience with the company or the domain of MV. The interviews revealed recurring themes related to perceived cognitive effort, structure and clarity, visual design, attention, and challenges with memory. Notable differences emerged in how participants experienced the two training formats.

General Impressions and Topic Complexity: All participants described the training as positive, manageable in effort, and good for beginners, despite recognizing the complexity of the topic. Control group participants, however, noted increasing difficulty over time and emphasized that applying the knowledge in real sales contexts would require further support. Experimental participants did not report increasing difficulty and described the experience as clear, engaging, and better than other training materials they had encountered at work.

Structure and Sequence: Control participants found the interwoven structure of 2D and 3D technologies confusing and had trouble distinguishing between the two technologies. One noted that seeing applications before understanding the technology contributed to confusion. In contrast, experimental participants described the structure as intuitive and easy to follow. Both appreciated the progression from technology to application, saying it helped clarify how the products are used and allowed them to mentally anticipate applications before seeing them.

Understanding and Memory of Product Names: All participants reported that remembering specific products and their functions was a challenge. For one participant, it prompted the use of personal memory strategies. Differentiating between products was described as difficult, and the scenario-based post-test questions (selecting the most suitable camera for a specific application) were described as the most challenging ones. However, the experimental participants reported fewer issues with confusion in general.

Visual Support: Images and videos were consistently described as essential for understanding the content on a deeper level. Control participants appreciated highlighted keywords and images for maintaining focus, but one noted that dense text without visuals led to passive scrolling. Another was distracted by two videos that ended abruptly and was confused by a portfolio overview that introduced unfamiliar products. Experimental participants praised the visual layout and the short, muted video on laser triangulation. Both appreciated the final visual hierarchy, and one said that, if they were a salesperson, they would print it out to keep at their desk.

Attention and Focus: Control participants described attention declining during later sections and moments of passive scrolling. Experimental participants said they remained engaged throughout, though one noted that while the topic was not "fun," it was still easy to concentrate on.

Design and Interface: The platform's interface received positive feedback across groups. Control participants praised the side menu and progress bar, and one said the user-friendly interface elevated even less effective content. However, they also requested clearer visual separation between 2D and 3D content. Experimental participants highlighted clickable info icons, color-coded elements (e.g., green for advantages, orange for limitations), bullet points, and overall visual clarity.

Suggestions for Improvement: Control participants recommended separating 2D and 3D sections, improving visual differentiation, and including summaries after each section. Experimental participants asked for more detailed explanations of product functions, more section summaries, and additional videos for specific technologies.

Table 7. Key insights from post-experiment interviews

Condition	Insight
All	➤ Described the overall experience as positive and manageable (no overwhelm) ➤ Found applications, visuals, and videos helpful for attention and deeper understanding ➤ Experienced difficulty recalling product names ➤ Found scenario-based post-test questions particularly challenging ➤ Suggested adding summaries at the end of sections
Control	➤ Struggled to distinguish between 2D and 3D content due to interwoven presentation ➤ Preferred that applications appear last in the structure ➤ Requested enhanced visual separation (e.g., clearer color-coding) ➤ Reported difficulty maintaining attention and experienced passive scrolling ➤ Highlighted confusing portfolio overview and distracting video endings
Experimental	➤ Described the structure as intuitive, clear, and easy to follow ➤ Appreciated seeing applications last, which supported the consolidation of understanding ➤ Found the visual hierarchy helpful for grasping portfolio structure ➤ Highlighted clickable icons, concise videos, and appealing layout ➤ Requested additional explanatory videos and more product-specific detail

6 Discussion

Effects of the Design Intervention

This study set out to examine whether cognitive science-informed redesign of a self-study module (an overview of the company's MV products) could reduce perceived cognitive load and support learning outcomes. Guided by schema theory (Anderson, 1983; 1984), cognitive load theory (CLT; Sweller et al., 2019), and the cognitive theory of multimedia learning (CTML; Mayer & Fiorella, 2022), the intervention altered only the structure and presentation of existing content. While overall knowledge gains were comparable across groups, the results demonstrate that even subtle changes in instructional design can affect learner experience.

Learning Outcomes and Role of Prior Knowledge

Although both groups showed significant improvement in knowledge, no significant difference in total gain was found between conditions. One plausible explanation for this outcome is the presence of a ceiling effect; a well-known issue in educational measurement where high initial scores limit the opportunity for detectable improvement (Taylor, 2010). In this study, pre-test scores were already elevated, particularly in the experimental group ($M = 6.62$ out of 12),

reducing the room for measurable post-test gain. Regression analysis supported this interpretation, showing that higher pre-test scores significantly predicted lower knowledge gain. Indeed, 7 out of the 12 knowledge questions had average pre-test accuracy above 50%, suggesting that many items were too easy, despite efforts to tailor them to entry-level knowledge.

For the five more difficult questions (pre-test accuracy < 0.5), the experimental group showed slightly higher gains ($M = 1.92$) than the control group ($M = 1.17$), although the difference was not statistically significant. Nevertheless, a clear trend emerged, with the experimental group outperforming the control group on both total knowledge gain and difficult items. It is worth noting that internal company participants, who were slightly overrepresented in the control group (42% vs. 30%), tended to have higher pre-test scores and lower gain, potentially limiting observable gains in the control condition.

Another likely reason for the small difference in knowledge gain is that the intervention was narrow in scope as it altered only structure and presentation in a single module. The control group received an already enhanced version of the original PowerPoint module, which had been revised to include improved content and changes aligned with multimedia learning principles. These included using less formal and more conversational language (personalization principle), removing irrelevant information and adding meaningful content (coherence and redundancy principles), and incorporating informative visuals to support understanding (multimedia principle) (Mayer & Fiorella, 2022). As Mayer and Fiorella (2022) and Sweller et al. (2019) note, such small-scale design changes typically yield modest effects, especially when learners already have relevant prior knowledge. The observed effect size was indeed very small ($d = 0.045$), and a power analysis simulation showed that detecting this difference would require around 135 participants per group; beyond the study's scope. However, if the same design principles were systematically applied across multiple training modules and scaled throughout the organization, even small individual gains could accumulate to produce meaningful improvements in learning and knowledge transfer at scale.

Instructional Clarity and Cognitive Load

Although knowledge gain did not differ significantly between groups, the design intervention aimed to improve learning by *managing* intrinsic load and *reducing* extraneous load to *foster* germane load; core components of CLT (Sweller et al., 2019). These were assessed in the post-survey through self-reported measures of intrinsic, extraneous, and germane load (7-point scale), along with general cognitive load (9-point scale).

The clearest benefit of the redesign was the significant reduction in extraneous load in the experimental group. This effect held when controlling for prior knowledge (pre-test scores) and perceived topic difficulty (intrinsic load). Given that the extraneous load item was phrased as "The way the content was presented was confusing and difficult to follow," the result suggests that the experimental group found the material clearer and more cognitively accessible. This points to a successful reduction of extraneous load. However, it is worth noting that self-assessing cognitive load remains a known challenge (Klepsch et al., 2017; Sweller et al., 2019), but care was taken to ensure that questions were easy to understand for entry-level users. Notably, a mean rating of

1.54 on a 7-point scale is exceptionally low and supports the claim that the experimental design provided instructional clarity.

Although it is difficult to isolate which specific design features were responsible for the reduction in extraneous load, the experimental material incorporated multiple evidence-based strategies from CTML (Mayer & Fiorella, 2022) known to reduce it. These included, for example, structured progression (technology → applications), 2D/3D separation (segmentation), alignment of visuals/text (contiguity), simplified layout (coherence), clear headings and highlighted text (signaling). Together, these interventions appear to have reduced extraneous load, possibly by enhancing clarity and lowering working memory demands (Sweller et al., 2019; Mayer & Fiorella, 2022).

Post-experiment interviews reinforced the quantitative findings and clarified which design elements enhanced the learning experience. Control group participants reported confusion particularly due to the interwoven 2D/3D content, the early placement of applications, and heavy text sections which made it difficult to distinguish concepts and maintain focus; often resulting in passive scrolling. This mirrors findings from the pre-study, where salespeople described similar struggles with attention and a tendency to skim dense self-study materials without fully internalizing the content. In contrast, experimental participants described the structure as intuitive and appreciated the progression from technology to applications, which helped them mentally organize the content and anticipate product use; supporting schema construction (Anderson, 1984).

The experimental group also highlighted visual design features; such as color-coded elements, bullet points, clickable info icons, and a clear final hierarchy, as helpful for understanding. The short, well-integrated video was appreciated, while the control group said the videos with sound and abrupt endings were distracting. These elements align with CTML principles like signaling, segmentation, coherence, and contiguity (Mayer & Fiorella, 2022), and likely contributed to lower extraneous load and sustained engagement. While both groups valued visuals, only the experimental group reported staying focused throughout, suggesting that targeted design improvements meaningfully enhanced clarity and cognitive efficiency (Sweller et al., 2019).

The control group spent, in general, 1 minute more on the training (15.7 min) than the experimental group (14.2 min), but the control group varied more (8–31 compared to 8–21). This may reflect greater cognitive friction or difficulty processing the material. Intrinsic load ratings were similar across groups (control = 3.75; experimental = 3.69), suggesting that topic complexity was perceived as moderate. Given that pre-test scores were relatively high, this aligns with the CLT claim that prior knowledge reduces intrinsic load (Sweller et al., 2019). Post-experiment participants described the topic as “difficult but manageable,” further reinforcing this interpretation. This indicates that, despite the topic’s inherent complexity, the overview module may have been easier for participants than anticipated. However, it is important to note that this module was intentionally designed to provide a basic introduction; more advanced product-specific training is likely to pose significantly greater cognitive challenges. Therefore, the design intervention tested here may have an even greater impact in more complex training contexts, where intrinsic load is

higher and instructional design plays a more critical role in facilitating learning.

Importantly, intrinsic load was positively correlated with both general load and extraneous load, meaning that as intrinsic load increases, general and extraneous load also tend to increase to a statistically meaningful extent. These correlations indicate that when information is even moderately complex, any additional instructional confusion amplifies overall mental effort (Sweller et al., 2019; Mayer & Fiorella, 2022). Interestingly, focusing on difficult knowledge questions revealed that intrinsic and extraneous loads were negatively and significantly correlated with knowledge gain, while germane load correlated positively. This pattern aligns with CLT and CTML: learning is undermined by unmanaged complexity and poor presentation but enhanced by deep, schema-building engagement (Sweller et al., 2019; Mayer & Fiorella, 2022).

Germane load, while not significantly different across groups, was slightly higher in the experimental condition ($M = 5.54$ vs. 5.08). These findings may seem contradictory at first but are theoretically consistent. As Sweller et al. (2019) note, germane load reflects the investment of cognitive resources into learning-relevant activities such as schema construction and automation. Thus, a higher germane load is desirable as it indicates deeper processing, which also increases perceived general effort (control = 5.08 , experimental = 5.69). This suggests that although the experimental group spent slightly less time on the training, they may have engaged in more productive cognitive processing during that time.

Motivation, Engagement, and Self-Efficiency

Although no significant difference in reported motivation was found between groups, both were generally motivated to learn (~ 3 – 4 on a 5-point scale), with the experimental group reporting a slightly higher mean score; 0.37 points above the control group. More importantly, motivation was positively and significantly correlated with germane load, suggesting that more motivated participants invested greater mental effort in meaning-making. This result is consistent with Self-Determination Theory (Deci & Ryan, 2020) and the concept of generative processing (Mayer & Fiorella, 2022), both of which emphasize motivation as an active driver of deep cognitive engagement.

Motivation was also negatively correlated with time spent on the training, indicating that more motivated learners tended to process the material more efficiently, likely due to greater focus and reduced distraction. However, this did not correspond to higher knowledge scores, and the relationship between time and engagement proved more nuanced. Post-experiment interviews revealed that control group participants, who spent slightly more time, often described passive scrolling and confusion, suggesting inefficient engagement rather than deeper processing. However, pre-study findings also described low motivation and “click-through” behavior, typically associated with shorter time on task. Taken together, these findings suggest that disengagement can manifest as either rushing through content or lingering without focus. Time spent, therefore, is not a reliable indicator of learning efficiency on its own; motivational and cognitive factors must also be considered.

As Schrader et al. (2022) note, well-organized and visually clear materials can enhance motivation by reducing perceived effort and supporting task engagement. The

experimental material, featuring simplified layouts, visual hierarchy, and chunked content, may have supported this by fostering a more focused and efficient learning experience. These findings reinforce the connection between design clarity, motivation, and meaningful cognitive processing, as emphasized by CLT (Sweller et al., 2019) and self-regulated learning theory (Zimmerman, 2002).

Self-efficacy, measured as post-training confidence in explaining the company's MV portfolio, followed a pattern similar to motivation. While the control group's confidence decreased slightly from pre- to post-training, the experimental group's confidence increased; though not significantly. This directional difference suggests that the redesigned material may have better supported learners' sense of competence, a key driver of motivation and effort (Bandura, 1997; Zimmerman, 2002).

Notably, pre-training self-efficacy was significantly negatively correlated with general cognitive load: participants who felt more confident experienced less mental strain. This aligns with research showing that self-efficacy reduces perceived task difficulty and enhances cognitive efficiency (Pajares & Schunk, 2001; Perry et al., 2001). Female participants reported significantly lower baseline self-efficacy than males (~1 point on a 5-point scale), echoing Bandura's (1997) observation that women often underestimate their competence in technical domains due to socialization and systemic bias. Since the experimental group included a higher proportion of female participants (70%), this may help explain the observed self-efficacy increase in that group.

These findings are particularly relevant given the pre-study's identification of widespread disengagement and low confidence among general salespeople, especially those new to MV. Interviews pointed to poor content structure, fragmented systems, and abstract materials as key contributors to cognitive overload and low perceived control; well-known demotivators in Self-Determination Theory (Deci & Ryan, 2020). The redesigned training appears to have mitigated some of these issues, not by altering the content itself, but by improving its structure and presentation. By reducing extraneous load, clarifying the learning path, and guiding attention, the intervention may have fostered greater perceived control and competence.

When all measured variables were entered into a multiple regression model predicting knowledge gain, the model explained 53% of the variance, leaving 47% unexplained by the included predictors. This underscores the complexity of learning and cognition, suggesting that factors beyond instructional design, motivation, confidence, and prior knowledge also influence individual learning outcomes.

Unmeasured contributors may include stress and cognitive fatigue, which can impair focus and memory (Plass & Pawar, 2020); emotional intelligence (Lin, 2025); metacognitive skills, such as goal-setting, self-monitoring, and strategy use (Azevedo & Dever, 2022); and individual differences in attention regulation and persistence, especially in self-directed learning contexts (Zimmerman, 2002). Additionally, working memory capacity varies across individuals and can affect how cognitive load is perceived and managed. Some researchers therefore recommend measuring or controlling for working memory capacity when using self-report measures of cognitive load, as it directly shapes how much information a learner can process and how demanding a task feels (Mayer & Fiorella, 2022).

Summary of Key Insights

The discussion of the design intervention's impact on learning and perceived cognitive load can be summarized as follows. A clear trend emerged in the experimental group, with slightly higher knowledge gain and higher reported confidence and motivation. Most notably, the experimental group experienced a significant reduction in extraneous cognitive load. Together, these findings suggest that the design intervention created conditions for enhanced learning efficiency. This indicates that even small changes in structure and presentation, such as segmenting, signaling, and aligning visuals with text, can meaningfully enhance clarity and reduce unnecessary mental effort.

Broader Learning Challenges in the Onboarding Journey

While the experimental results show that targeted redesign can reduce extraneous load and support learning within a single module, the broader pre-study findings point to deeper, systemic challenges. Cognitive overload emerged not just from specific materials, but from how self-study training is structured, sequenced, and embedded in the overall onboarding process.

Intrinsic load & Information Complexity

A central challenge identified in the pre-study is the high intrinsic load experienced by new salespeople during onboarding. This stems not only from the technical complexity of the content, particularly in domains such as 3D Machine Vision, but also from the sheer volume and distribution of information. MV systems are characterized by high-element interactivity, meaning that multiple components (e.g., optics, lighting, software, resolution, interfaces) must be understood in relation to each other for meaningful comprehension (Sweller et al., 2019). Given this inherent complexity, it becomes essential to optimize how information is sequenced and presented to free up working memory for meaningful, germane processing (Mayer & Fiorella, 2022; Sweller et al., 2019).

One core strategy recommended by the CTML to manage intrinsic load is segmenting: dividing information into learner-controlled, manageable chunks (Mayer & Fiorella, 2022). While the company's modular training structure aligns with this principle, the unintended consequence is an overwhelming perception of quantity; dozens of discrete modules can feel more burdensome than a smaller number of well-integrated lessons. Where possible, merging smaller modules into cohesive, thematically structured blocks, organized by function, use case, or sales process, might reduce overwhelm. Additionally, controlling the order in which content is delivered can support progressive schema construction. Rather than exposing learners to multiple platforms and formats simultaneously, onboarding could introduce one platform or content stream at a time, possibly accompanied by contextual guides or curated links to ease navigation.

To further navigate the complexity of information, natural mapping strategies (Norman, 2013) can be applied; such as organizing product training by function or use case (e.g., "high-speed cameras," "AI-supported sorting solutions"). This supports intuitive categorization and makes abstract product categories more relatable for salespeople focused on customer problems. Interface-wise, employing collapsible sections in training modules allows learners to progressively disclose information and explore details only when

cognitively ready - another form of segmentation that reduces simultaneous processing demands.

Let us not forget the importance of modality. CTMLs modality principle states that using spoken narration rather than on-screen text, especially when paired with visuals, can enhance dual-channel processing and reduce overload in the visual channel (Castro-Alonso & Sweller, 2022). While the company has increasingly incorporated videos, these often suffer from redundancy, where the same information is simultaneously shown as text, narrated, and visualized; violating CTML's redundancy principle (Kalyuga & Sweller, 2022). Materials should instead use either pair narration with visuals, or text-only with supporting images, not both.

Additionally, CTML's pre-training principle recommends introducing key concepts and terminology before presenting complex instruction to help manage intrinsic load by priming learners' schemas (Mayer & Fiorella, 2022). The redesigned overview module used in the experiment exemplified this principle; providing learners with a high-level understanding of MV technologies and product families before diving into detailed content. Notably, the pre-study revealed that such overviews were often missing in existing materials, with both salespeople and managers frequently expressing the need for better orientation. Thus, including entry-level overview modules, at the start of each product training path, is essential pre-training to ease schema construction. These should be designed specifically for novices, avoiding unnecessarily technical language, using clear visualizations, and focusing on structural relationships between products, technologies, and applications.

A misconception is that providing a detailed overview too early risks overwhelming the learner. However, what is often overlooked is that new information becomes overwhelming precisely when there is no foundation to attach it to. Without a schema, akin to a cognitive magnetic board, new information lacks structure and meaning, making it harder to encode or retrieve. A well-designed overview does not have to include every detail upfront but should establish a conceptual scaffold; a minimal, yet coherent framework into which future details can be integrated. As the experimental findings and interview insights both suggest, failing to provide this early structure can result in fragmented understanding, lowered confidence, and inefficient learning.

Balancing Simplicity in Overview Modules

Given that both pre and post-test scores were relatively high in the experiment, it suggests that the overview module may have been easier for participants than anticipated. This raises a key instructional dilemma; should overview modules be deliberately simple to build confidence and support schema construction - or does this simplicity risk creating a false sense of confidence and mismatched expectations for the more demanding content that follows? As the pre-training principle states, simplified introductions reduce cognitive load and help novices form mental models (Mayer & Fiorella, 2022). However, if overviews are too basic or disconnected from later material, they may set inaccurate expectations. When learners later encounter in-depth product training, the resulting mismatch can trigger cognitive dissonance; a psychological discomfort caused by conflicting information (Festinger, 1957). If learners are unprepared for this shift, dissonance may lead to disengagement, frustration, or resistance to learning.

Still, dissonance is not inherently negative. When properly supported, it can drive deeper engagement and

conceptual change (Köpeczi-Bócz, 2025; Gawronski et al., 2023). The theory of predictive dissonance (Kaaronen, 2018) emphasizes that learners constantly form expectations as they process content. When new information violates those expectations, a drive for resolution is triggered. For this to lead to meaningful learning rather than confusion, overview models must not only simplify content but also signal the complexity ahead. This can be achieved through brief metacognitive prompts (e.g., "This is a simplified model - more detail follows later"), or visual cues that preview what's to come. Such design strategies help learners calibrate expectations and prepare cognitively and emotionally for upcoming challenges.

Easy overview models also influence motivation by enhancing perceived control; the belief that one can influence learning outcomes (Perry et al., 2001). When learners feel oriented and in control, they are more likely to persist and apply effective strategies (Bandura, 1997; Deci & Ryan, 2020). In contrast, abrupt shifts in complexity without proper cues can undermine that sense of control, amplifying dissonance and reducing engagement.

This balance is especially relevant given the company's need to train employees with diverse knowledge levels. Notably, the company already provides a hierarchical structure with both basic (high-level introductions) and advanced modules (covering technical depth). This aligns well with the expertise reversal effect (Kalyuga, 2022), which shows that novices benefit from guidance and simplification, while experienced learners benefit from complexity and autonomy. Importantly, even technically skilled hires are not always familiar with the company's specific products. As reflected in the interview with a specialist MV salesperson, they still needed basic modules to understand the portfolio - demonstrating its value even for advanced users. Thus, overview models should be *strategically* simple: designed not only to reduce cognitive load and support schema formation, but also to foster perceived control, anticipate dissonance, and provide cues that cognitively prepare learners for future complexity.

One specific insight that emerged during post-experiment interviews was that one of the aspects that confused participants the most and seemed to pose an extraneous load was product names, such as "TriSpector1000" or "PicoCam2". These were consistently expressed as difficult to remember. It can be reasoned that at an introductory overview level, listing numerous product names may be unnecessary and disturb more than it contributes to learning. These names may be meaningful to engineers, but for novices, they are often redundant and do little to support early schema construction. To avoid this, one strategy could be to replace product names in overview modules with functionality or application-based descriptors, such as "high-speed camera" or "compact precision sensor", that are relevant to the users and exploit natural mapping, as recommended by Norman (2013).

This approach can help differentiate between product types early on and allow learners to build rough conceptual groupings. Then, in later, more advanced modules, the actual product name could be introduced alongside the functional label (e.g., Compact-precise sensor: PicoCam2), helping learners tie earlier mental models to specific products. This might not only support progressive schema development but also facilitate product recall and knowledge transfer. From a predictive processing perspective (Kaaronen, 2018), including subtle signals that clarify "this is not the product

name” can cue learners to anticipate future complexity. This kind of metacognitive prompting can trigger positive productive dissonance, an aha! moment, when the full product name appears later. This dissonance could enhance engagement and motivation by confirming expectations and reinforcing learning.

Accommodating Diverse Knowledge Levels

A recurring challenge identified in the pre-study was designing global training materials that accommodate both technically experienced new hires and those without prior product knowledge, as well as differing cultural approaches to learning. The company’s current approach to dividing content into basic and advanced levels is a reasonable response to this challenge and was generally appreciated by stakeholders. However, several issues emerged in how these levels are interpreted and used in practice.

Many participants reported that advanced modules, originally designed as PowerPoints to be delivered in trainer-led sessions *after* self-study, were frequently repurposed as standalone self-study materials. One reason for this was the expressed lack of booking times for trainer-held advanced training. When used without instructional support, these materials can overwhelm novices, as they assume a prior understanding of terminology, system logic, and product functionality. This misalignment reflects the expertise reversal effect, which shows that instructional strategies beneficial for experts (e.g., reduced guidance, high information density) can actually hinder learning for novices, and vice versa (Kalyuga, 2022).

In addition, several stakeholders raised concerns about the expert blind spot (Koedinger & Nathan, 2000), stating that subject-matter experts, often responsible for creating and reviewing training, may underestimate what novices need in terms of cognitive support. As a result, even basic modules sometimes skew too technical, limiting accessibility for less experienced learners. Further complicating the issue is uncertainty about when self-study modules are used. Although the intended sequence is for learners to complete basic modules before engaging in advanced or hands-on sessions, this order is often reversed in practice. Salespeople may skip or delay self-study and then complete it only to meet documentation requirements, undermining its role in schema construction and foundational understanding.

To address these issues, it may be worth adapting advanced materials into guided e-learning formats with embedded support, enabling them to be used independently if needed. Clearer instructional sequencing, reinforced by managers and platform design, could also help learners follow the intended progression. For example, advanced training could be locked and only made accessible once the basic level has been completed, particularly for learners identified as beginners to the topic. Finally, involving instructional designers, not just subject-matter experts, in content creation may help ensure that both basic and advanced materials are developmentally appropriate, cognitively aligned, and better scaffolded for diverse learner backgrounds.

Fragmentation and Navigation Challenges

Beyond the inherent complexity of content, onboarding is hindered by extraneous load, particularly, as due to fragmented information and poor navigation across internal platforms. As CLT emphasizes, such unnecessary effort

detracts from actual learning by consuming limited working memory resources (Sweller et al., 2019). Interview and survey results repeatedly highlighted how confusing navigation and unclear interfaces led to frustration and disengagement.

These challenges reflect well-established usability issues. According to Norman (2013), poor natural mapping, vague labels, and limited search affordances increase the gulf of execution; the gap between users’ intentions and system responses. In the training portal, assigned role-based training profiles offer helpful structure and reduce choice overload. However, several participants reported that these profiles were difficult to locate and lost in the amount of information presented on the start page. Beyond assigned content, users must rely on the catalogue search to find additional training, but this tool is notoriously difficult to use. One reason could be its uninformative or overly technical titles, making it hard for novices to identify relevant content.

From the perspective of extended and distributed cognition, poorly designed interfaces are not minor issues but they disrupt the very tools learners rely on to think. As Clark and Chalmers (1998) argue, cognition extends into the tools we use, and Hutchins (1995) highlights how it is additionally distributed across people and environments. Interfaces are part of the learner’s cognitive system and should therefore reduce, not add to, mental effort. To reduce such extraneous load, the following actions could be taken:

- Re-label training modules using sales-relevant, user-friendly terminology, and improve searchability with proper tagging in the user’s language.
- Differentiate content types visually (e.g., using icons or color-coding) to prevent confusion between self-study modules and booking pages for advanced training.
- Provide a visual onboarding guide or concept map of available platforms and content types.
- Introduce AI-based support tools, such as chatbots or guided search assistants, to aid learners in navigating large content ecosystems. Such tools have shown promise in reducing navigation-related cognitive load (Sayed et al., 2023).
- Conduct usability testing to uncover additional design flaws and inform iterative improvements to improve usability in the training portal and other internal pages.

Situated Learning and Application Context

Application-based examples are widely used and valued in the company’s sales training, and for good reason: they help demonstrate relevance and bridge the gap between product knowledge and customer value. Perceived relevance is highly important as it determines how deeply information is processed (Schrader et al., 2022). Situated learning theory emphasizes that knowledge is most effectively acquired when it is embedded in real-world contexts and social practices (Lave & Wenger, 1991; Suchman, 1987). In this view, learning is not merely about acquiring abstract facts but about engaging with tools, environments, and problems in *meaningful* ways.

However, findings from both the pre-study and the experiment suggest that presenting applications too early, *before* learners understand the underlying technologies, may overwhelm learners and hinder schema formation. Then, instead of serving as anchors for understanding, applications

risk becoming decontextualized examples; as learners lack the background knowledge to connect them to the relevant product features or system architecture. This contradicts CLT and schema theory's statement that meaningful learning requires guided and progressive schema construction (Sweller et al., 2019).

Moreover, while many self-study modules reference real-world use cases, it was noted that these scenarios remained abstract and underspecified, failing to fully ground learning in authentic sales situations. Without customer narratives, task sequences, or social context, the materials fall short of true situated learning. To improve this, application examples should go beyond stating "This product can be used for this application." Following the worked-example principle (Renkl, 2022), scenarios should walk learners through a concrete sales challenge: what the customer needs, how the product fits, and what steps are taken to configure and sell the solution. This would not only support comprehension but also facilitate knowledge transfer to similar real-world cases (Anderson, 1984).

Another limitation is the lack of access to physical products. While some modules include hands-on tasks, many salespeople do not have their own cameras to follow along. This restricts opportunities for object manipulation, which is crucial for learning, as hands-on interaction facilitates deeper comprehension and retention by aligning cognitive processes with physical actions (Winn, 2003). To address this, the company might want to consider incorporating interactive 3D models that allow learners to explore product components virtually; clicking on parts to receive explanations and build familiarity. Such designs would allow for epistemic actions and align with embodied and extended cognition theories, which emphasize the role of action and perception in supporting learning (Kirsh & Maglio, 1994; Clark & Chalmers, 1988).

Further benefits of epistemic actions, external operations that simplify mental computation (Kirsch & Maglio, 1994) could be utilized by dragging and dropping product components into a system diagram to see how they fit together. By actively assembling systems, learners can construct and test mental models, supporting schema development and deeper integration of technical knowledge.

Thus, while application-based learning is essential, it must be sequenced, situated, and supported. Applications should be contextualized within customer narratives, grounded in prior concept learning, and ideally include interactive elements that allow learners to explore, manipulate, and simulate use. This would not only enhance engagement but also support more robust and transferable mental models.

Supporting Motivation and Self-efficacy

The pre-study revealed widespread disengagement with self-study materials as several stakeholders referred to the training portal as "Death by PowerPoint," reflecting a sense of monotony and low motivation. The experience was described as passive and unengaging, e.g. "scrolling through just to get to the quiz", rather than as meaningful learning. While the company has made efforts to create more interactive materials (e.g., clickable visuals, embedded animations, and videos), these interactions are often surface-level. They require physical activity, but not necessarily mental engagement or reflection; what Mayer and Fiorella (2022) refer to as generative processing. Without

deeper cognitive involvement, such interactivity does little to promote actual understanding.

According to Self-Determination Theory (Deci & Ryan, 1985, 2020), intrinsic motivation depends on perceived autonomy, competence, and relatedness. Yet many learners in the pre-study described the self-study experience as overwhelming, disjointed, or unclear; conditions known to reduce motivation, perceived control, and self-efficacy (Bandura, 1997; Perry et al., 2001).

Autonomy is supported when learners feel a sense of control over their progress (Deci & Ryan, 1985). While role-based training profiles are necessary to guide salespeople through the extensive content, they can also reduce perceived autonomy by limiting choice. To counter this, salespeople could be encouraged to plan how and when to complete their assigned training, for example by integrating modules into their calendar and setting personal milestones. Furthermore, the training portal does offer basic progress indicators, but these could be improved with motivational feedback that links progress to real-life sales scenarios. This could help salespeople see how each step connects to practical outcomes. Even within a structured learning path, small elements of choice and relevance might strengthen autonomy and foster deeper engagement.

Competence is supported when learners feel capable of mastering the material (Deci & Ryan, 1985). This sense is undermined when content appears too complex, abstract, or disconnected from real-world relevance. This is particularly problematic in areas like MV, which several managers described as something salespeople perceive as intimidating or "scary". Training on MV was frequently assigned only when a salesperson, customer, or market showed explicit interest. However, this reactive approach can create a self-reinforcing cycle: when a topic is perceived as too difficult, interest drops, new salespeople avoid it, and training remains underutilized.

To break this cycle and build competence, MV training must feel accessible and achievable. This can be done by designing materials that establish early competence experiences, such as structured overviews, gradual increases in complexity, and language that highlights progress. When learners experience small, meaningful wins and understand how new knowledge connects to their role, their sense of competence can grow, which in turn might drive motivation and sustained engagement.

Relatedness is often overlooked in independent self-study environments, yet salespeople consistently value social interaction and peer support during onboarding. Incorporating collaborative learning formats, such as post-module debriefs, peer discussions, or collaborative onboarding plans can foster a sense of community and shared experience. Emotional design also plays a key role here. As Plass and Hovey (2022) argue, features such as warm colors, facial expressions, and human-like gestures or voices foster social presence, making content feel more relatable and human. For example, replacing robotic narration with natural, expressive voice-overs, or including a friendly guide avatar, can make abstract or technical topics feel less alienating and more accessible.

Notably, the experiment findings suggested that well-designed instructional materials can support not just comprehension but also motivation and self-efficacy. The experimental group, who received structured overviews and clearer instructional sequencing, reported higher levels of motivation and confidence. This reinforces the view that

instructional design itself is motivational when it supports comprehension, clarity, and perceived relevance (Norman, 2013; Deci & Ryan, 2020; Mayer & Fiorella, 2022).

To better assess engagement, the company could track not only completions in the training portal but also time spent and interaction patterns to distinguish between active learning and passive clicking. However, since time alone is an unreliable metric, it should be interpreted alongside motivation measures to give a more accurate picture of learner involvement.

Germane Load and Generative Processing

While earlier sections have discussed how good instructional design can manage intrinsic load and reduce extraneous load, it is equally important to support germane load; the effort learners invest in organizing and integrating new knowledge into meaningful schemas (Sweller et al., 2019). In the current onboarding landscape, opportunities exist to support this sort of generative learning. One area for improvement opportunity is the style and tone of content. Training materials often adopt a formal, technical tone. While appropriate externally, this style can hinder comprehension internally. According to the personalization principle, using conversational, learner-friendly language increases engagement and retention (Mayer & Fiorella, 2022). A warmer, more approachable tone, especially in entry-level materials, can reduce intimidation and foster mental involvement.

Secondly, although self-study is emphasized, survey respondents placed significantly higher value on face-to-face training and colleague interaction. This aligns with findings that collaborative formats enhance learning outcomes (Janssen et al., 2022). The company's adoption of the 70-20-10 model reflects this recognition, yet opportunities for social learning could be further developed. The previously mentioned suggestions to promote relatedness not only foster social connection but also support germane cognitive processing. Collaborative training formats would promote shared understanding and reflect principles of extended and distributed cognition (Hutchins, 1995).

Additionally, current self-study quizzes primarily assess completion rather than understanding. However, these quizzes could be redesigned to stimulate generative learning strategies, such as reflection, explaining, mapping, or imagining use (Fiorella & Mayer, 2022). Incorporating scenario-based questions, open-ended prompts, and use-case mapping could transform assessments into tools for active schema construction to promote germane processing.

Lastly, it was identified that salespeople received little feedback during self-study. As Norman (2013) stresses, feedback is essential for learning as it closes the gap between action and understanding. Post-training quizzes should therefore also provide instant, explanatory feedback; not just whether an answer is right or wrong, but *why*. Self-check prompts at the end of sections could invite learners to reflect on their confidence or identify areas needing review. Interactive scenarios, such as selecting the appropriate product for a given customer case, could simulate realistic decisions and provide step-by-step feedback to guide learners' reasoning. Beyond digital tools, timely feedback from managers, through brief follow-up discussions or informal check-ins, can further reinforce learning, correct misunderstandings, and signal that the training content is valued. Together, these strategies can enhance learner engagement and foster metacognitive regulation which is

essential in self-directed learning environments where learners must monitor, evaluate, and adapt their own understanding (Azevedo & Dever, 2022)

Study Limitations

This study faced several limitations related to sampling, measurement, and context. First, the pre-study included limited input from newly hired general salespeople, the primary target group, due to low response rates and availability. Insights were instead gathered from broader stakeholder groups, which, while valuable, lacked firsthand onboarding perspectives. Interview questions were also framed broadly, rather than anchored to a specific training module, which may have reduced clarity and comparability.

In the experimental phase, recruitment shifted from onboarding salespeople to participants unfamiliar with MV and the company portfolio. While this approximated the target group conceptually, differences in work context (e.g., time pressure, performance), motivation, and cognitive load should be considered when interpreting results. Additionally, internal company representation was uneven across groups, and no internal participants completed post-experiment interviews, limiting contextual feedback.

The small sample size ($N = 25$) significantly limited statistical power. Power simulations showed that over 130 participants per group would be required to detect the observed effect size, making the study underpowered to identify small yet potentially meaningful differences.

Measurement tools also introduced constraints. Self-reported cognitive load is known to have reliability limitations (Klepsch et al., 2017), and some constructs may have overlapped. The knowledge test showed signs of a ceiling effect, with many pre-test scores already high, reducing observable gain. This aligns with regression results showing a negative correlation between prior knowledge and gain. Moreover, only multiple-choice formats were available in Slido, limiting the ability to assess deeper understanding or transfer. Including open-ended or matching items would have provided richer insight (Anderson & Krathwohl, 2001).

Furthermore, several key variables, including gain scores and load ratings, displayed non-normal distributions. While ANOVA is robust to some violations, small samples increase the risk of distortion (Foxcroft & Navarro, 2019). As such, findings must be interpreted with caution.

Importantly, the study did not assess long-term retention, as knowledge was measured immediately after the intervention. Future research should examine whether observed learning gains are sustained over time.

Additionally, the control material had already been improved from the original PowerPoint module, which may have reduced the contrast between the two groups. A comparison against the unaltered version might have revealed greater differences; however, this would have introduced inconsistencies in format and content - preventing a scientifically meaningful comparison.

One point worth mentioning is the long-standing question of validity when applying theoretical principles in practical settings. In this study, CTML principles were applied by carefully following Mayer & Fiorella's (2022) design recommendations that translate into concrete instructional strategies. The study also assumes the validity of these principles in reducing cognitive load, grounded in the decades of empirical support documented in the literature (Mayer & Fiorella, 2022).

Finally, this thesis adopted a deliberately broad, interdisciplinary lens, which may have limited depth in specific areas. However, this lens better reflects the complexity of real-world training design, where cognitive, motivational, and contextual factors interact.

Suggested Actions for the Company

An important objective of this thesis was to offer actionable recommendations to help the company improve how new salespeople, especially those learning about machine vision, engage with and retain product knowledge. Based on the findings and cognitive science frameworks applied, the following steps are recommended to the organization:

- Improve navigation and usability of the training portal and internal pages to reduce extraneous cognitive load. Conduct user testing to ensure changes align with real user needs.
- Structure content delivery progressively across platforms to support schema formation and manage intrinsic load, and ensure learners follow the intended progression (basic before advanced).
- Include overviews at the start of training modules to anchor new information, connect to prior knowledge, and support schema construction.
- Make these overview modules *strategically simple* - keep them accessible to build confidence, but include cues or brief prompts to signal upcoming complexity to prepare learners. Leave product names out of overview modules, as these might cause extraneous load not vital to high-level understanding.
- Make sure the self-study materials do not introduce unnecessary extraneous load but guide user attention effectively, eliminate redundancy, and support coherence and contingency.
- Expand the use of situated application examples, but avoid introducing them before foundational product and technology knowledge to ease information integration.
- When there is a lack of access to products in onboarding, create interactive elements that allow salespeople to explore and manipulate products, and simulate use of them.
- Strengthen feedback and collaboration during the onboarding journey, for example through reflective tasks, manager check-ins, or peer discussions.
- Gather post-onboarding feedback via a short survey sent some months after a new salesperson's registration. This can be automated through the training portal and provide essential first-hand insights for continuous improvement.

The Value of Cognitive Science in the Workplace

One of the central motivations behind this thesis was to highlight the relevance and applicability of cognitive science in real-world, non-academic contexts. While much of the existing research in cognitive psychology and educational science is conducted in formal educational settings, such as schools and universities, these environments do not always reflect the realities of workplace learning, where time pressure, self-study formats, and information overload are equally common.

Yet, these organizational settings are deeply relevant. Around 60% of the global working-age population participates in the labour force, and a significant majority of those employed work in private enterprises or companies (International Labour Organization, 2023). Nearly all employees go through some form of onboarding, nowadays often involving e-learning or self-study modules.

These are precisely the moments where cognitive science offers clear value. Principles such as managing cognitive load, supporting schema formation, and minimizing extraneous processing may seem self-evident to those trained in cognition, but they are not necessarily everyday knowledge in workplace settings. Although CTML principles are designed to be easily implemented in instructional design, understanding the cognitive architecture behind these principles is essential for applying them effectively. Recognizing this gap is not only important for organizations but also empowering for cognitive science students and early-career professionals, who may underestimate the practical worth of their academic training.

In the company studied in this thesis, for instance, those responsible for developing training materials predominantly came from engineering backgrounds and were subject matter experts - often the same individuals who designed the systems or products being taught. While many had completed internal courses in instructional design, such training cannot substitute for the deep, research-based understanding of the human mind developed through years of academic study. This is not a critique of their dedication or competence, but rather a reflection of a broader structural issue: the underutilization of cognitive science in the design of workplace training.

One reason for this is that cognitive considerations often require attention to subtle, detail-level aspects - something that is easily deprioritized when time or resources are constrained. However, cutting back on this investment during early onboarding design can have long-term costs. Poor learning outcomes may later require additional resources to address performance gaps, productivity issues, or customer-facing consequences.

Thus, as a final recommendation, the company, and others, should consider investing in cognitive science competence, whether by hiring trained specialists or collaborating with universities. In workplace contexts where employees are expected to quickly and independently absorb complex information, cognitive expertise is not just helpful; it is strategically important. In fact, some even argue that cognitive load management should be considered a core managerial responsibility to improve efficiency and performance across the organization (Kilinç et al., 2024).

Future Research

On that previous note, there is a clear need for more research into how cognitive science can be applied in workplace learning. While theoretical foundations are well-established in academic literature, there is a void in understanding how these principles function in complex, fast-paced organizational environments; especially during onboarding and self-study, where learners are often novices facing high cognitive demands. A few notable exceptions do demonstrate how CTL can be applied effectively in workplace contexts to promote learning and improve performance (Bolander et al., 2019; Evanick, 2024; Kilinç et al., 2024; Blissett et al., 2021; Sewell et al., 2019; Lin, 2025). Despite these contributions, gaps do remain; particularly in how CLT, CTML, and

schema theory are applied in sales training, onboarding, and corporate self-study.

Although some organizations conduct internal evaluations or research-based design work, these efforts are rarely published or made accessible due to confidentiality, limited academic collaboration, or a lack of incentives to communicate outcomes externally. This means that valuable applied knowledge remains hidden, limiting opportunities for knowledge transfer between organizations. As Vetenskapsrådet (2024) emphasizes, one of the most important aspects of research is that it is communicated and shared where it can do good. This calls for not only conducting applied cognitive research in workplace settings but also ensuring that the results are accessible and actionable. To address these challenges and advance the field, future research should further aim to:

- Study sales onboarding through a cognitive lens, focusing on how novices process and organize complex new information.
- Evaluate schema-based design and cognitive load principles in self-paced workplace learning, especially in high-demand domains.
- Replicate this study with newly hired salespeople, larger and better-matched samples, improved measurement tools, and more varied test formats to avoid ceiling effects. Incorporate delayed post-tests to allow for the assessment of long-term knowledge retention and provide a more comprehensive understanding of learning outcomes.
- Test isolated CTML principles by assigning different learner groups to receive only one design change each. This can help clarify which principles have the strongest impact on learning outcomes and usability in a given context.
- Promote interdisciplinary collaboration between cognitive scientists, instructional designers, and subject-matter experts in organizational training.
- Publish applied case studies of cognitively informed training design to create a shared evidence base and support ongoing improvement.

7 Conclusion

The pre-study revealed key challenges of cognitive overload in the onboarding journey of new salespeople, linked to fragmented materials across platforms that are difficult to navigate, are high in technical complexity, and vary in levels of instructional clarity. To address these problems, a redesigned overview MV training module was developed, drawing on Cognitive Load Theory (CLT), the Cognitive Theory of Multimedia Learning (CTML), and Schema Theory. The intervention focused on improving structure and presentation through strategies such as segmentation, signaling, and visual alignment - without altering the core content.

Although overall knowledge gains were comparable between groups, the experimental version significantly reduced extraneous cognitive load and showed trends in improved performance on difficult items, as well as higher reported motivation and confidence. These findings suggest that targeted design improvements can enhance learning

efficiency and reinforce a central point: it is not just the amount or complexity of information that overwhelms learners, but how that information is organized and presented to them.

While the design intervention had only a small effect and differences in germane load and knowledge gain were not significant between conditions in this experiment, the potential for cumulative impact should not be overlooked. If these principles were applied systematically across multiple training modules and scaled throughout the organization, even modest improvements could accumulate into meaningful gains over time. This is particularly important in onboarding contexts where content, such as machine vision, is intrinsically complex and working memory demands are high.

Managing cognitive load thus becomes a critical aspect of instructional design, and CTML provides robust, research-based guidelines for this task. Ultimately, effective workplace training is not merely about delivering content, but about designing to *ease* cognition. The research field of cognitive science offers practical tools to reduce unnecessary mental effort, manage complexity, and foster deeper learning. This thesis recommends that organizations adopt these principles to create onboarding that is clearer, more engaging, and better aligned with how people learn.

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Appendices

A. Usage of Generative AI

Spelling and Grammar

Automatic spelling and grammar checking was enabled in Google Docs, where the thesis was written.

Literature Search

Litmaps was used to identify relevant literature. Although ChatGPT was occasionally consulted to find sources, it was not relied upon due to its tendency to generate non-existent references. Instead, most source discovery was done via Litmaps or the university library search tool (LUBsearch). The sources provided by ChatGPT were always double-checked and reviewed in their original format. However, Chat GPT was used at certain occasions to summarize long articles to save time in the literature review process.

Utilizing Chat GPT

ChatGPT was used as a tool for improving language clarity, fluency and variation. When a sentence appeared awkward or unclear, alternative phrasings (typically eight) were requested. These suggestions served as inspiration for rewriting and often led to the creation of new sentences that combined elements from several proposals. This ensured that the final version remained original and aligned with the intended tone and structure.

It was also used to identify synonyms when specific terms felt overly formal or inappropriate for the context. Typically, five alternatives were requested, and the surrounding context was provided to improve the relevance of suggestions. To maintain ownership over the writing, longer self-written sections were generally not submitted to ChatGPT. However, during the final editing stage, when the thesis needed to be significantly shortened, ChatGPT was used to identify redundant or verbose sections and to propose areas suitable for condensation.

Other utilizations of ChatGPT were to summarize informal notes from meetings and supervisor discussions (excluding interview data due to privacy considerations). It was also used to support the development of alternative incorrect answer options (distractors) for the knowledge tests. Further, it was also utilized to provide guidance for statistical analysis in Jamovi when needed. When used for such purposes, ChatGPT was always asked to include a link to the original source, allowing me to verify the accuracy of the information.

B. Pre-Study Interview Guide for Sales Offices

Interview Introduction

- Thank the participant for taking the time to speak with me.
- Ask for permission to record the interview to support accurate note-taking.
- Request informed consent: explain that the information shared will be used as background material for my master's thesis and to inform the analysis.
- Briefly introduce the study purpose: to understand challenges and opportunities in the onboarding and training of salespeople, especially regarding self-study materials and machine vision training.

Sales Organization

- Could you start by describing your role at [Company Name]?
- What does the sales organization look like in [Country]? (e.g., structure, offices, roles)
- What is the typical background of a salesperson in your country (education, prior experience)?

Learning Journey for New Salespeople

- How does the onboarding process look for new salespeople in your country?
- What kind of training material do they receive early on? (e.g., self-study, hands-on)
- How do the basic self-study modules in the [Training Portal] fit into this process? Do they include machine vision?
- How are training modules assigned in the portal based on sales roles?
- *Persona prompt:* Imagine you're a new salesperson at the company. What would your first two weeks look like? What might be most challenging to learn?
- How long is the onboarding period in practice?
- Who attends the more advanced trainings, and how are they delivered?
- Do you use any local training material apart from what's in the training portal?
- Are products (e.g., cameras) available on-site for hands-on practice during self-study?

Perception of self-study materials, structure, and content

- Do you have any insight into how salespeople use and perceive these training materials?
- What have you heard from salespeople about the self-study materials? Any general impressions or feedback?
- Are there known challenges with content, structure, or navigation?
- Do the materials serve their purpose? Do salespeople use them as intended?
- How do they experience navigating the training portal and finding relevant content?
- Are certain technologies, concepts, or product areas perceived as particularly hard to grasp?
- Is the basic level perceived as too easy, too advanced, or appropriate?
- What is your involvement (if any) or insight in the development or review of these materials?

Learning Machine Vision

- What does training in machine vision look like in your region/unit?
- When are machine vision modules typically assigned in the learning journey?
- What are the main challenges your salespeople face when learning about machine vision?
- How are the machine vision self-study modules perceived in your unit?

Feedback on Method + Survey Request

- Now that you've heard about the thesis focus, do you have suggestions on what else should be investigated?
 - Have you had any personal thoughts or ideas related to onboarding or training that you haven't had the chance to follow up on?
- Ask for permission to distribute a follow-up survey to salespeople in their unit. Clarify that participation in the survey is voluntary and anonymous.
- Request contact details for sending the survey if permitted.

Closing

- Thank the participant again for their time and valuable insights.
- Ask if it would be okay to contact them later in case follow-up questions arise.
- Invite them to reach out if they have further thoughts or would like to add anything later.

C. Pre-Study Survey

1. Description of Survey & Consent

Hi there! My name is Linnéa and I am a master thesis student at [unit name, at company name]. My work will focus on analyzing the self-study material at [company name] from different cognitive principles.

Why a survey? To gather background information on how the salesforce uses and perceives the self-study material. This data will help me understand the users, their experience, and guide my analysis. I am seeking responses from all sales representatives (not just in Vision)!

Why should you do it? Your insights will contribute to helping improve the salesforce's learning experience in the future which can lead to enhanced sales performance.

 How long will it take? About 5-10 minutes.

 Is it confidential? Yes! Your responses are anonymous and will be removed from Slido by June 2025. Data may be exported and stored safely on a local computer. A summary of data from this survey will be shared with [company name] and used in my thesis. Your participation is voluntary and you can stop at any time.

 If you have any questions or concerns, feel free to email me at [company email]!

By checking 'Yes' below, you confirm that you understand the purpose of this survey and give your consent to participate in it:

- ☐ Yes
- ☐ No

2. Which sales unit do you belong to?

- ☐ Sweden
- ☐ Norway
- ☐ United States
- ☐ Canada
- ☐ Finland
- ☐ Austria / Southeast Europe
- ☐ Czech Republic & Slovakia
- ☐ Great Britain / UK
- ☐ France
- ☐ Italy
- ☐ Netherlands
- ☐ Spain
- ☐ Switzerland
- ☐ Belgium
- ☐ South Africa
- ☐ Other

3. What is your sales role?

- ☐ Regional Sales
- ☐ Key Account
- ☐ Industrial Sales
- ☐ Specialist (Vision)
- ☐ Specialist (Safety)
- ☐ Other

4. How long have you been in your current role at [company name]?

- ☐ 0-1 year
- ☐ 2-4 years
- ☐ 5-7 years

- ☐ 8-10 years
- ☐ 10+ years

5. What is your age group?

- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 44-54
- ☐ 55-64
- ☐ 65+

6. What is your highest level of education?

- ☐ Elementary school (grade 1-9)
- ☐ High school (grade 10-12)
- ☐ University degree or above

7. Did you have a technical background when starting at [company name]?

By technical background, I refer to any engineering academic background or equivalent technical work experience.

- ☐ Yes, I have a technical academic degree
- ☐ Yes, I had practical work experience with technical products/systems
- ☐ Yes, I have a technical academic degree and practical work experience with technical products/systems
- ☐ No, but I've always had a strong interest in technical subjects and have been skilled in them
- ☐ No

8. What material were you provided to go through when you started your role at [company name]?

This refers to what training material you initially used when you were getting acquainted with [company name]'s products and/or your area of expertise.

You can pick multiple answers.

- ☐ Basic Modules in the training portal (self-study)
- ☐ Advanced trainings with a trainer
- ☐ Advanced trainings in the training portal or PowerPoints (self-study)
- ☐ Global Training Material Pages (Internal page with PowerPoints, videos, etc)
- ☐ Market Information Pages (Internal page)
- ☐ Company Website
- ☐ User manuals
- ☐ Other local training material
- ☐ Other material

9. Rank what resources have been most valuable for your learning journey at [company name]?

This question refers to the informational resources from which you have learned the most regarding relevant markets, technologies, products, applications, etc., for your role.

Please rank these resources in order of their informational value to you by dragging the options to the box ★

- ☐ Videos / Tutorials
- ☐ The [company name] website
- ☐ Global Training Material pages
- ☐ Visits to other offices at [company name]
- ☐ Market Information pages
- ☐ User manuals
- ☐ Talking to colleagues

- ☐ The training portal (self-learning basic modules)
- ☐ Support from local MPM/MAE
- ☐ Advanced trainings with a trainer / MPM

1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

10. How often have you completed any basic learning modules in the training portal?

This refers to the self-study material at the basic level that is intended to be completed independently before any further advanced training. Remember it's anonymous & no judgement involved! 🙌

You can pick multiple answers.

- ☐ Never
- ☐ Initially, I went through introductory modules for [company name] such as 'This is [company name] and 'Basic Conduct'
- ☐ Initially, I went through basic modules on Products, Technologies and/or Applications, etc
- ☐ I continuously use the training portal to complete basic modules for new product launches or to refresh my memory on existing products

11. Have you completed any advanced training?

- ☐ Yes, on my own in the training portal / through PowerPoints
- ☐ Yes, with a trainer (on-site or online)
- ☐ No
- ☐ Not sure

12. In your learning journey at [company name], how have you experienced the self-study material? 📖 1

This particularly refers to the basic modules that are intended to go through by yourself in the training portal, or any other PowerPoints you have viewed for example through the Global Training Material page.

You can pick multiple answers, and write a free-text answer in the next question.

- ☐ I have never seen or used any self-study material
- ☐ I did not experience any challenges with the material – it was easy to take in information and learn the content
- ☐ Content: Information is too easy / not necessary
- ☐ Content: The language used is difficult to understand (e.g too technical)
- ☐ Usability: There is too much information to take in / It was difficult to stay focused and alert
- ☐ Usability: I would have liked to see more visuals, animations or videos

- ☐ Context: It is not always easy to understand the technologies and functional principles behind the products
- ☐ Context: it is not always easy to get an overview of the [company name] portfolio
- ☐ Context: It is not always easy to understand the products within an application
- ☐ Navigation: the material is difficult to find / there are too many modules to go through
- ☐ Other (please specify in the next question)

13. (Free text) How have you experienced the self-study material?

If you have any other comments on the self-study material and possible areas of improvement, other than the pre-defined options above, please type them here!

14. Have you completed any training in Machine Vision? 14/17

This particularly refers to [machine vision unit name] (for example: product family names)

- ☐ Yes, basic (in the training portal, PowerPoints, etc)
- ☐ Yes, advanced (PowerPoints, F2F training sessions, visits to [machine vision unit name] etc.)
- ☐ Yes - basic and advanced
- ☐ Yes - basic, advanced & expert!
- ☐ No
- ☐ Not sure / Don't remember

15. If you have completed basic Machine Vision training, which area* did you find most difficult to initially understand or learn about?

* a specific [company name] product/camera, any technology used within these, an application, a certain self-study module, or just in general. You can mention several areas!

Note: If you have NOT completed any Machine Vision training, please write what aspect you perceive would be the hardest to learn about.

16. Is there anything else you would like to share about your experience with the self-study material at [company name]?

I am very curious to read about your personal experience with the self-study material at [company name] – both the positives and the negatives!



Inspiration: Reflect on the most surprising experience during the training period.

17. Thank you for completing this survey! But before you go -

 Don't forget to press the green 'Send' button to hand in the survey!

 If Vision is not your main focus area of sales and you have not done specific vision training, I am wondering if you would be interested in participating in my main study!

If you are - Go to this Slido [link & password] for more information and to fill in your email address so I can contact you. Please note that only I will see your email and since it is in a separate Slido, your identity will not be tied to your individual answers in this survey.

Thank you!
/Linnéa

- ☐ I am a salesperson and will go to the Slido to show my interest in participating in the main study
- ☐ I am already very familiar with machine vision training material / I do not have time to help with the main study



Machine vision

Portfolio overview

Basic

Product positioning, market, and competition

Version 2.0

Goals

Introduction

With this training, you will ...

- › get to know the **product segment machine vision** and the related **product family groups**
- › get to know **applications** of 2D and 3D machine vision
- › learn about the **technical aspects** behind 2D and 3D machine vision
- › get to know the **portfolio overview** of machine vision



Whenever you see this icon, please watch this slide in presentation mode (either press "Shift + F5" or click the  icon in the lower right corner).

Version 2.0 | Machine vision | Portfolio overview | Basic

< 2 >

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- › **Introduction of Machine vision sensors**
- › Applications of 2D Machine vision sensors
- › Applications of 3D Machine vision sensors
- › Technical Aspects of 2D Machine vision sensors
- › Technical Aspects of 3D Machine vision sensors
- › Portfolio Overview Machine vision sensors



Machine vision

When to use vision systems?



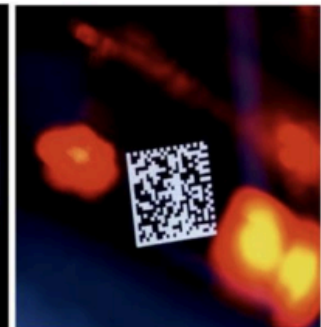
Where?



OK?



How large?



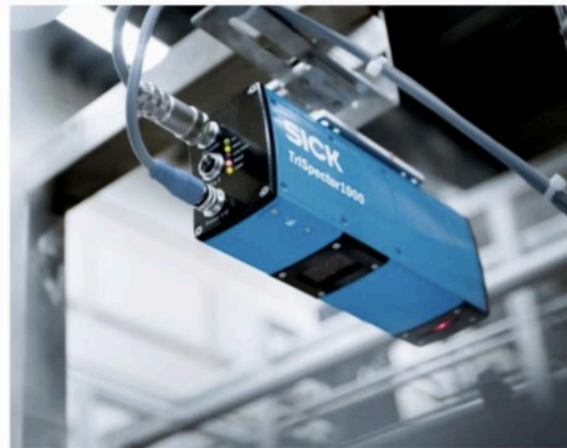
What?

And any combination of these tasks

Machine vision sensors



2D Machine vision



3D Machine vision

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- › Applications of 3D Machine vision sensors
- › Technical Aspects of 2D Machine vision sensors
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- › Portfolio Overview Machine vision sensors



2D Machine Vision

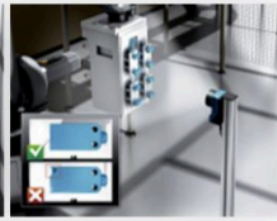
Applications



Identification and AI classification of objects



Robot guidance



Quality inspection of shapes



Label checking

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3D Machine Vision

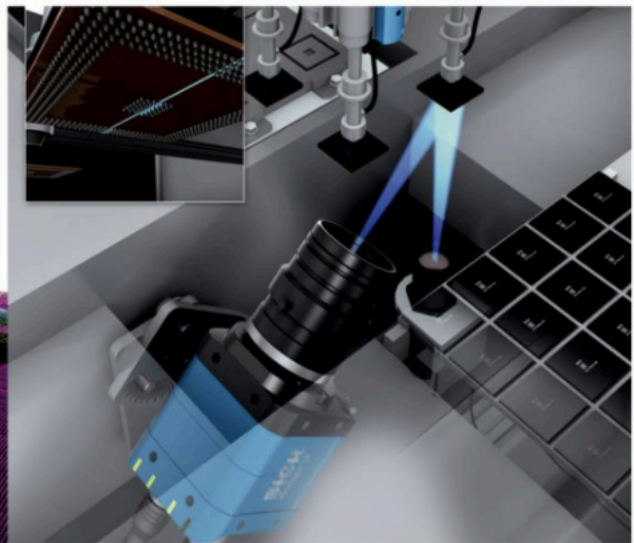
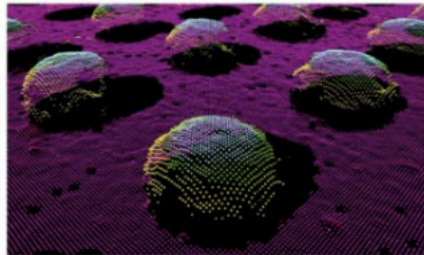
Application: Quality control in electronics industry

Application

- › Quality control of electronic components
 - 3D profile for shape control and measurement

Solution

- › Ranger3



3D Machine Vision

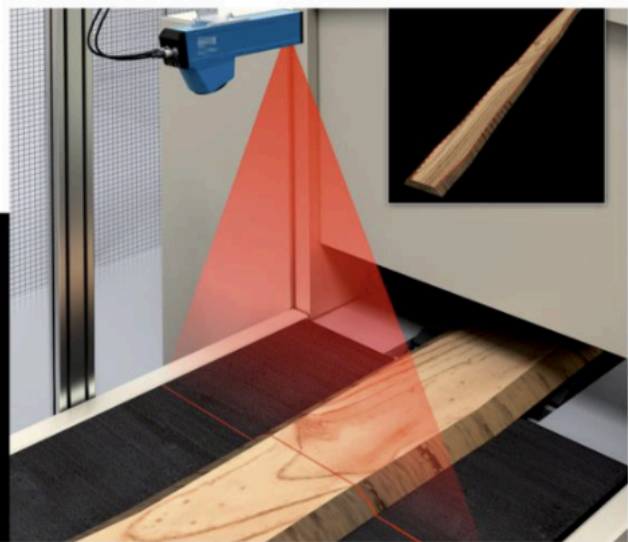
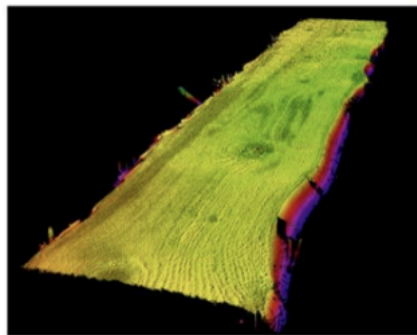
Application: Analysis wood industry

Application

- › Quality control and automatic cutting of logs and boards
 - 3D profile for shape control and measurement
 - Remission and scattered light data for detection of knots, discolorations, etc.

Solution

- › Ruler3000



3D Machine Vision

Application: Anti collision

Application

- › Anti-collision for autonomous vehicles
 - Monitoring of the complete 3D space in front of the vehicle

Solution

- › Visionary-T Mini



Contents

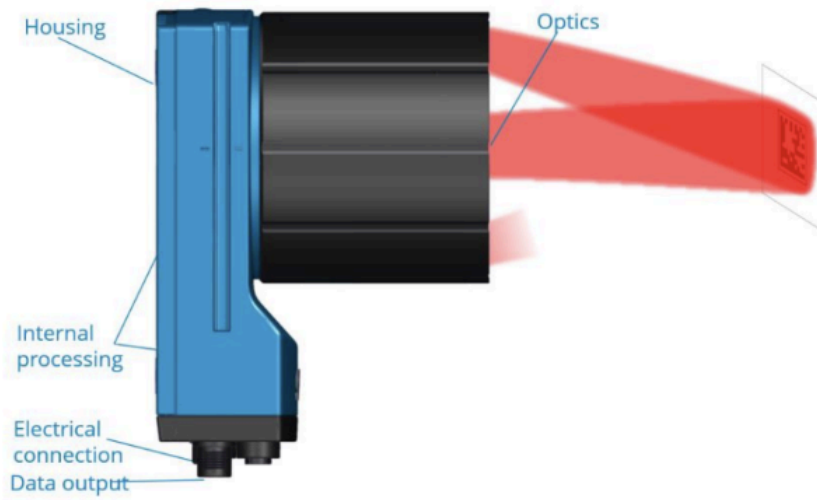
Introduction

- › Introduction of Machine vision sensors
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- › Applications of 3D Machine vision sensors
- › **Technical Aspects of 2D Machine vision sensors**
- › Technical Aspects of 3D Machine vision sensors
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2D Machine Vision

Technology



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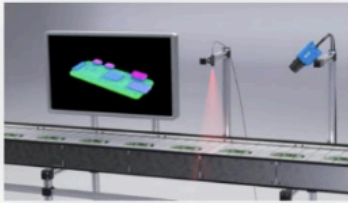
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- › **Technical Aspects of 3D Machine vision sensors**
- › Portfolio Overview Machine vision sensors

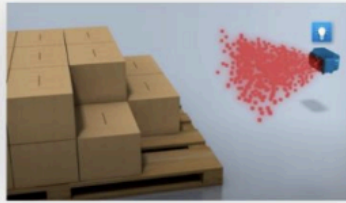


3D Machine Vision

3D Technologies



Laser triangulation



Time-of-flight (ToF)

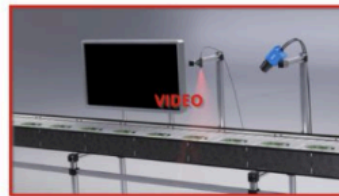


Stereo (Active und passive)

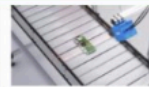
3D Machine Vision

Laser Triangulation

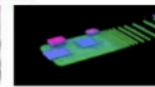
- › Very high resolution and accuracy
- › Light source: laser line
- › No need for ambient light
- › Relatively short measuring range
- › Shadowing possible if the laser is hidden behind an object
- › Movement required



› A laser line is projected onto the object.



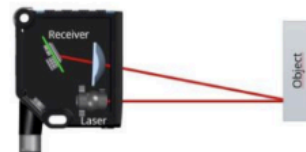
› The height profile is captured by the camera.



› By moving, several height Profiles are captured, resulting in a 3D image.

Functional principle

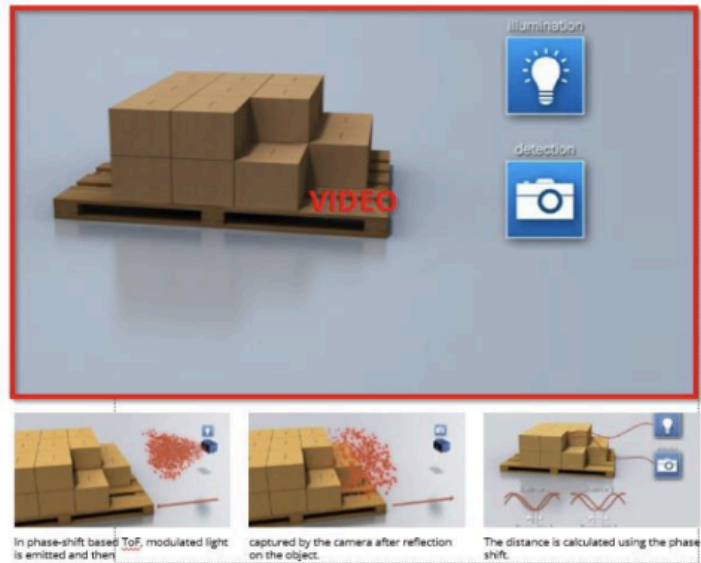
- › A laser line is projected onto an object to be measured
- › The reflection/scattering is projected onto a light-sensitive element
- › Depending on the position of the light spot and the known geometry of the sensor optics, the distance is calculated



3D Machine Vision

Time-of-flight (ToF)

- › Medium resolution and accuracy
- › Light source: Amplitude modulated IR light
- › No need for ambient light
- › Wide measuring range
- › 3D snapshot technology: no moving parts, works in stationary applications



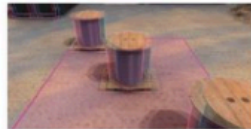
3D Machine vision

Stereo

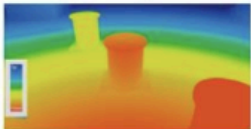
1. Acquisition of two images from slightly different perspectives.



2. The two images are superimposed.



3. An image with depth information is created.



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- › **Portfolio Overview Machine vision sensors**



2D Machine vision

Portfolio Overview



- › Inspector8xx
- › InspectorP6xx
- › Inspector
- › InspectorP Rack Fine Positioning



- › picoCam
- › picoCam2
- › midiCam
- › midiCam2

3D Machine vision

Portfolio Overview



› [TriSpector1000](#)



› [Ranger, Ranger 3](#)



› [ScanningRuler, Ruler3000](#)



› [Visionary-T Mini](#)



› [Visionary T](#)



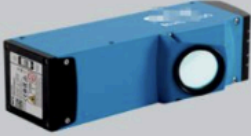
› [Visionary-B Two](#)



› [Visionary S](#)

Portfolio Overview Machine vision

Machine vision

3D	 › Trispector	 › Ranger	 › Ruler	 › Visionary B Two	 › Visionary T-Mini
	Laser Triangulation			Stereo (Active&Passive)	ToF
2D	 › Inspector	 › picoCam			



Thank you for your attention!

E. Designed Material: Control Condition

Please note that pages have been zoomed out to 67% for overview purposes.

Lesson 1 of 12

Experiment Information

15 15 E-Learning Author

Thank you for helping out with my thesis! 🙏

Purpose of the study: My thesis focuses on analyzing how self-study material can be made more user-friendly and how knowledge transfer can be maximized. This experiment tests if applying a few selected cognitive principles can improve knowledge retention from a selected training material, which covers machine vision, products, technologies, and applications.

Participation: Participation in this experiment is anonymous in terms of that your answers will not be linked to your identity. The focus of evaluation is the material, not you! Participation is voluntary, and you can stop at any time.

In this experiment, you will:

- 1 Complete a survey
- 2 Go through a self-study material at your own pace
- 3 Complete a survey again

Time: This experiment is expected to take a total time of 30-45 minutes. Please complete all steps at one time and sit alone your usual office environment or at home, with minimum distractions.

Guidance: All instructions will be provided in this e-learning page, including links to the questionnaire where you will complete the tests. Simply click forward to continue and instructions will be given at each step of the way!

You can click on the menu symbol (☰) in the top left corner to hide the side menu

Contact: For any questions, contact me through Webex (Linnéa Edén) or email (linnea.eden@e)

🟢 By clicking "Start Experiment" below, you agree that you have understood the purpose of this study, what you will do in it, and give your consent to participate in it:

Pre-Test

15 1.5 E-Learning Author

Instructions

You will now receive a link to a survey designed to test your initial knowledge of machine vision and SICK's products. Complete this test **before** looking at the training.

- You will be asked to enter a name to access the survey
- Do **not** use your real name
- Please choose a **word** or **code** that is unique (e.g. favorite movie character? or restaurant?)
- **Remember** it! It is important you use the **same word** or **code** for both the pre and post test. This will help me match your answers, while keeping everything anonymous! 😊

UNDERSTOOD

Click the **link below** to take the test.

Once you've completed it, **return to this page** and click 'Continue' to proceed with the training



[Start the test here!](#)

CONTINUE TO THE TRAINING

Training Overview

15 1.5 E-Learning Author



Goals

With this training, you will ...

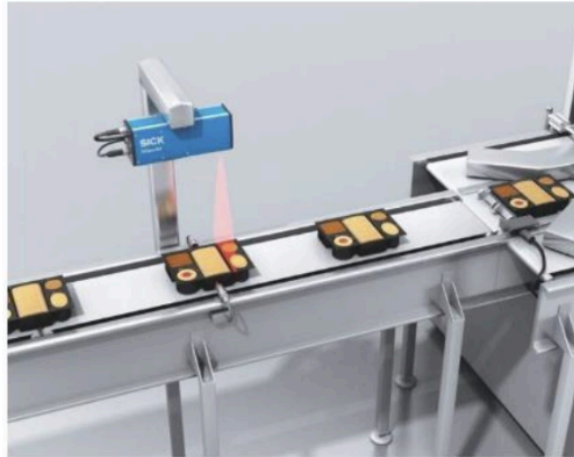
- get to know the **portfolio overview** of machine vision
- learn about what **machine vision** is
- get to know the **applications** of 2D and 3D machine vision cameras
- learn about the **technical aspects** behind the cameras

I'M READY

Introduction to Machine Vision

15 15 E-Learning Author

What is Machine Vision?



Machine Vision is a technology that enables systems to **see**, **understand** and **act** based on visual information from the environment.

It refers to the entire process of **capturing** an image, **processing** and **analyzing** that image and using the results to **perform** specific tasks.

Why is Machine Vision used?

Machine Vision is used in many different industries to **automate** inspection and analysis.

It helps automated systems **answer** practical questions such as:



Where?



OK?



Size?



What?

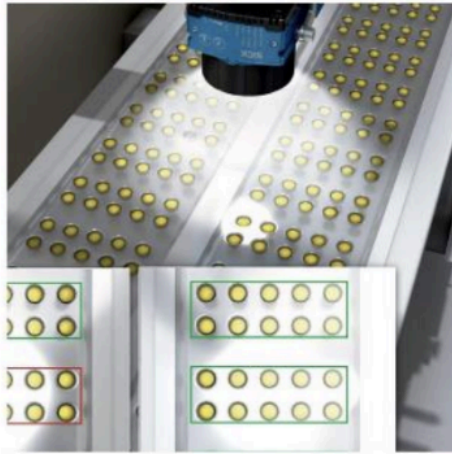
Or any **combination** of these tasks.

CONTINUE

Machine Vision Sensors

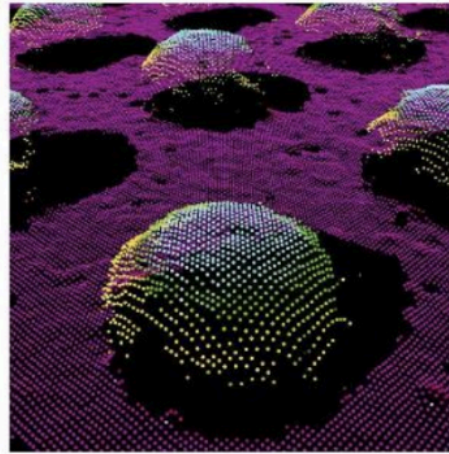
Machine Vision systems typically use **vision sensors**, or **cameras**, to capture images.

There are two main types of vision sensors:



2D sensors

Collects **light intensity data** in each pixel, producing a **flat**, two-dimensional image with **height** and **width** information - similar to your normal smartphone.



3D sensors

Collects height, width **and depth** information to create a three-dimensional model - like we see the world through our eyes.

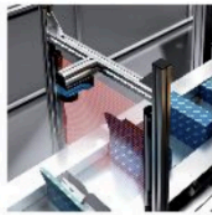
CONTINUE

2D Applications

15 1.5 E-Learning Author

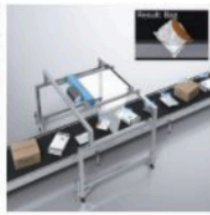
What can 2D cameras be used for?

2D cameras are suitable when you need information that can be captured from **flat surfaces** in good **lighting conditions**.



Presence Inspection

Ensuring objects are present, in the correct position or amount



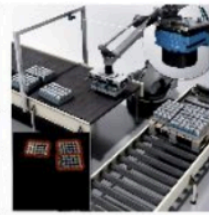
Identify & Classify

Identifying objects and labeling them



Quality control

Detecting defective goods



Robot guidance

Locating objects for robots to pick

CONTINUE

3D Applications

15 1.5 E-Learning Author

What can 3D cameras be used for?

3D technology is suitable when you need information about **measurements, shape, volume, height, distances** and **precise details** - even with poor lighting conditions.

EXPLORE APPLICATIONS

High-Speed Inspection in Rail Industry

Application

- Camera mounted on the train performs **high-precision inspections** of rail tracks at **high-speed** in outdoor, challenging conditions

Solution

- Ranger3
 - Fast and precise **customizable** inspection in complex, high-speed applications



CONTINUE

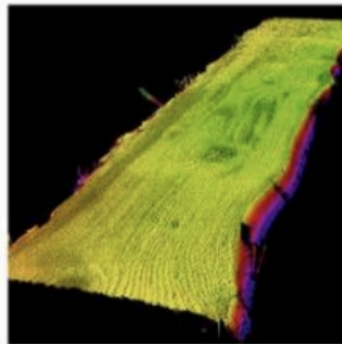
Quality Analysis & Board Cutting in Wood Industry

Application

- **Detect defects** and **measure** the boards shape and dimensions to help decide how to cut the board to get the most usable wood

Solution

- Ruler3000
 - Precise **measurements** and detailed **quality analysis**



CONTINUE

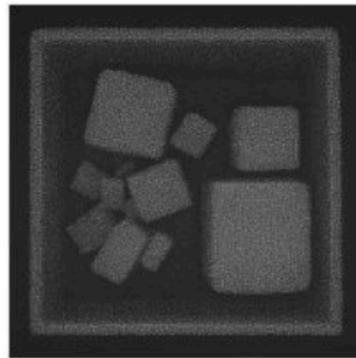
Fill Level Monitoring in Logistics Industry

Application

- **Detects presence** and **measures volume** of items in a container. Sends a signal when full to trigger container change

Solution

- Visionary-T Mini
 - Fast scanning and reliable **volume detection** in static scenes



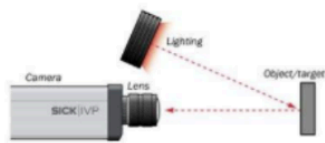
CONTINUE

2D Technology

15 1.5 E-Learning Author

How does a 2D camera work?

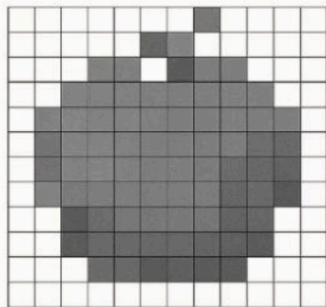
A 2D camera is essentially a "regular" camera that works on **optical principles**:



Light is **projected** onto an object and **reflects back** toward the camera.



The **reflected light** (shaped by an object's color, texture, and material) is focused by a **lens** onto the camera's **sensor**.



The sensor is made up of a grid of tiny squares called **pixels**. Each pixel captures how much light hits that spot.



The light values are turned into **digital data**, which together form a flat, two-dimensional image

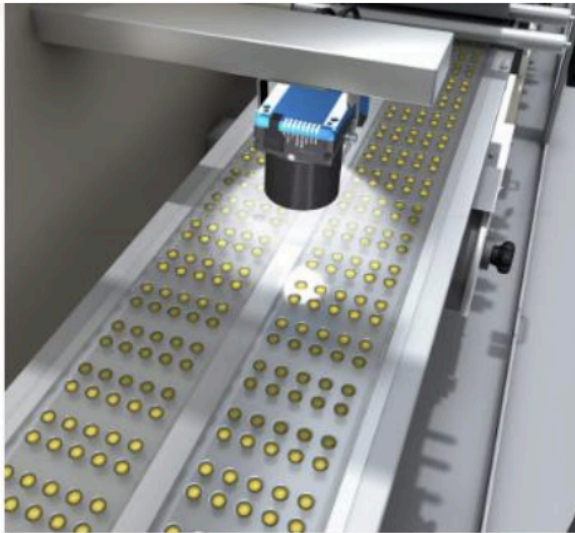
SICK's 2D cameras

SICK have **streaming cameras**, that capture images and sends them to a computer or other another processing unit for image processing, and **smart 2D cameras**, that capture images and can perform image processing directly **on-device**.

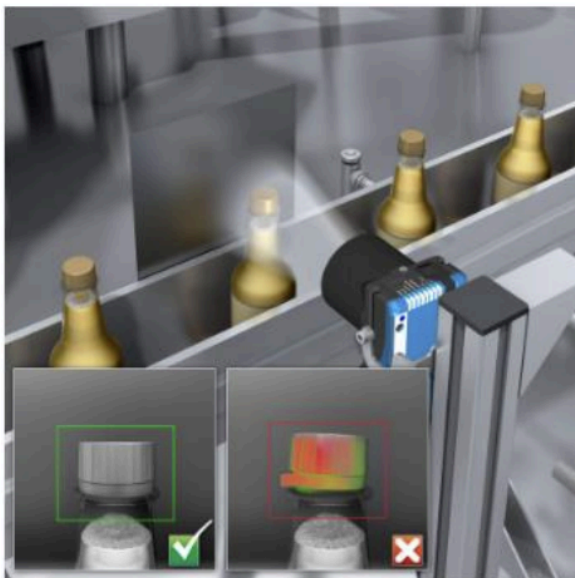
Integration of 2D smart camera in automated systems



The camera connects to a computer with software (SICK Nova) that lets you **configure** how the camera should operate



Once everything is set up, the camera can **run by itself** and be integrated into the system



The visual data captured is **processed** and **analyzed** in real time on-device



Based on the image analysis, the camera can **send out signals** (like OK or Not OK) to the rest of the **system** to perform actions based on this information

CONTINUE

3D Technologies

15 1.5 E-Learning Author

How does 3D cameras work?

Three main technologies can be used to **produce** 3D images

- 1 Laser Triangulation
- 2 Time-of-flight
- 3 Stereo (Active or Passive)

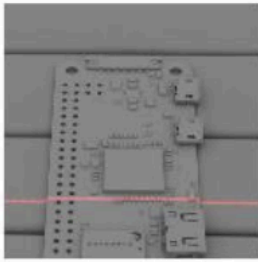
EXPLORE 3D TECHNOLOGIES

Laser Triangulation

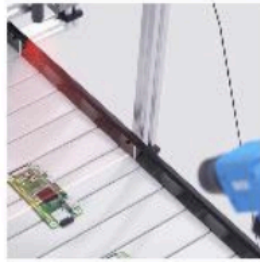
Features

- Very **high resolution** and **accuracy**
- Uses a **laser line** to illuminate the object
- Works **without external lighting**
- The **measuring range** is relatively short
- The laser can be **hidden** behind an object, causing missing data
- Requires that the object to be captured is **moving**

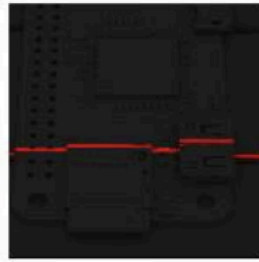




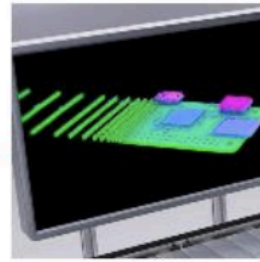
A laser line is **projected** onto an object. The line bends and changes shape depending on the surface



A camera, placed at an angle, **captures** how the line moves on the object



Based on how the laser line **shifts** and the known angles between the laser, camera, and object, the system calculates the height of each point on the surface - creating a **height profile**



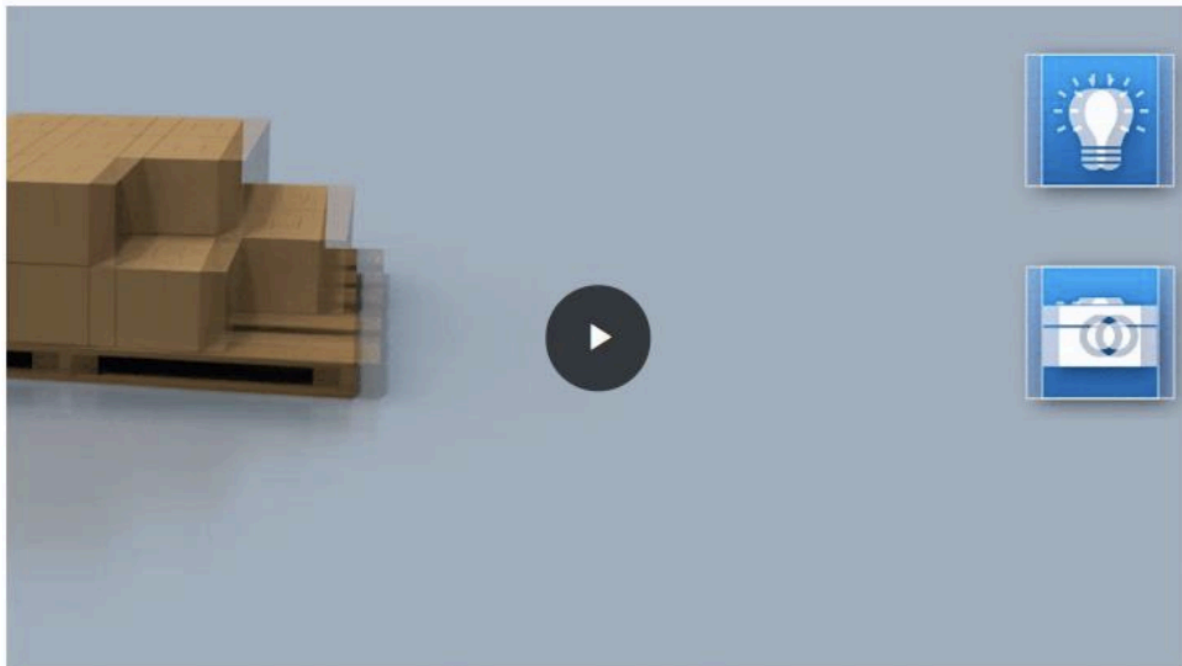
As the object moves, **multiple height profiles** are collected and turned into a 3D image

CONTINUE

Time-of-Flight (ToF)

Features

- **Medium resolution** and **accuracy**
- Uses **infrared light** to illuminate the object
- Works **without** external lighting
- **Wide measuring** range
- **No movement** of object needed
- No color image



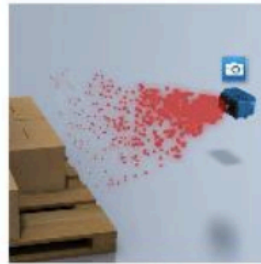
Functional principle



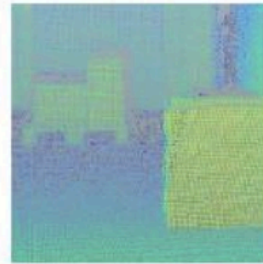
The camera takes a 2D picture and **sends out** bursts of wavy infrared light



When the light hits objects in the scene, it is **reflected back** to the camera



The camera calculates distance by **comparing the shift** in the **returning** wave to the **original** wave. The farther the light travels, the more the wave shifts



Distance is mapped to every pixel of the image, creating an image with depth information

CONTINUE

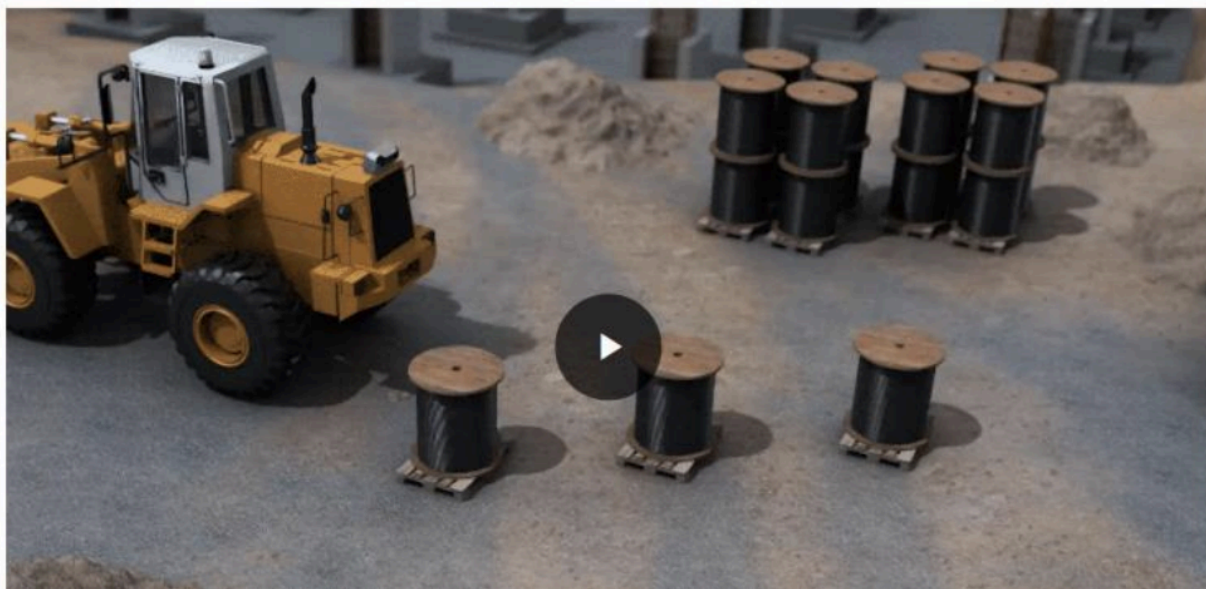
Stereo

Features

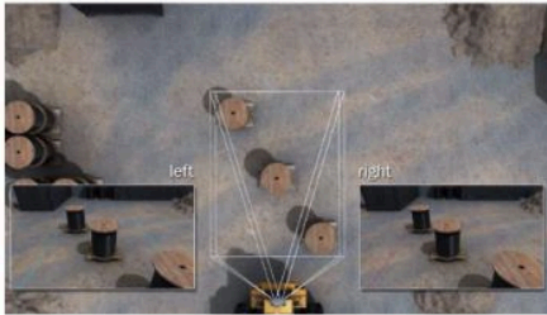
- **Medium resolution and accuracy**
- **Large measurement range**
- Provides depth images in **color**
- **No movement** of object needed

Passive vs Active Stereo Technology

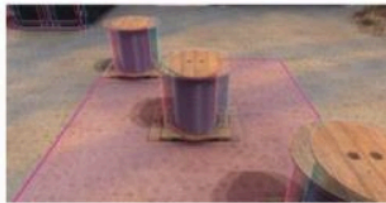
- **Passive stereo** uses only the light already in the scene, making it ideal for bright areas like outdoors
- **Active stereo** uses camera built-in lightning and projects this light to see better, making it ideal for dark scenes with low contrast like indoor settings



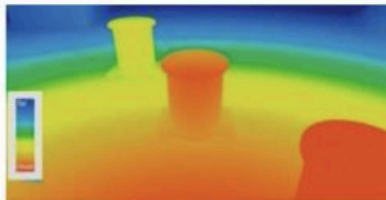
Functional principle



Two lenses take images of the same scene from slightly **different angles**

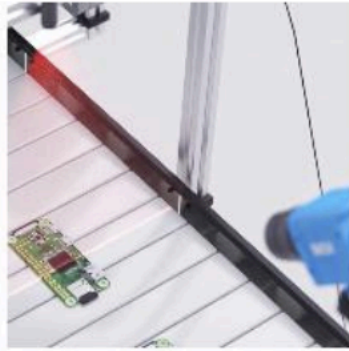


The camera compares the two images to see how much objects **shift** between the two views. *Like our brain compares views from the eyes.*

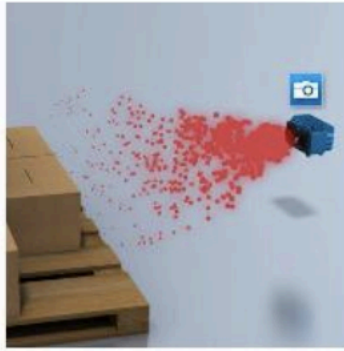


The shift is used to **calculate** distance as a closer object shifts more than a distant object. An image with depth information is created:

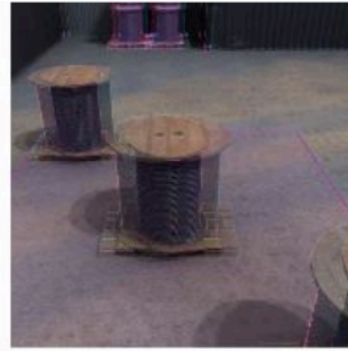
Comparison of 3D Technology



Laser triangulation
Fine detail & high precision



Time of Flight
Fast detection in large and static scenes



Stereo
Detailed detection in static and colorful scenes

CONTINUE

Portfolio Overview

15 1.5 E-Learning Author

2D Machine Vision



Inspector series

- **Inspector8xx**
 - High-performance 2D smart camera for fast inspections
- **InspectorP6xx**
 - Smart 2D camera available in compact or high-resolution variants



Pico & Midi series

- **picocam2**
 - Compact industrial 2D streaming camera
- **midicam2**
 - Flexible high-resolution 2D streaming camera

CONTINUE

3D Machine Vision



TriSpector1000

Easy-to-use smart 3D camera for simple tasks



Ranger3

Flexible and customizable 3D streaming camera designed for complex tasks



Ruler3000

All-in-one smart 3D camera, ready and simple to use with everything built in



Visionary-T Mini

Compact 3D camera for fast detection of static scenes in tight spaces



Visionary B-Two

Passive 3D camera for detection and recognition in outdoor, static scenes - using depth and **color**



Visionary-S

Active 3D camera with built-in lighting for detailed object recognition in static scenes, using depth and **color**

CONTINUE

Machine Vision Portfolio Overview



CONTINUE

Thank you for your attention!

This is the end of the training material - click "Continue" to proceed to the post-test 

CONTINUE

Lesson 12 of 12

Post-Test

15 1.5 E-Learning Author

You will now receive a link to a survey designed to test your **current** knowledge level of machine vision and SICK's products. This is the **last step** of the experiment!

- Returning to the training material is not permitted while taking the test.
- When asked to type your name, use the **exact same word** or **code** that you entered in the pre-test!

UNDERSTOOD

Click the **link below** to take the test.

Once you've completed it, **return to this page** and click 'Finish' to finalize the experiment 

[Start the test here!](#)

FINISH

Thank you for your participation!

Thank you so much for your time and contribution to this study. You did a fantastic job! 😊 You can now close this page and enjoy the rest of your day.

The results from this experiment will be used for my master thesis and shared with the company, ensuring complete anonymity.

If you're interested in the results or have any questions about the study, feel free to contact me at linnea.eden@ 

F. Designed Material: Experimental Condition

Please note that pages have been zoomed out to 67% for overview purposes.

Lesson 1 of 12

Experiment Information

15 1.5 E-Learning Author

Thank you for helping out with my thesis! 🍷

Purpose of the study: My thesis focuses on analyzing how [redacted] self-study material can be made more user-friendly and how knowledge transfer can be maximized. This experiment tests if applying a few selected cognitive principles can improve knowledge retention from a selected training material, which covers machine vision, [redacted] products, technologies, and applications.

Participation: Participation in this experiment is anonymous in terms of that your answers will not be linked to your identity. The focus of evaluation is the material, not you! Participation is voluntary, and you can stop at any time.

In this experiment, you will:

- 1 Complete a survey
- 2 Go through a self-study material at your own pace
- 3 Complete a survey again

Time: This experiment is expected to take a total time of 30-45 minutes. Please complete all steps at one time and sit alone your usual office environment or at home, with minimum distractions.

Guidance: All instructions will be provided in this e-learning page, including links to the questionnaire where you will complete the tests. Simply click forward to continue and instructions will be given at each step of the way!

You can click on the menu symbol (☰) in the top left corner to hide the side menu

Contact: For any questions, contact me through Webex (Linnéa Edén) or email (linnea.eden@[redacted].se)

🟢 By clicking "Start Experiment" below, you agree that you have understood the purpose of this study, what you will do in it, and give your consent to participate in it:

Pre-Test

15 1.5 E-Learning Author

Instructions

You will now receive a link to a survey designed to test your initial knowledge of machine vision and SICK's products. Complete this test **before** looking at the training.

- You will be asked to enter a name to access the survey
- Do **not** use your real name
- Please choose a **word** or **code** that is unique (e.g. favorite movie character? or restaurant?)
- **Remember** it! It is important you use the **same word** or **code** for both the pre and post test. This will help me match your answers, while keeping everything anonymous! 😊

UNDERSTOOD

Click the **link below** to take the test.

Once you've completed it, **return to this page** and click 'Continue' to proceed with the training



[Start the test here!](#)

CONTINUE TO THE TRAINING

Training Overview

15 1 S E-Learning Author



Goals

In this training, you will...

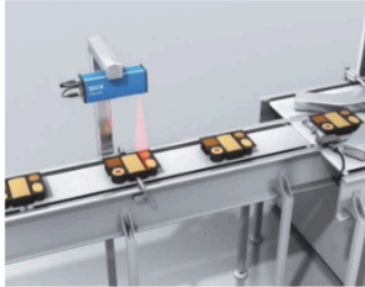
- learn about what **machine vision** is
- get to know the **SICK portfolio overview** of machine vision
- learn about the **technical aspects** behind 2D and 3D cameras
- get to know the **applications** of the cameras

I'M READY

Introduction to Machine Vision

15 1.5 E-Learning Author

What is Machine Vision?



Machine Vision is a technology that enables systems to **see**, **understand** and **act** based on visual information from the environment.

Machine Vision technology refers to the entire **process** of:

- 1 **Capturing** an image
- 2 **Processing** and **analyzing** the image
- 3 Use the results to **perform** specific tasks

CONTINUE

Why is Machine Vision used?

Machine Vision is used in many different industries to **automate** inspection and analysis.

It helps automated systems **answer** practical questions such as:



Where?



What?



Size?



OK?

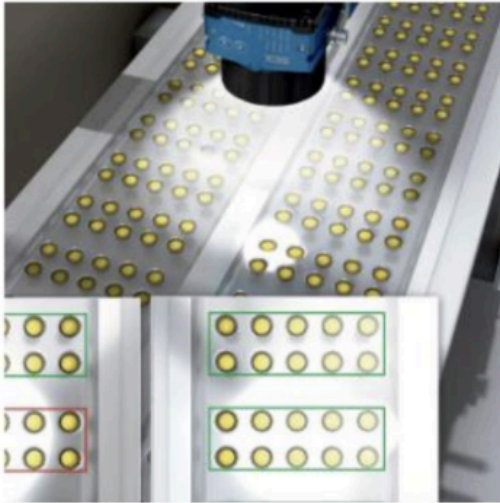
Or any **combination** of these tasks.

CONTINUE

Machine Vision Sensors

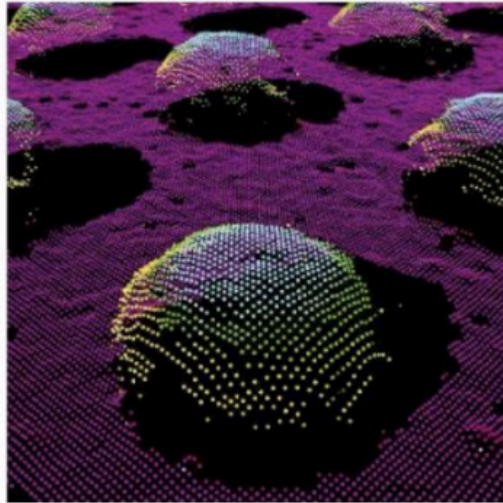
Machine Vision systems use **vision sensors**, or cameras, to capture images.

There are **two** main types of vision sensors:



2D sensors

- Collects light intensity data in each pixel, producing a flat, two-dimensional image with **height** and **width** information
- Similar to your normal smartphone camera

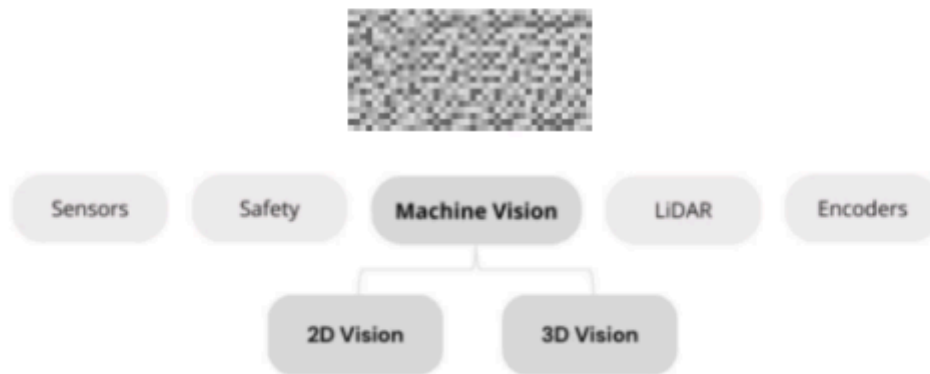


3D sensors

- Collects height, width **and** depth information to create a three-dimensional model
- Like we see the world through our eyes

CONTINUE

Machine Vision at



CONTINUE

2D Technology

15 1.5 E-Learning Author

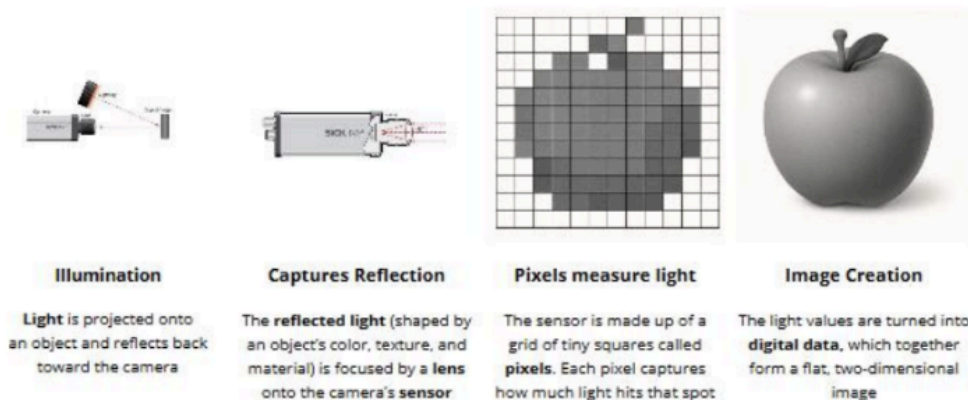
SICK's 2D cameras

SICK offers **streaming 2D cameras** and **smart 2D cameras**.

- A **streaming camera** capture images and sends them to a computer or another processing unit for image processing
- A **smart camera** capture images and perform image processing directly **on-device**

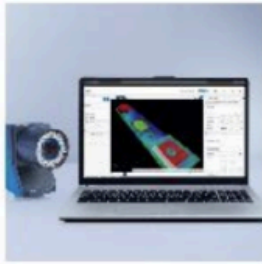
How does a 2D camera work?

A 2D camera is essentially a "regular" camera that works on **optical principles**:



CONTINUE

Integration of 2D smart camera in automated systems



Setup

The camera connects to a computer with software (SICK Nova) that lets you **configure** how the camera should operate

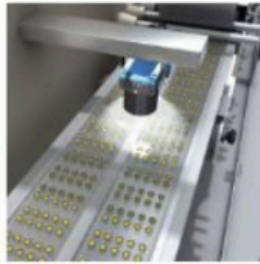


Image Capture

Once everything is set up, the camera can run **by itself** and be integrated into the system



Internal Processing

The visual data captured is **processed** and **analyzed** in real time on-device



Result

Based on the image analysis, the camera can **send out signals** (like OK or Not OK) to the rest of the **system** to perform actions based on this information

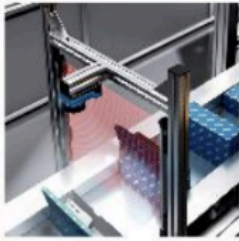
CONTINUE

2D Applications

15 1.5 E-Learning Author

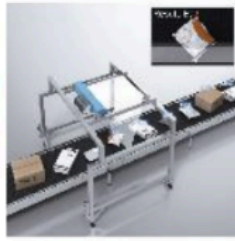
What can 2D cameras be used for?

2D cameras are suitable when you need information that can be captured from **flat surfaces** in good **lighting conditions**.



Presence Inspection

Ensuring objects are present, in the correct position or amount.



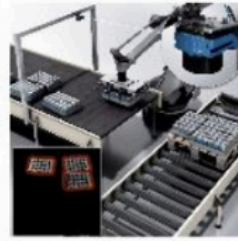
Identify & Classify

Identifying objects and labeling them



Quality control

Detecting defective goods



Robot guidance

Locating objects for robots to pick

CONTINUE

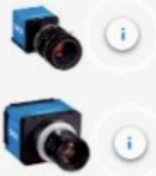
2D Portfolio

15 1.5 E-Learning Author

2D VISION

Streaming Cameras

pico & midi series



Smart Cameras

Inspector series



* Click on the "i" for more information about each camera

CONTINUE

3D Technologies

15 1.5 E-Learning Author

How does 3D cameras work?

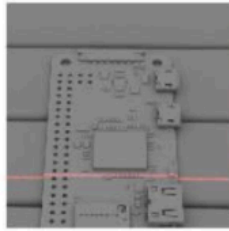
Three main technologies can be used to **produce** 3D images

- 1 Laser Triangulation
- 2 Time-of-Flight
- 3 Stereo (Passive or Active)

EXPLORE 3D TECHNOLOGIES

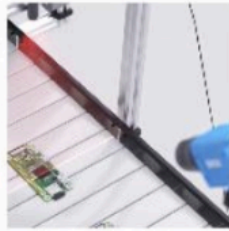
Laser Triangulation

Functional principle



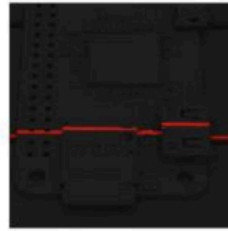
Laser line

A laser line is **projected** onto an object. The line bends and changes shape depending on the surface



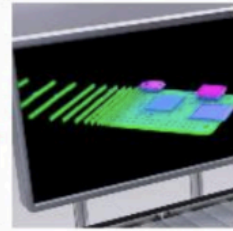
Reflection

A camera, placed at an angle, **captures** how the line moves on the object



Triangulation

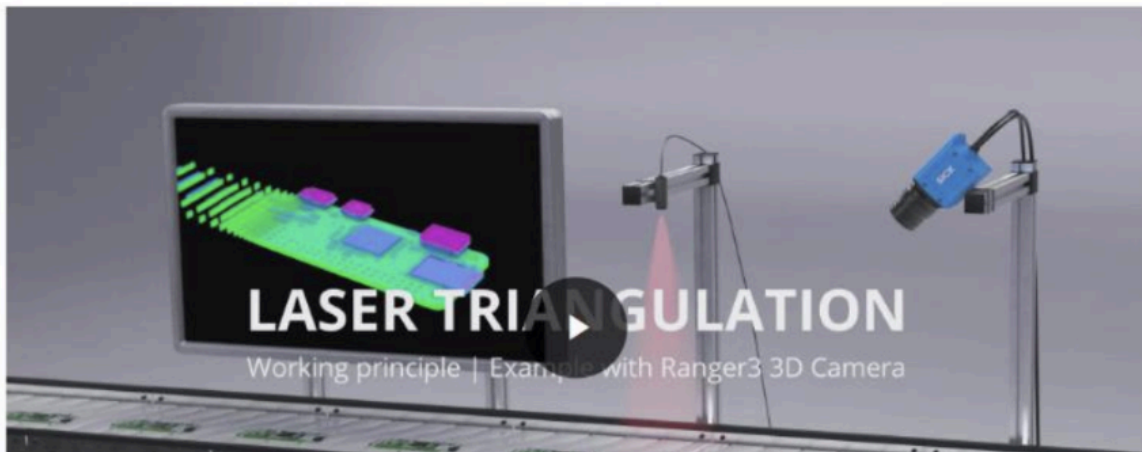
Based on how the laser line **shifts** and the known angles between the laser, camera, and object, the system calculates the height of each point on the surface - creating a **height profile**



Height profiles

As the object moves, **multiple height profiles** are collected and turned into a 3D image

Video demonstration



Features

- Uses a **laser line** to illuminate the object
- Works **without external lighting**
- Very **high resolution** and **accuracy**
- The **measuring range** is relatively short
- The laser can be **hidden** behind an object, causing missing data
- Requires that the object to be captured is **moving**

CONTINUE

🕒 Time-of-Flight (ToF)

Functional principle



Light sent out

The camera takes a 2D picture and **sends out** bursts of wavy infrared light



Reflection

When the light hits objects in the scene, it is **reflected back** to the camera



Light travels back

The camera calculates distance by **comparing the shift** in the **returning wave** to the **original wave**. The farther the light travels, the more the wave shifts



Mapping Distance

Distance is mapped to every pixel of the image, creating an image with depth information

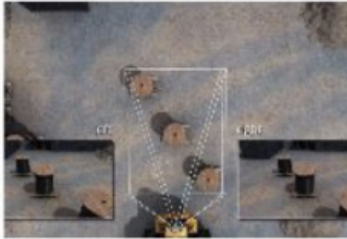
Features

- Uses **infrared light** to illuminate the object
- Works **without** external lighting
- **Wide measuring range**
- **No movement** of object needed
- **Medium resolution and accuracy**

CONTINUE

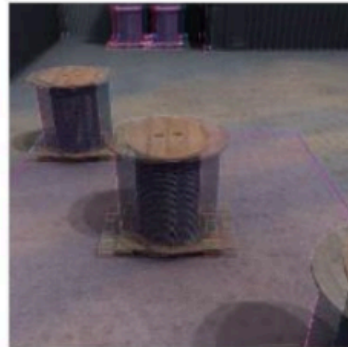
Stereo

Functional principle



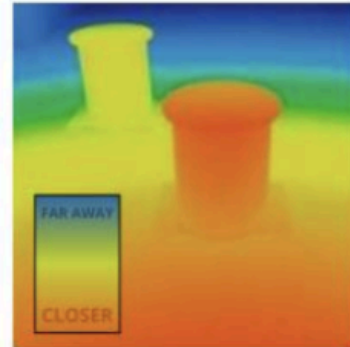
Capture two images

Two lenses take images of the same scene from slightly **different angles**



Compare

The camera compares the two images to see how much objects **shift** between the two views.
Like our brain compares views from the eyes.



Calculate Distance

The shift is used to **calculate** distance as a closer object shifts more than a distant object.
An image with depth information is created.

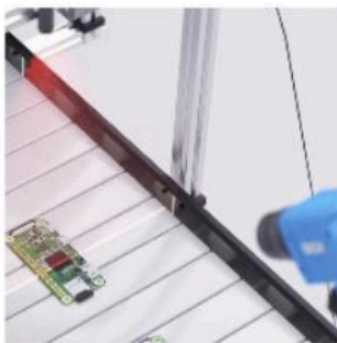
Passive vs Active Stereo Technology

 Passive Stereo	 Active Stereo
• Uses only the light already in the scene • Ideal for bright areas like outdoors	• The camera have built-in lighting and projects this light to see better • Ideal for low-contrast or dark scenes like indoor settings
Passive - does not add any light	Active - actively adds light

Features

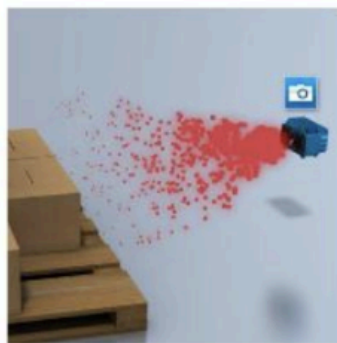
- Large measurement range
- Provides depth images in **color**
- No movement of object needed
- Medium resolution and accuracy

Comparison of 3D Technology



Laser triangulation

Fine detail and high precision for moving objects



Time of Flight

Fast detection in large and static scenes



Stereo

Detailed detection in static and colorful scenes

CONTINUE

3D Portfolio

15 1.5 E-Learning Author

3D VISION

Laser Triangulation



Time-Of-Flight



Stereo



* Click on the "i" for more information about each camera

CONTINUE

3D Applications

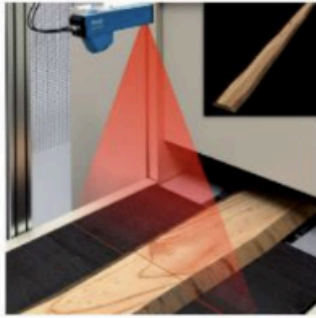
15 1.5 E-Learning Author

What can 3D cameras be used for?

3D technology is suitable when you need information about **measurements, shape, volume, height, distances** and **precise details** - even with poor lighting conditions.

EXPLORE APPLICATIONS

Quality Analysis & Board Cutting in Wood Industry



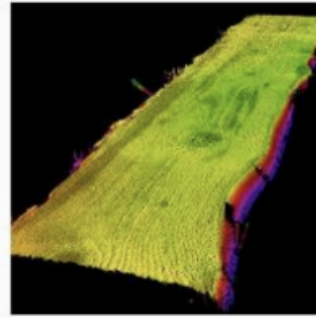
Application

Detect defects and **measure** the boards shape and dimensions to help decide how to cut the board to get the most usable wood



Solution: Ruler3000

Precise measurements and detailed analysis

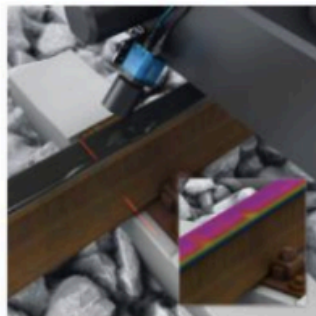


Data Output

Shows shape and surface flaws such as knots and discolorations

CONTINUE

High-Speed Inspection in Rail Industry



Application

Camera mounted on the train performs **high-precision inspections** of rail tracks at **high speed** in outdoor, challenging conditions



Solution: Ranger3

Fast and precise **customizable** inspection in complex, high-speed applications



Data Output

Depth map shows tiny defects and dimensional differences

CONTINUE

Fill Level Monitoring in Logistics Industry



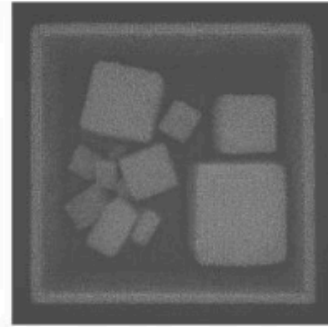
Application

Detects presence and measures volume of items in a container. Sends a signal when full to trigger container change



Solution: Visionary-T Mini

Fast scanning and reliable volume detection in static scenes



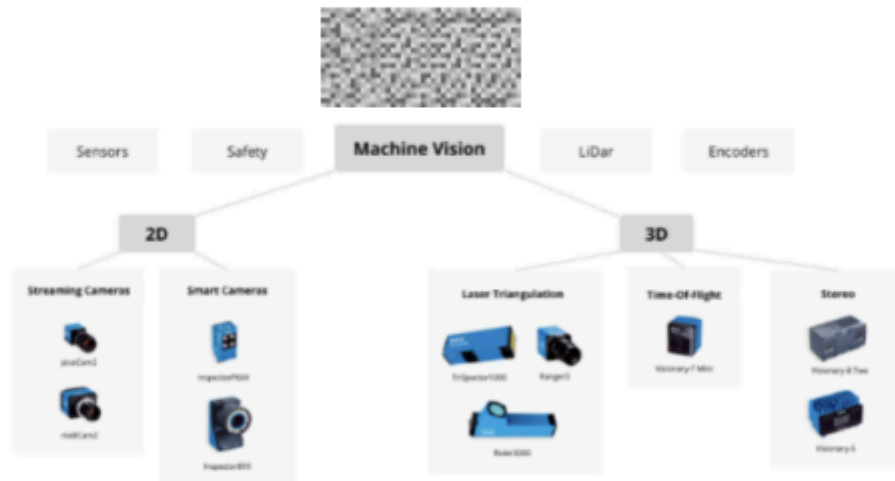
Data Output

Depth map of the scene

CONTINUE

Portfolio Overview

15 1.5 E-Learning Author



CONTINUE

Thank you for your attention!

This is the end of the training material - click "Continue" to proceed to the post-test 

CONTINUE

Lesson 12 of 12

Post-Test

15 1.5 E-Learning Author

You will now receive a link to a survey designed to test your **current** knowledge level of machine vision and SICK's products. This is the **last step** of the experiment!

-  Returning to the training material is not permitted while taking the test.
-  When asked to type your name, use the **exact same word** or **code** that you entered in the pre-test!

UNDERSTOOD

Click the **link below** to take the test.

Once you've completed it, **return to this page** and click 'Finish' to finalize the experiment 

[Start the test here!](#)

FINISH

Thank you for your participation!

Thank you so much for your time and contribution to this study. You did a fantastic job! 🥳 You can now close this page and enjoy the rest of your day.

The results from this experiment will be used for my master thesis and shared with the company, ensuring complete anonymity.

If you're interested in the results or have any questions about the study, feel free to contact me at linnea.eden@ 

G. Key Differences: Control vs. Experimental Condition

Summary of instructional design differences between the baseline and experimental conditions, focused on improving information presentation and reducing cognitive load.

Category	Control Material	Experimental Material
Independent Variable	—	Presentation of information (order, layout, segmentation, text-image integration)
Content Accuracy	Updated from original PowerPoint (outdated products corrected, more relevant applications, added basic explanations)	Same content as baseline
Order of Information	Introduction → 2D & 3D Applications → 2D & 3D Technology → Portfolio Overview	Introduction → Portfolio Overview → 2D Technology → 2D Portfolio → 2D Applications → 3D Technology → 3D Portfolio → 3D Applications → Portfolio Overview
Organization of 2D/3D	2D and 3D information interleaved	2D and 3D information separated
Portfolio Context	Portfolio overview only shown at end	Early portfolio overview in the introduction with visual hierarchy how machine vision fits into broader company portfolio 2D and 3D portfolio introduced separately after their technology sections Improved portfolio overview at the end with visual hierarchy better displaying relationships within the portfolio.
Presentation Layout	Text and images often separated; vertical and horizontal arrangement inconsistent	Text and images tightly integrated, horizontal reading flow maintained consistently
Order of information on page-level	e.g Where? OK? Size? What? Technology features before technology descriptions.	Where? What? Size? OK? Technology features after technology descriptions.
Text Structuring	Longer paragraphs	Text segmented into bullet points, shorter sentences, added subsection titles, added image explanations (e.g data output)
Visual Design	Informative images selected; redundant/irrelevant images replaced	Informative images selected and placed adjacent to corresponding text. Background removed in product images.
Signaling	Inconsistent use of bolding or cues	Consistent use of signaling (bolded keywords, clear titles for sections, colored concepts or bullet points)
Segmenting	Multiple concepts presented on the same slide	Information broken into smaller, segmented blocks to manage cognitive load
Visual Hierarchies	No visual hierarchies or summarizing visuals	Visual hierarchies added after introduction and in summary section showing relationships

Instructional Tone	Conversational, learner-friendly language to ease intrinsic load	Same text as baseline
Multimedia Enhancements	Cleaner, more informative visuals	Emojis used to reinforce concepts intuitively, videos edited or removed, color coordination of terms
Video Use	Included voice-over videos with abrupt endings + with text duplication	Only clear, informative videos used with no audio; redundant videos removed to reduce redundancy

H. Experiment Pre-Survey

Pre-Survey

1. Participation Information & Consent

This test will assess your knowledge of machine vision and [company name]'s machine vision portfolio before the training. It is not expected that you know the answers beforehand!

Participation is anonymous. Data will be exported and stored on a local server and deleted in June 2025. A summary of results from this study will be presented in the master thesis.

By clicking 'Yes' you agree that you have been informed of the purpose of the test, give your consent to participating in it and for your data to be collected:

- ☐ Yes
- ☐ No

2. What is your role?

- ☐ I work within [company name]
- ☐ I do not work with [company name]

3. What is your age?

- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65+

4. What is your gender?

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ I prefer not to say

5. Imagine you've installed a home security camera, but it's not working properly. You need to call tech support and explain the problem. How confident would you feel talking about the camera settings and follow their instructions to fix it?

- ☐ 1 - Not at all confident
- ☐ 2 - Slightly confident
- ☐ 3 - Moderately confident
- ☐ 4 - Very confident
- ☐ 5 - Extremely confident!

6. Q1: You're explaining machine vision to a friend. Which is the best description?

- ☐ It helps cameras zoom and store images
- ☐ It replaces sensors for navigation
- ☐ It lets machines see and act based on images ☒
- ☐ It adds security to production lines

7. Q2: Which task is machine vision well suited for?

- ☐ Measuring temperature of a part
- ☐ Finding the height and position of an object ☒

- ☐ Adjusting lightning in a warehouse
- ☐ Tracking staff movement in offices

8. Q3: Which of these is not a [company name] product?

- ☐ picoCam2
- ☐ Visionary-T Mini
- ☐ OptiScan3000 ☒
- ☐ Ruler3000

9. Q4: Which option best describes how a 2D camera captures an image?

- ☐ The lens captures a digital image and reflects it to the sensor
- ☐ Light hits the lens, is focused onto the sensor, and converted into digital signals ☒
- ☐ The sensor emits infrared light and detects distance
- ☐ The lens records depth by using a laser line

10. Q5: What makes a [company name] camera "smart"?

- ☐ It stores inspection data in the cloud
- ☐ It requires a computer for all processing
- ☐ It processes images and sends decisions without a computer or other processing unit ☒
- ☐ It rotates automatically to track objects

11. Q6: You want to detect missing cookies on a tray. Which camera is best?

- ☐ Visionary-T Mini
- ☐ Ranger3
- ☐ InspectorP6xx ☒
- ☐ Ruler3000

12. Q7: How does laser triangulation technology work?

- ☐ Measures time for laser to return
- ☐ Detects how much a laser line shifts on an objects surface ☒
- ☐ Uses two cameras for depth
- ☐ Scans with a laser grid

13. Q8: Scenario: Is 3D a good fit?

A packaging line needs to check label placement on flat boxes. Which camera type is the best fit, and why?

- ☐ 3D, because it gives more depth information
- ☐ 2D, because it gives high contrast and resolution for position checks ☒
- ☐ 3D, because it works better than 2D in general
- ☐ This task should be done by manual inspection

14. Q9: Which of the following statements best describes a 3D camera using stereo technology?

- ☐ It calculates depth by measuring how long light takes to return to the sensor
- ☐ It uses a rotating laser to scan objects from multiple angles
- ☐ It compares images from two perspectives to estimate distance ☒
- ☐ It projects a structured light pattern and analyzes deformation to estimate distance

15. Q10: Choose the best camera for this application

On a moving conveyor belt, packages come in many shapes and sizes. The goal is to measure their volume while they move. Which camera is the best fit?

- ☐ Visionary-T
- ☐ Inspector8xx
- ☒ Ruler3000
- ☐ Visionary-B Two

16. Q11: Choose the best camera for this application

A vision system checks the size and volume of black and white plastic parts before they are packed. The parts are stationary during inspection. Which camera is the best fit?

- ☐ Inspector8xx
- ☒ Visionary-T Mini
- ☐ Ruler3000
- ☐ picoCam2

17. Q12: Choose the best camera for this application

A company wants to inspect engine components on a production line in high-speed. The parts have complex shapes and reflective surfaces, and the setup requires customized optics and laser to capture accurate 3D data in a noisy industrial environment. Which camera fits best?

- ☐ Ruler3000
- ☒ Ranger3
- ☐ Visionary-B Two
- ☐ Visionary-T Mini

18. What time is it currently for you?

Please write the digital time in the format: XX:XX

This question is included in both the pre-test and post-test to measure time consumption.

19. That's it!

Please hand in the survey by pressing 'Send', then return to the previous page.

- ☐ Will do
- ☐ No

I. Experiment Post-Survey

Post-Survey

1. Participation Information & Consent

This test will assess your knowledge of machine vision and [company name]'s machine vision portfolio before the training. It is not expected that you know the answers beforehand!

Participation is anonymous. Data will be exported and stored on a local server and deleted in June 2025. A summary of results from this study will be presented in the master thesis.

By clicking 'Yes' you agree that you have been informed of the purpose of the test, give your consent to participating in it and for your data to be collected:

- ☐ Yes
☐ No

2. What time is it currently for you?

Please write the digital time in the format: XX:XX

This question is included in both the pre-test and post-test to measure time consumption.

3. Q1: You're explaining machine vision to a friend. Which is the best description?

- ☐ It helps cameras zoom and store images
☐ It replaces sensors for navigation
☒ It lets machines see and act based on images ✓
☐ It adds security to production lines

4. Q2: Which task is machine vision well suited for?

- ☐ Measuring temperature of a part
☒ Finding the height and position of an object ✓
☐ Adjusting lightning in a warehouse
☐ Tracking staff movement in offices

5. Q3: Which of these is not a [company name] product?

- ☐ picoCam2
☐ Visionary-T Mini
☒ OptiScan3000 ✓
☐ Ruler3000

6. Q4: Which option best describes how a 2D camera captures an image?

- ☐ The lens captures a digital image and reflects it to the sensor
☒ Light hits the lens, is focused onto the sensor, and converted into digital signals ✓
☐ The sensor emits infrared light and detects distance
☐ The lens records depth by using a laser line

7. Q5: What makes a [company name] camera "smart"?

- ☐ It stores inspection data in the cloud

- ☐ It requires a computer for all processing
- ☐ It processes images and sends decisions without a computer or other processing unit ☒
- ☐ It rotates automatically to track objects

8. Q6: You want to detect missing cookies on a tray. Which camera is best?

- ☐ Visionary-T Mini
- ☐ Ranger3
- ☐ InspectorP6xx ☒
- ☐ Ruler3000

9. Q7: How does laser triangulation technology work?

- ☐ Measures time for laser to return
- ☐ Detects how much a laser line shifts on an objects surface ☒
- ☐ Uses two cameras for depth
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- ☐ Ruler3000
- ☒ Ranger3
- ☐ Visionary-B Two
- ☐ Visionary-T Mini

15. Imagine a friend asks you what machine vision is and what kinds of machine vision products [company name] offers. How confident would you feel explaining this to them?

- ☐ 1 - Not at all confident
- ☐ 2 - Slightly confident
- ☐ 3 - Moderately confident
- ☐ 4 - Very confident
- ☐ 5 - Extremely confident!

16. How motivated did you feel to learn about machine vision and [company name] products during the training?

- ☐ 1 - Not at all motivated
- ☐ 2 - Slightly motivated
- ☐ 3 - Moderately motivated
- ☐ 4 - Very motivated
- ☐ 5 - Extremely motivated

17. The content and topic of the training was very complex

- ☐ 1 - I strongly disagree
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 - I strongly agree

18. The way the content was presented was confusing and difficult to follow

- ☐ 1 - I strongly disagree
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 - I strongly agree

19. I actively tried to make sense of the content and understand it

- ☐ 1 - I strongly disagree
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7 - I strongly agree

20. How much mental effort did this training require from you?

Mental effort refers to how hard you had to concentrate and think to understand the material.

- ☐ 1 - Very, very low mental effort
- ☐ 2 - Very low mental effort
- ☐ 3 - Low mental effort
- ☐ 4 - Rather low mental effort
- ☐ 5 - Neither low nor high mental effort
- ☐ 6 - Rather high mental effort
- ☐ 7 - High mental effort
- ☐ 8 - Very high mental effort
- ☐ 9 - Very, very high mental effort

19. That's it!

Please hand in the survey by pressing 'Send', then return to the previous page.

- ☐ Will do
- ☐ No

J. Post-Experiment Interview Guide

1. General impressions

- a. Can you tell me about your overall experience of going through the training?
- b. What stood out to you the most - either as something you liked or found challenging?

2. Prior knowledge & Intrinsic load

- a. Before this training, how was your familiarity with machine vision and [company name] portfolio?
 - i. Did you consider the topic itself to be easy or difficult?
- b. Was there any question in the post-test that you found particularly difficult to answer?

3. Schema construction: Understanding

- a. Was it clear to you how the different parts, like technology, products and applications, were connected?
- b. Was there a point where something suddenly clicked for you or helped you see the bigger picture?

4. Extraneous load: Clarity and Presentation

- a. Were there any moments where you found the material difficult to follow or understand?
- b. Were the images and text easy to follow, or did you find yourself jumping back and forth?
- c. Did you find yourself distracted or confused by how information was presented?

5. General Cognitive Load

- a. How mentally demanding did the training feel overall?
 - i. Were there moments where you felt overloaded or like there was a lot to take in at once?
- b. Was the effort due to the complexity of the topic itself, or how information was presented to you?

6. Germane load: Meaning making

- a. Did anything in the training material help you make sense of the topic in a deeper way?
- b. Can you think of a part that helped you connect the pieces together?

7. Final reflection

- a. If you could improve one thing about the training material, what would it be?
- b. Is there anything else you want to share about your experience?

K. In-depth accounts from Post-Experiment Interviews.

Participant 1 (Baseline)

The participant found the training material generally clear and approachable despite the complexity of the topic. Some general prior knowledge of the difference between 2D and 3D helped in answering a few pre-test questions. However, it was noted that truly understanding the products and being able to apply the knowledge in real-life sales scenarios would be much more challenging and potentially overwhelming without guidance or structured learning.

The scenario-based examples were especially appreciated, as they helped clarify how products could be used in context. However, the post-test scenario questions, such as selecting the most suitable camera for a specific application, proved more difficult. Distinguishing between product functions and remembering key differences between the products was a recurring challenge for the participant.

Visual elements played a crucial role in learning. Images were described as essential for deeper understanding, and highlighted keywords made the text easier to follow. Both visuals and application examples were particularly helpful in building a broader understanding.

With a background in cognitive science, the participant reflected that it might have been more effective to first understand the products and how they work before being introduced to their applications. While the application-first structure aligned with their personal learning preference, it was acknowledged that it contributed to confusion - especially due to the lack of clear separation between 2D and 3D content. A summary after each section was suggested as a way to reinforce learning and aid retention.

Product names were perceived as difficult to remember, prompting the use of personal memory strategies. To improve clarity and engagement, the participant suggested enhancing visual distinction, such as using different colors for 2D and 3D product names, and incorporating more engaging design elements. This was especially relevant in the 2D technology section, where dense text without close visual support led to passive scrolling. It was expressed that the presence of images consistently helped refocus attention.

Two of the final videos were noted as distracting due to abrupt endings mid-sentence, disrupting the learning flow. It was also confusing to receive a product portfolio overview at the end that included products not previously introduced.

Despite these issues, the platform itself received strong praise. The interface, particularly the side menu, progress bar, and clear structure, was considered by the participant to be highly supportive of learning and capable of elevating even less effective content.

Participant 2 (Baseline)

The participant described the overall experience as positive, particularly in the beginning. As the material progressed, however, it became harder to maintain focus, especially when trying to memorize and differentiate between various cameras. This resulted in some confusion and uncertainty during the post-test, especially with questions involving 3D technologies and the distinction between 2D and 3D.

With no prior knowledge of the company or machine vision, the participant found the topic complex but felt the material helped make it more accessible. The videos and images were appreciated and described as clear and supportive of understanding. Minimal text and the highlighting of key terms were also seen as helpful design choices.

The 3D application section in the beginning of the material stood out as particularly effective in aiding deeper comprehension, though the examples tied to 2D cameras were perceived as less clear. A consistent challenge was distinguishing between 2D and 3D content and remembering which cameras used which technologies. This was partly attributed to the structure of the material, where 2D and 3D concepts were presented in an interwoven manner.

As attention waned later in the training, concepts became harder to keep track of. The participant noted that reviewing the material a second time would likely improve retention. The experience was mentally demanding, but not overwhelming, with the cognitive load linked more to the inherent complexity of the subject matter than the design itself. To improve the material, the participant suggested separating the 2D and 3D sections more clearly, which could enhance clarity and support better long-term understanding.

Participant 3 (Experimental)

The participant, reported a positive overall experience with the training material. The structure was described as clear, easy to follow, and quick to complete. Compared to other training materials encountered at work, this one was considered significantly better, avoiding the common issues of being overly poorly structured and boring to complete. Although the participant had no prior experience with the company, existing knowledge of machine vision and a personal interest in cameras enabled them to

answer some pre-test questions prior to engaging with the material.

The topic was perceived as neither particularly easy nor complex. The participant found the connections between content elements to be logical and clear, and reported no confusion related to the material's structure or presentation. The experience was described as cognitively demanding in a positive way - engaging, but not overwhelming. Despite being asked several follow-up questions aimed at identifying potential difficulties or confusing elements, the participant had little negative feedback to offer.

The interactive feature of clicking on the information icons for each product was highlighted as a strength. However, the participant noted difficulty in remembering the specific functions of each camera, identifying these items as the most challenging on the post-test. The video explaining the laser triangulation technique was specifically mentioned as helpful for deeper understanding, and both images and videos were credited with supporting comprehension. The visual design was considered appealing, contributing to engagement. The participant also noted that placing the application section last was beneficial, as it helped consolidate understanding. If any improvements were to be made, the participant would have preferred more detailed information and a brief summary at the end of each section, particularly clarifying which products serve which functions.

Participant 4

The participant had an overall positive impression of the training. They described the material as well-structured in an intuitive way, with an appropriate level of information for an entry-level learner. The participant had no prior knowledge of the company or of machine vision and found the topic generally complex, particularly the 3D technologies.

They noted that the scenario-based questions in the post-test were the most difficult, especially remembering specific product names. However, the visual hierarchy presented at the end of the training was highlighted as helpful for understanding how the portfolio was organized and how different elements were connected.

The participant did not report any confusion or distraction and found the material easy to follow. They experienced a moderate but manageable cognitive effort, attributing the difficulty primarily to the inherent complexity of the topic. However, they also remarked that they did not find the topic particularly "fun".

The separation of the 2D and 3D sections was appreciated, making it easier to progressively build understanding and see correspondences between the two areas. They also liked that applications were presented last, allowing them to mentally anticipate how technologies might be used before seeing specific examples, which supported their schema-building process.

The participant appreciated the use of color coding (e.g., green for advantages and orange for limitations) and thought the text layout was clear, with bullet points that avoided overwhelming the reader. They found the visuals informative, particularly liking the short, muted videos, although they wished there had been a video for each 3D technology.

Finally, they emphasized the usefulness of the visual hierarchy summarizing the portfolio, stating that if they were a salesperson, they would have printed it out to keep as a quick reference at their desk.