جامعة أبو بكر بلقايد
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EduVision AI-Powered Software for Interactive Presentation

<u>Prepared by:</u>

Lazar Abdel-Moudjib

Moulai-Khatir Abdessamed

<u>Presented on 29/06/2025 before the jury composed of</u>

Mr. Bentaallah Mohamed Amine	President (University of Tlemcen)
Mme. Cherifi Ikram	Examiner (University of Tlemcen)
Mr. Benazzouz Mourtada	Supervisor (University of Tlemcen)

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بسم الله الرحمان الرحيم

"وَأَن لَّيْسَ لِلإِنسَانِ إِلاَّ مَا سَعَى ۝ وَأَنَّ سَعْيَهُ سَوْفَ يُرى "

[النجم:38-39]

First of all, we are thankful to God Almighty for granting us the health, strength, and patience to complete our graduation project. We are profoundly grateful to Almighty Allah for guiding us throughout this journey.

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Dedication

Glory to our parents for their patience and support during these years of study, and to our brothers and sisters for their encouragement.

Thanks to our friends who stood beside us, and to those with whom we spent countless hours.

Finally, to anyone who has contributed to this dissertation directly or indirectly, to all, we say

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I. General Introduction

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I.1. Project Context

This master's thesis explores the integration of interactive educational technologies as a way to modernize and improve student engagement in Algerian classrooms. The development of any country mostly depends on the knowledge and skills of its people, and that's what education is really about. It's the foundation that pushes societies forward. When we compare our system to developed countries, it's clear that education plays a huge role in the difference. Sadly, our education system hasn't really evolved much. It's still kind of old, static, and doesn't really fit with the mindset of today's students.

Meanwhile, other countries are already using modern tools that go along with the digital age, while here we're still stuck with traditional methods. But with AI and all the new technologies coming out, we believe that we can do better. Maybe if we start using more interactive platforms and modern approaches, we can make learning more interesting and help students be more involved. This work aims to explore how these tools could be used to make our classrooms more dynamic and adapted to the generation growing up with technology all around them.

I.2. Problematic

We chose this topic because it's something we're living every day. As students we clearly see that the old methods of teaching aren't keeping up with how fast the world is changing. With the rise of technology, our ability to concentrate has dropped, not because we want to but because our brains are constantly exposed to fast, short content like TikTok and Instagram reels. We're consuming huge amounts of information in very small pieces, and that has changed how our minds work. A student in 2025 doesn't think or focus the same way as a student from the year 2000. We see it in ourselves after 30 minutes in class, we start losing focus and the rest of the session becomes hard to follow. But classes are 90 minutes long, so something clearly isn't working. That's why we started thinking of a solution, something that makes education more interactive and dynamic so it can grab students' attention and help them stay focused longer.

I.3. Contribution

Our proposed solution is called EduVision. It's an attempt to improve the way education works today by making it more interactive and engaging, especially for the current generation of students. The idea is to move away from the old static methods and give professors better tools to communicate with students in a more modern and efficient way.

The project is made up of three main parts. First, there's a software component, basically a graphical interface that allows professors to create and manage their lessons, kind of like how PowerPoint works. They can add text, images, shapes, and even 3D objects, and organize their course into slides.

Then, the second part is the AI model which is the core of the system. It uses a camera to watch the data show projection and detect interactions. It’s trained to recognize movements and actions coming from the third part of the system: the smart pen.

This pen is the hardware piece. It includes Bluetooth and a few small components. When the professor uses the pen, the model detects what they're doing. For example, if they want to switch to the next slide, they don’t need to walk to the PC, they can just click a button on the pen or gesture in a direction. They can also write directly on the projection, and the writing will be captured and added to the actual document, which can then be saved and shared with students.

We're also exploring extra interactive features like dynamic maps. For example, if a history professor is talking about Africa they can click on Algeria in the projected map and a popup would appear showing details like the country’s population, area, etc. All of this is designed to give teachers more flexibility and help students stay focused and understand better.

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II.1. Introduction

Learning doesn't only happen in schools, it's kinda something people do all the time, without thinking. But in formal education, it's more organized and follows certain ways. That's why many experts, like psychologists and educators, tried to explain how learning works. Their ideas are called learning theories. These help explain how people get knowledge, remember it, and use it later on.

A learning theory is a structured body of principles aimed at explaining how individuals acquire, retain, and recall their knowledge throughout their learning journey.

These theories usually help in building teaching methods. There are three main ones that are often used today: behaviorism, cognitivism, and constructivism. Each has its own view about how learning works.

In this chapter, we talk more about these theories and also link them to modern tools, like EduVision. The VARK model will be given special attention because it's really helpful in student motivation and learning.The theories we show here also had influence on how EduVision was created, to help both learners and teachers.

II.2. Behaviorism

Behaviorism comes from old ideas of philosophers like John Locke and David Hume, from Anglo-Saxon background. It really took shape in the United States from the early 1900s up through the 1960s, with pioneers such as Ivan Pavlov, John B. Watson, Edward Thorndike, B. F. Skinner, and Robert Gagné. At its heart, behaviorism defines learning as a change in observable behavior, driven by the consequences of actions. In other words, we learn when our behavior is either rewarded or goes unrewarded by our environment. The more a behavior is reinforced, the more likely it is to happen again.

II.2.1. Learning by Association

Edward Thorndike's foundational work on trial-and-error learning illustrated how behaviors become associated with outcomes. In the famous puzzle-box tests, cats slowly figured out how to get out by pressing a lever. After many tries, they made less mistakes, and the right action got reinforced. This shows the "law of effect", when a behavior gets a good result it's more likely to happen again. But if the result is bad or uncomfortable, the behavior don't repeat much.

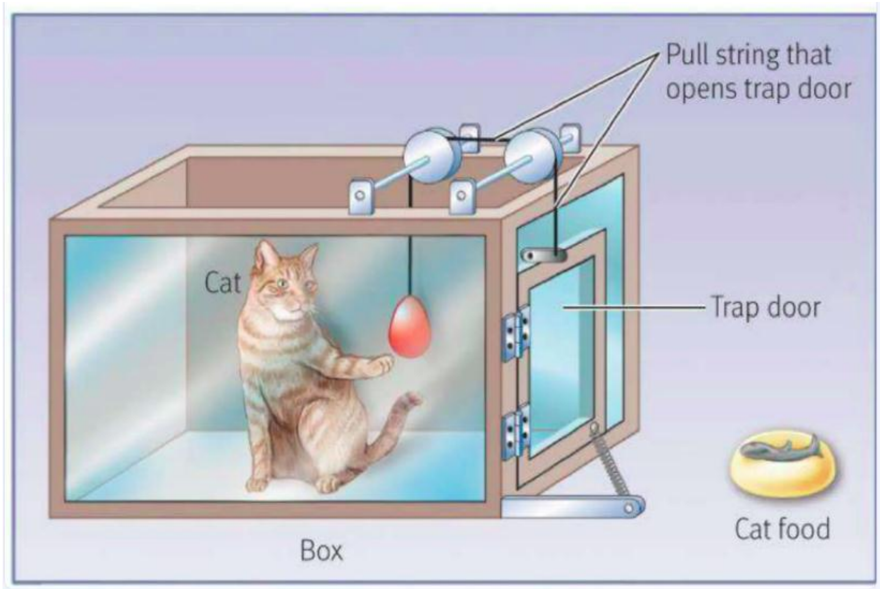

Figure II.1 - Thorndike’s puzzle-box experiment

II.2.2. Behavioral Conditioning: From Pavlov to Skinner

Classical Conditioning (Pavlovian) is when a neutral thing gets linked with a natural reaction. Like in Pavlov’s experiment, dogs started salivating when they hear a bell because they got used to hearing it with food. After some time, just the bell made them react. This kind of learning is automatic and not something the subject control.

Operant Conditioning was developed by Skinner. This one is about actions that people or animals choose to do. If something good happens after the action, like getting food, they do it more (positive reinforcement). If doing something helps them avoid something bad, like a shock, then that’s also reinforcement (negative reinforcement).

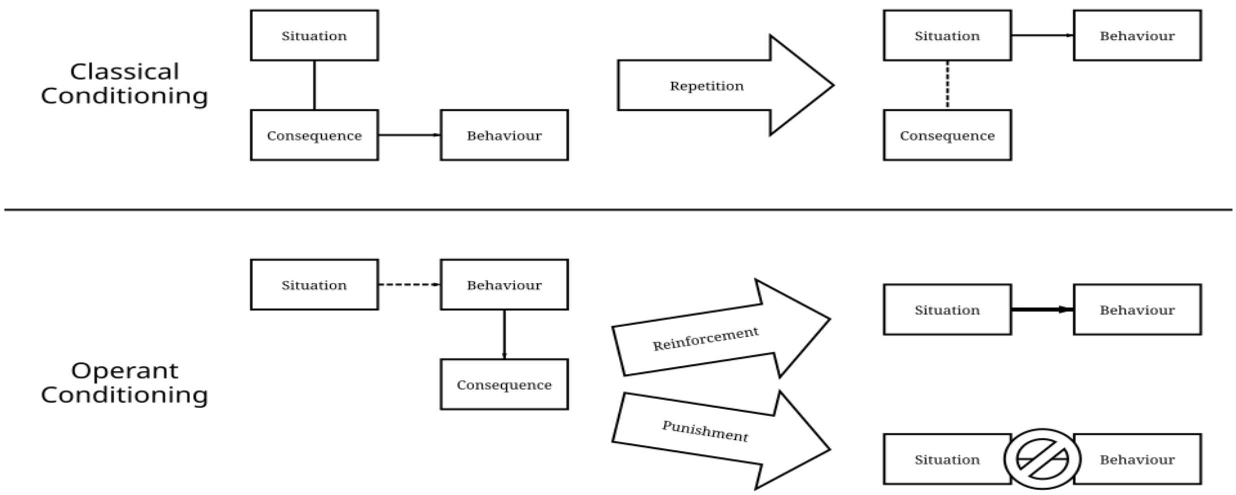

Figure II.2 - Comparative diagram of classical and operant conditioning processes.

II.2.3. Seven Core Principles of Behaviorism

- **Association**: People learn by connecting actions and results, like how Thorndike's cats learned to escape the box.
- **Conditioning**: Learning includes classical (involuntary) and operant (voluntary), with things repeated until learned.
- **Law of Effect**: Behaviors that get a reward get stronger. Ones followed by bad results tend to fade out.
- **Observable Behavior**: Watson (1913) said only what can be seen should be studied, not thoughts or feelings.
- **Tabula Rasa**: People start as blank slates. What they experience builds their behavior.
- **Reinforcement**: Learning is directed by rewards (positive) or by removing bad stuff (negative).
- **Discrimination and Imitation**: Learners can tell the difference between stimuli, and they copy others' behavior too. Bandura later added that people learn a lot by just watching others.

II.2.4. Applications in Education

Even today, behaviorist methods are still used in schools. Methods like direct teaching, programmed learning, or step-by-step tutoring all follow clear goals and give constant feedback. For example, digital learning tools give points or badges when students get answers right, and show corrections when wrong, so students know what to change.

With time, students begin to connect right answers with rewards, which helps them build better habits and pay more attention.

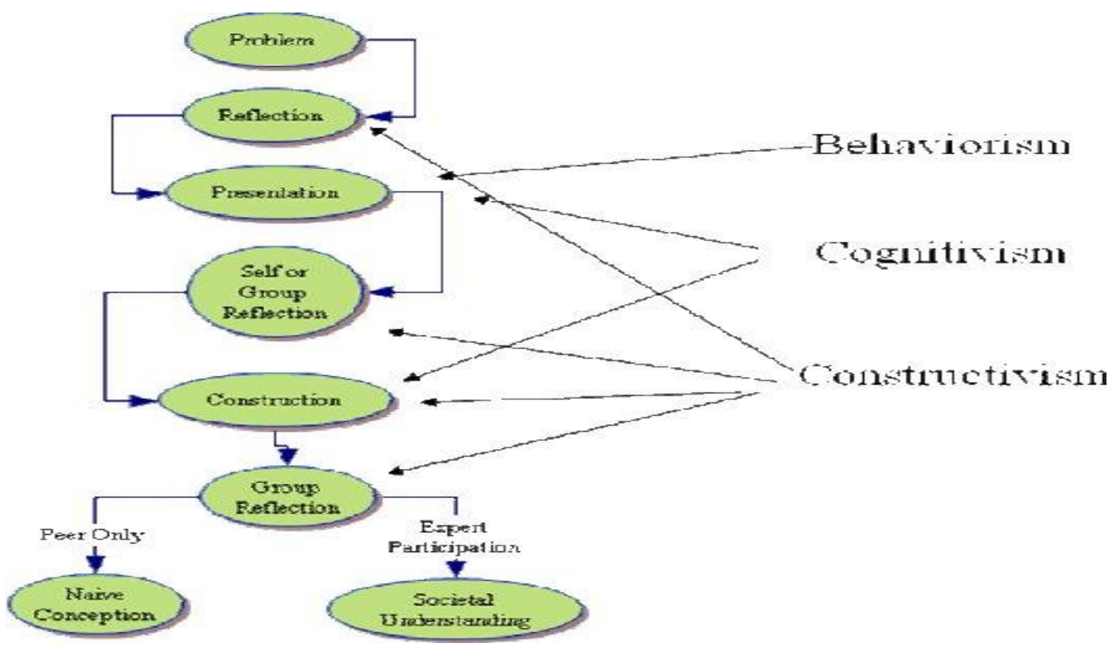

FIGURE II.3 - Behaviorist instructional cycle

II.2.5. Behaviorism in EduVision

To incorporate behaviorist principles within EduVision, we propose a reinforcement-based feature at the conclusion of each class. Specifically, students would be presented with a time-limited question selected by the instructor. A correct answer would be rewarded with a small bonus such as an additional quiz point proportional to the question’s difficulty.

This method helps keep students focused during class because they look forward to rewards. Some feedback from classmates and students shows that using games and competition in learning makes them more involved, especially those who like challenge-based stuff. So, this is like a real use of positive reinforcement boosts focus and makes students more likely to join in.

II.2.6. Balancing Behaviorism with Broader Learning Theories

Even if behaviorism is strong in many ways, it has some limits. It mostly cares about what can be seen and measured, like actions and not about the thinking or feelings inside. It doesn't pay much attention to things like logic, emotions or creativity. Because of that, EduVision uses a mix of methods. It includes behaviorist elements like fast feedback and repeating tasks, but also adds ideas from constructivism, like making students write interactively or explore using maps. It also gives them visual tools and questions to think about what they learn. This mix of methods helps make sure students don't just get the answers right, but also understand what they are doing and why.

II.3. Cognitivism

Cognitivism is about how the brain works during learning. It looks more at how we take in, save, and bring back information. Not like behaviorism, which watches what people do, cognitivism goes deeper into what's happening in the mind. When we study new things, we often connect them to stuff we already know. This is what makes learning stick it's active and not just a reaction.

This theory sees learners as people who build meaning by linking new ideas with old ones. It's used a lot in lesson planning because it helps teachers understand how memory works, like how students remember stuff for a long time and how they organize knowledge into patterns or groups (schemas). Whether tackling a math problem or analyzing a historical event, learners rely on mental structures shaped by past knowledge and experience.

II.3.1. Mind as Information Processor

Cognitivists see the mind like an internal processor. It uses stored information and ties it to external inputs to build new learning. Since learning involves activating existing knowledge and gathering details from past experiences to make sense of the world, cognitivists argue their theory is fundamental for explaining how we learn. In fact, cognitivism is often regarded as the foundation for most contemporary learning design and research.

II.3.2. Key Principles of Cognitivism

Cognitivism aims to enhance learners' abilities to understand, reflect on, integrate, and process information. According to this perspective, new knowledge is added on top of prior knowledge in the learner's memory. Here are its main principles for more effective learning in educational settings:

- **Targeted and Relevant Learning:** Content should directly relate to learners' goals.
- **Self-Directed Learning:** Learners take active control over their own study process.

- **From Analysis to Discovery:** Instruction moves from examining parts to discovering whole concepts.
- **Use of Schemas:** Organizing information into schemas helps learners build mental models.
- **Enhanced Long-Term Memory:** Learners better retain material when they organize and encode it meaningfully.
- **Structured Content in Context:** Presenting material within a clear, overarching framework aids comprehension.

II.3.3. Applying Cognitivism in Interactive Learning Environments

Cognitivism is reflected in our project through features that support internal mental processes such as information encoding, recognition, and retrieval. For example, when a teacher presents a lesson using slides enriched with textual explanations and detailed examples, this aids learners in anchoring new information to existing cognitive structures. These explanations serve as mental cues that facilitate recognition and recall during later learning phases. Moreover, we've integrated an intelligent interactive map, a tool particularly valuable for subjects like history and geography. A history teacher can, for instance, display a map of Africa, and by clicking on a country like Algeria, a pop-up appears showing contextual data such as population, area, or historical facts. This form of multimodal interaction strengthens cognitive processing by helping learners visually connect abstract concepts with concrete data, thereby enhancing memory formation and retrieval.

II.4. Constructivism

Constructivism is a learning theory that emphasizes how individuals actively construct knowledge through experience and interaction. Learners are not passive recipients of information but active participants who build understanding by connecting new concepts to prior experiences and questioning what they encounter. Learning is viewed as a continuous, reflective process shaped by engagement with people, tools, and environments.

II.4.1. Theoretical Foundations

At its core, constructivism highlights the social and contextual nature of learning. Students engage in discussions, problem-solving, and exploration to co-create meaning with peers and instructors. Teachers act as facilitators rather than transmitters of knowledge guiding learners to think critically, ask questions, and find connections. The process is dialogic and dynamic, with understanding shaped through trial, error, and discovery.

In psychology, sociology, and education, constructivism presents humans as creative agents who shape their environments. Learners actively engage with content and build personal meaning, using their imagination and prior knowledge as foundations.

Berger and Luckmann, pioneers of social constructivist thought, emphasized that all human knowledge is socially constructed and rooted in interaction with others.

II.4.2. Key Principles of Constructivism

- **Active Knowledge Construction**: Learners build knowledge through interaction with peers and their environment.
- **Curiosity and Exploration**: Students use their senses and natural curiosity to explore and interpret the world.
- **Creativity and Sharing**: Learners create and exchange ideas, a habit that extends into adulthood through platforms like blogs and social media.
- **Continuous Growth**: Learning is lifelong and shaped by individual experiences and developmental milestones.

II.4.3. Importance of Constructivism

Over the past two decades, constructivist methods have been embraced for fostering deep learning, curiosity, and self-confidence. By encouraging exploration, questioning, and experimentation, constructivism promotes lasting understanding and active engagement.

II.4.4. Constructivist Teaching Techniques

- **Problem-Solving**: Students apply critical thinking to real-world challenges, learning through mistakes and collaboration.
- **Student-Centered Learning**: Learners guide their own educational journey, developing independence and motivation.
- **Active Learning**: Emphasis on participation through discussions, group activities, and hands-on projects.
- **Discovery Learning**: Learners retain more when they explore and construct knowledge independently.

II.4.5. Application in EduVision

In the EduVision platform, constructivist principles are reflected in features like interactive maps and collaborative annotations. For instance, history students can click on a country to view contextual data and annotate it together in real time. This approach encourages active, socially driven learning that deepens understanding and engagement.

II.5. VARK Learning Styles

The VARK model made by Fleming groups learners depending on how they like to take in info. There are four main types: Visual (V), Auditory (A), Read/Write (R), and Kinesthetic (K). Visual learners go for pictures, diagrams, and charts. Aural learners like to listen like through lectures or audio. The Read/Write ones do better when they get to read notes, texts or write things down. Kinesthetic types prefer doing stuff like labs or tasks using movement and hands-on work. But not all people fit into one group. Many learners actually choose more than one style in the VARK quiz, so they can be bimodal, trimodal, or even mix all four.

In fact, the majority of students are found to be multimodal, meaning they learn from multiple sensory channels. For example, in the study by El-Saftawy et al. (2024), 40% of trainees were trimodal and 30% were multimodal learners, whereas only 10% were strictly unimodal.

Each VARK modality maps to different instructional methods. Visual learners benefit from charts, labeled images, and video diagrams; Aural learners benefit from spoken narration or group discussions; Read/Write learners need textual handouts and written explanations; Kinesthetic learners require hands-on activities and practice-based exercises. In laboratory sciences for example, tasks such as sample collection, microscopic examination, and diagnostic procedures inherently draw on all four modalities. Identifying microscopic parasites requires visual discrimination, listening to instructions or discussion (aural), consulting written protocols (read/write), and manipulating samples (kinesthetic).
So, when VARK-based methods are used in teaching, especially in labs, it helps students get better at using practical skills. This happens because the lessons are made to match the way students naturally process info with more than one sense.

II.5.1. Learning Theories: Zeigarnik Effect and Memory Retrieval

Two other thinking-based theories were added to help learning using the VARK model: one is the Zeigarnik effect, and the other is about how memory works and can be pulled back up.

The Zeigarnik effect says that people tend to remember things they didn't finish more than the ones they did. If a task is left halfway done, it kind of stays in the brain and makes people think about it more. That makes it easier to remember. For example, short learning tasks that stop before finishing like a video that doesn't explain everything or a question without the answer can make students pay more attention and remember better. One training done by El-Saftawy and others showed this when they used WhatsApp to send half-done messages or open-ended questions. Trainees had to ask questions or look for missing info, which made them remember more.

As for the second theory, memory storage and retrieval it focuses on repeating stuff and practicing it so it goes into long-term memory. The study used lots of repeated content like videos, images, and quizzes to keep the info coming back. Learners saw and used the same concepts over time, which helped them keep it in their heads better. Also, doing this in a group online gave more interaction, making learners remember parasitology stuff more by using recall actively.

Social media platforms such as Facebook and WhatsApp were leveraged as dynamic learning environments. These platforms connect learners in virtual communities, making it easy to share multi-sensory content. In the described study, instructors posted bite-sized training materials via these apps: labeled microscope images and short narrated videos (visual and auditory), written summaries and discussions (read/write), and prompts for students to photograph and share their own lab work (kinesthetic). This approach illustrates how technology can deliver VARK-oriented content, blending classical teaching with modern communication tools.

II.5.2. Educational Relevance of VARK

Understanding learners' VARK preferences is important for inclusive and effective education. By tailoring instruction to match sensory preferences, teachers can engage students more fully. The study under discussion found that accommodating each learner's mix of modalities can "foster an inclusive learning style". For example, even within a single class some students absorb information best from diagrams, others from verbal explanation and others from practice. By providing content in all four modes, educators can reach all learners.

Moreover, the VARK framework is linked to broader brain-based learning research. El-Saftawy et al. note that "brain-based VARK learning styles enhance learning achievement by understanding memory and inspiration for practical application". This suggests that VARK taps into cognitive and motivational processes: visual and auditory materials can create stronger memory cues, while kinesthetic activities make learning concrete. In fact, neuroscience evidence indicates that learning via multiple sensory channels stimulates more extensive neural networks, potentially improving comprehension and retention.

Empirical studies support the educational value of multimodal instruction. In health and science education students often show multimodal learning patterns and those who engage with material through multiple modalities tend to perform better. Consistent with prior research in medicine and pharmacy education, this study found about 70% of trainees had tri-modal or multimodal preferences. Importantly, trainees who experienced instruction via multiple VARK channels significantly outperformed those receiving uni- or bimodal materials. Post-test scores were highest in the tri-modal and multimodal groups, indicating that combining various sensory inputs leads to deeper learning. For example, using visual diagrams and auditory narration and hands-on tasks gave students an advantage. These results highlight a key implication: **teaching with multiple learning styles simultaneously can enhance achievement.**

The hands-on part of lab training made the Kinesthetic type of learning extra important here. The study showed that kinesthetic learning sometimes mixed with other styles was the one most students liked best. This makes sense, since chemistry students usually need to work with tools and real lab stuff. When the lessons moved away from only lectures and more toward doing actual tasks, the students reacted better and showed more interest. That tells us for training that's about skills, doing the task matters a lot more than just hearing or reading about it.

Visual aids like microscope pics and videos, along with audio explanations, were used too. But still, it was the doing part the kinesthetic part that really helped students take the ideas and apply them in real lab situations.

II.5.3. Implementation and Outcomes

The described training program exemplifies how VARK principles and learning theories can be operationalized. The **Figure** (below) illustrates the instructional design: each trainee took a pre-test, engaged with VARK-enhanced content via WhatsApp/Facebook (using short videos, labeled images, texts, and interaction prompts), and then took a post-test.

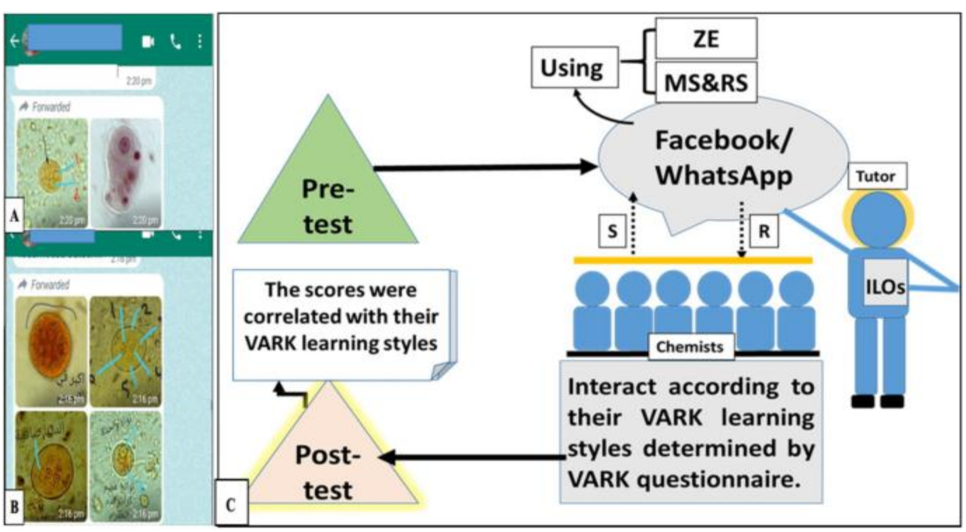

FIGURE II.4 - VARK modalities and learning theories via social media.

The materials were crafted to serve multiple modalities simultaneously. For example, mini-videos contained labeled diagrams (visual) and narrated commentary (auditory), while accompanying posts provided written reviews (read/write). Trainees were encouraged to contribute by sharing their own lab photos and videos (kinesthetic). Instructors also applied the Zeigarnik effect by leaving segments incomplete and prompting learners to seek the missing information. Messages were repeated over several days to reinforce memory. This multi-faceted approach reflects a “brain-based” learning strategy where content is chunked and interleaved to maximize retention.

The **VARK questionnaire** was administered at the end to identify each student’s profile. Students answered 16 questions with four options each; choosing multiple answers is allowed, so individuals can score in more than one category. The scoring (Figure 2) determines if a learner is unimodal, bi-, tri- or multimodal based on tied scores.

Chemist no 1

Name ....

Questions	A category	B category	C category	D category
1	K	A	R	V
2	V	A	R	K
3	K	V	R	A
4	K	A	V	R
5	A	V	K	R
6	K	R	V	A
7	K	A	V	R
8	R	k	A	V
9	R	A	K	V
10	K	V	R	A
11	V	R	A	K
12	A	R	V	K
13	K	A	R	V
14	K	R	A	V
15	K	A	R	V
16	V	A	R	K

Total no. of Vs	5
Total no. of As	8
Total no. of Rs	8
Total no. of Ks	8

Results: Trimodal with A, R, and K had equal scores

FIGURE II.5 - VARK questionnaire scoring for a trainee

As in Figure 2, the trainee’s results might show tied top scores in three modalities, yielding a trimodal profile (e.g. Aural, Read/Write, Kinesthetic). The study data showed that **no single modality dominated** all learners. Only 10% of trainees were strictly unimodal (mostly kinesthetic or visual), 20% were bimodal, 40% trimodal, and 30% fully multimodal.

These preferences had clear effects on outcomes. Learners with multiple sensory input in their instruction scored higher on skill tests. Statistical analysis found that the tri-modal and multimodal groups achieved significantly higher post-test results than the unimodal or bimodal groups. In other words, “the assemblage of multiple learning styles (tri-modal and multimodal) appeared to significantly improve learning performance”. This suggests that integrating different VARK channels not only accommodates learner differences, but actually **amplifies learning** by engaging more cognitive pathways.

This Figure summarizes the learning style distribution among the students. Note that the majority required instruction across two or more modalities, underscoring the need for varied teaching methods.

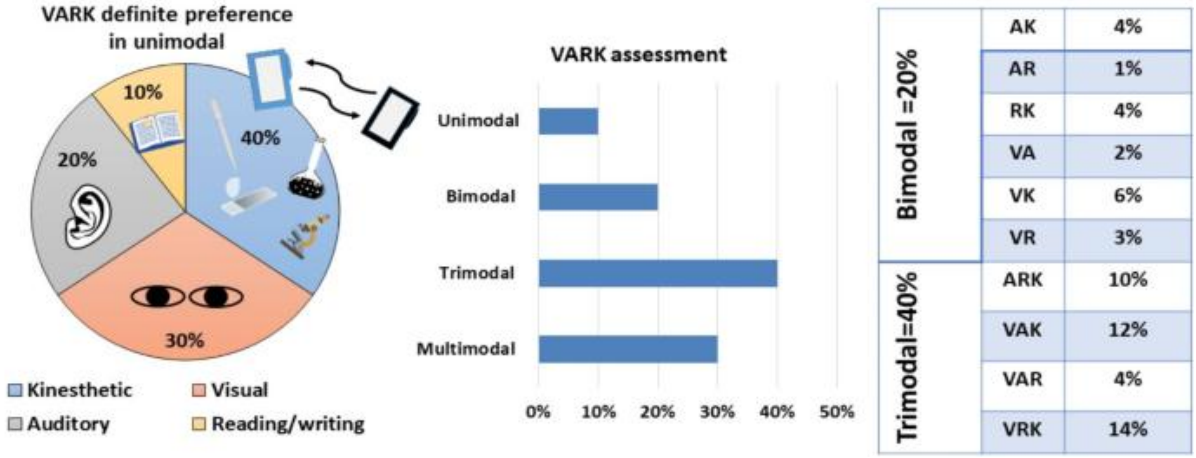

FIGURE II.6 - Distribution of VARK learning preferences

II.5.4. Implications for Teaching and Learning

These findings have several implications for educators. First, instructors should **incorporate multiple sensory channels** in lesson design whenever possible. For example, teaching a practical skill could combine a live demonstration (kinesthetic), illustrative diagrams (visual), spoken commentary (auditory), and written summaries or handouts (read/write). This multi-modal strategy aligns with learners' preferences and has been shown to enhance understanding and performance.

Second, the study highlights the value of **short, interactive content and repetition**. By delivering information in segments and revisiting key points (leveraging the Zeigarnik and memory-retrieval principles), educators can boost retention. Practical methods include using brief videos that leave a question unanswered, or posting reminder quizzes. These tactics create cognitive "hooks" that keep students mentally engaged with the goals.

Third, technology such as social media can be a potent delivery platform. Platforms like WhatsApp or learning management systems allow teachers to distribute various media formats easily and interact with students in real time. In the study, such platforms enabled trainees to ask questions, share findings, and receive feedback quickly. This flexibility can help bridge the traditional gap between theoretical instruction and hands-on training.

Finally, the results suggest that emphasizing hands-on, kinesthetic experiences is crucial in skill-based fields. In laboratory or clinical education, allocating sufficient time for practice will likely improve competence and confidence. The authors note that kinesthetic learning “should have a special emphasis in training” for laboratory skills.

In summary, the theoretical framework and findings of this research underscore that tailoring teaching to learners’ VARK preferences and integrating sound learning theories can create more effective and inclusive instruction. By recognizing that students learn through diverse modalities, educators can design richer learning experiences that lead to **deeper understanding, faster acquisition, and improved performance**.

II.5.5. Key takeaways

- Cater to all four VARK modalities in lesson content (visual, auditory, text, hands-on) to reach every learner.
- Use interactive, multi-sensory materials (videos, images, audio, discussions) together to reinforce concepts from different angles.
- Apply brief, interrupted segments (Zeigarnik effect) and spaced repetition to enhance memory.
- Leverage technology (social media, online platforms) to distribute diverse content and foster engagement.
- Recognize that most learners are multimodal; moving beyond one-style teaching can boost motivation and learning outcomes.

II.5.6. Educational relevance

These principles and research findings support a shift toward **personalized, multi-channel learning environments**. By applying the VARK model and supporting theories, instructors in sciences (and other fields) can **improve practical skill training**. The evidence shows that such methods not only accommodate individual differences, but also leverage them to create a more effective, engaging educational experience for all.

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III.1. Introduction

Learning theories don’t exist in isolation they evolve through years of research, collaboration, and experimentation. To understand how educational tools like EduVision fit into the broader landscape, it’s important to look at what has already been done in the field. From innovative teaching strategies to the use of digital technologies in the classroom, many projects and tools have shaped the way we think about learning today.

In this chapter, we’ll explore key educational technologies and research efforts that have influenced modern teaching methods. These include interactive solutions like Smart Boards and Epson BrightLink, student engagement tools like Kahoot, and open-source platforms such as OpenBoard. By examining these systems, we can better understand the foundation upon which EduVision is built and how it seeks to improve on existing approaches in a more integrated and user-centered way.

III.2. Smart Boards

Smart boards, also called interactive whiteboards, are basically big digital screens that can be used like a traditional board but with some extra features. You connect it to a computer and a projector, and then you can control things by touching the screen with your hand or a special pen. It works like a giant tablet, kind of. Teachers or students can write, move stuff around, show videos, draw shapes all by just tapping on the board.

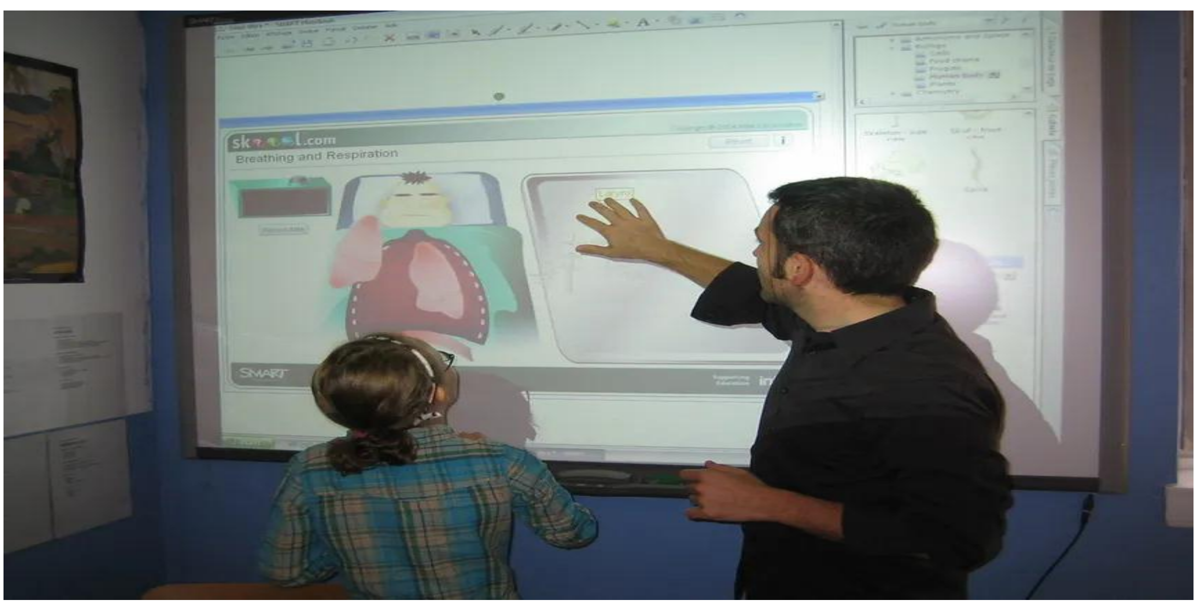

FIGURE III.1 - SmartBoard

III.2.1. Rationale Behind the Development of Smart Boards

The main idea behind smart boards was to make classes more interesting and help students stay focused. Instead of sitting and just watching the teacher explain things, students could go to the board, write something, solve problems, answer quizzes, and so on. This way, learning becomes more like a game or an activity, not just listening and writing.

Also, smart boards help different types of students. Visual learners see colors and shapes, audio learners get to hear stuff, and students who learn by doing (like touching or moving things) can benefit too.

III.2.2. Applications in Educational Settings

Smart boards are mostly used in schools from primary to high school and also in universities and sometimes business meetings. Teachers use them to show slides, play videos, do live quizzes with students, and even display 3D models in science or geography.

For example, in some classrooms, students come up to the board and solve math problems. In others, they use the pen to underline parts of a text or drag images around. Some teachers even let students vote during the lesson and show the answers instantly as a graph.

III.2.3. Evaluating the Effectiveness of Smart Boards

A lot of studies say that smart boards can help students pay more attention and even improve their results but only when the teacher knows how to use them well. For example, if a teacher just shows slides and doesn't interact, then it's the same as using a regular projector. But when they ask questions, let students come up to the board, draw, or solve stuff then the results are better. In one UK study, students using smart boards in math made more progress than those who didn't. But it also said that this only happens when the teacher uses the board regularly and creatively.

Also, a study in Botswana showed that students felt more interested and understood better when smart boards were used. But still, it depends on things like Internet connection and teacher training.

III.2.4. Cost Considerations and Associated Challenges

Here's the thing smart boards are expensive. One can cost between 2,000 and 6,000 dollars. And that doesn't even include the software updates, repairs, or teacher training. In many countries, including Algeria, that's too much. Some schools can't even buy one, and even if they do, they might not use it properly. Also, usually, only one or two students use it at the same time while the others watch. So it's not 100% interactive for everyone, unless you have more devices or smart pens.

III.2.5. Comparative Analysis with EduVision

Our project is inspired by the same idea make classes more interactive but in a cheaper and more flexible way. Instead of buying a full smart board, we want to use a simple projector and a smart pen that can be tracked by a camera. This way, the board becomes interactive without replacing it.

Also, we use AI to detect the pen movements and gestures. So we don't need a touchscreen or special sensors. And because our tool is portable, it can be used in different classrooms or even schools. Plus, we want it to be made for Algerian classrooms with the limitations we have, like weak Internet or limited budgets. Our goal is to bring the same benefits of smart boards, but in a more affordable and accessible way.

III.3. Epson BrightLink

Epson BrightLink is basically a projector and an interactive whiteboard rolled into one. Instead of mounting a separate projector above a board, you get this ultra-short-throw laser unit that sits right in front of your wall and turns it into a giant touchscreen. The most popular model, the 1485Fi, does full HD (1080p) with a 3LCD laser so the picture is bright and sharp, even if your classroom lights are on. You don't get that annoying "rainbow effect" you sometimes see on cheaper projectors, and the laser bulb lasts up to 20,000 hours without needing replacement.

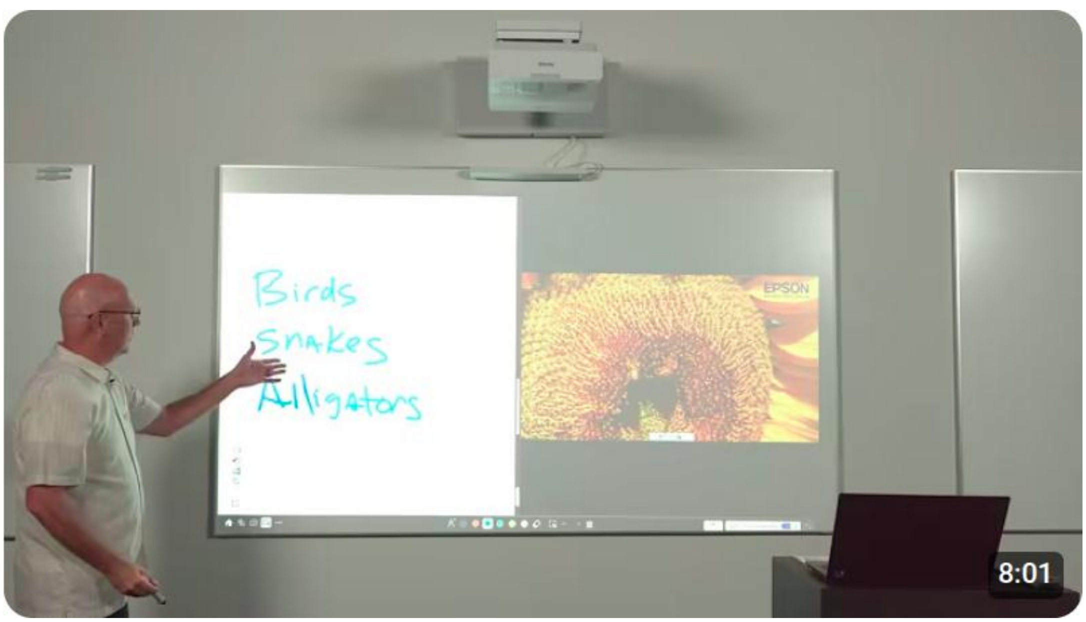

FIGURE III.2 - Epson Brightlink 700 Series

III.3.1. Technical Functionality and Features

Under the hood, there's a little camera and infrared emitter in the gadget that tracks either your finger or the stylus pens that come with it. You can literally tap, pinch-zoom, draw, or erase on your wall just like on a tablet. The software (Epson Easy Interactive Tools or iProjection) runs on your PC or Mac, and everything you do on the wall shows up in whatever program you're using PowerPoint, PDF reader, even a web browser. And it's multi-touch, so up to ten students can be messing around at the same time, each with their finger or pens. Kinda neat for group work.

III.3.2. Purpose of Development and Target Users

Epson built BrightLink to simplify things. Schools were tired of juggling lamps, mounts, separate boards, drivers… it was a mess. So they put it all in one box: laser projector + interactive board + touch sensors. Teachers love it because they can save their annotations (that little box in the corner "Save as PDF" is gold) and email them to absent students. I've heard uni professors say it's a lifesaver in lecture halls no more running back to the podium to change slides, you just tap next on the wall. Typical users? Obviously K–12 and higher ed, but also companies using it in meeting rooms. I saw a banker do investment training where he pulled up charts, drew trendlines on them, then saved the whole thing as a record. Very slick.

III.3.3. Research Findings and Observations

There aren't tons of independent studies just on BrightLink, but the ones floating around suggest it boosts engagement kids stay on task about 20% longer, according to a small study in Colorado middle schools. They said group work got livelier when they were all crowding the board. Another trial in New Zealand primary schools had kids feeling "more like real scientists" when annotating live microscope slides projected by BrightLink. And a case in Germany, schools tracked electricity and lamp costs, finding they saved a few hundred euros over three years because laser = no lamp changes. Of course, these were vendor-supported, but they line up with broader IWB research: when tech just works, everyone's happier.

III.3.4. Educational Applications and Key Features

- **Split-Screen Mode**: You can show two things at once like a YouTube video on one side and your slides on the other. Great for guest speakers or remote lessons.
- **Screen Recording**: Hit the record button and it captures your voice, your annotations, everything. Perfect for students who miss class or need review.
- **Widgets & Timers**: Toss a countdown widget on the screen for timed quizzes or group discussions just start it and it counts down in the corner.
- **Any App Annotation**: Doesn't matter what's on your desktop, you can scribble on top of it. Excel charts, PDF documents, even social media pages.

III.3.5. Cost, Maintenance, and Common Challenges

Here’s the kicker it’s not cheap. A brand-new 1485 Fi runs between $2,500 and $3,500 depending on your school discount and reseller. You do get a 3-year warranty, and you don’t need to swap lamps, but you still have to clean filters and recalibrate every so often if your wall shifts (especially in humid places). Also, you need decent wall space no bumpy or dark walls, or the touch accuracy goes wonky. And you’ll need a short training session; teachers who just dive in often miss half the features.

III.3.6. Comparison with Eduvision

BrightLink is a great, reliable all-in-one, but for Algerian schools it’s still pricey. Our EduVision idea uses the same principles interactive projector, touch or pen input but with a simple webcam and a custom smart pen, so you only buy a cheap camera and pen instead of an entire laser projector bundle. We lose split-screen and built-in software, but we gain portability (you move it from room to room), offline capability (no Internet required), and a price tag that’s a fraction of the cost. All in all, BrightLink shows what’s possible when you merge projection with touch, and it gives us a solid benchmark. Our challenge is to match its interactivity in a package Algerian schools can actually afford and maintain.

III.4. OpenBoard

In the realm of digital education, OpenBoard stands out as a free, open-source interactive whiteboard software designed to enhance teaching and learning experiences. It provides a user-friendly environment for educators to present digital content effectively and interactively. In our project, OpenBoard inspired the development of our graphical user interface (GUI), which connects the underlying logic of our system with the interface used by instructors.

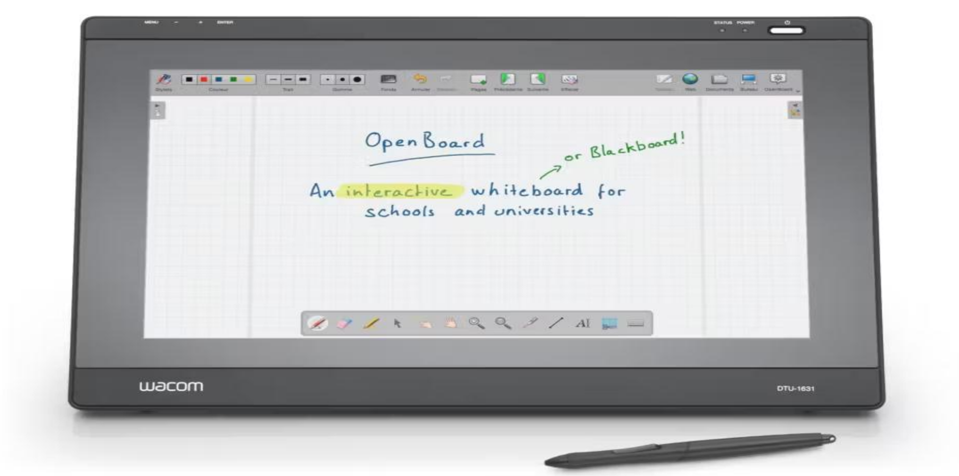

FIGURE III.3 - OpenBoard Software

III.4.1. Background and Development

OpenBoard originated from the Open-Sankoré project and has been maintained by a global community committed to accessible educational tools. It is compatible with Windows, macOS, and Linux platforms, making it a flexible option for diverse learning environments. Its open-source nature ensures broad accessibility without financial constraints a crucial factor for educational systems in developing countries.

III.4.2. Key Features and Functionality

OpenBoard offers a simplified yet effective interface that includes tools for drawing, handwriting, importing images, displaying PDFs, and embedding multimedia content. This intuitive interface reduces technical barriers for educators, allowing them to concentrate on content delivery. Moreover, OpenBoard supports live annotations over documents and the integration of external resources such as maps, simulations, and web content a level of interactivity we've similarly emphasized in our own platform.

III.4.3. Pedagogical Applications

The software is widely used across educational levels from primary schools to universities and even in professional training settings. Its interactive features promote greater student engagement, such as inviting learners to collaborate on the board or participate in real-time exercises. These functionalities parallel our system's goal: to create a dynamic learning experience that encourages active participation.

III.4.4. Accessibility and Socioeconomic Impact

A major advantage of OpenBoard is its cost-free availability. Unlike commercial alternatives that require expensive licenses or proprietary hardware, OpenBoard can be freely downloaded and used on standard devices. This aligns with our project's mission to deliver a scalable, low-cost solution tailored to the needs of Algerian classrooms and other resource-constrained settings.

III.4.5. Observed Benefits in the Classroom

Though formal academic research on OpenBoard is limited, widespread anecdotal evidence and pedagogical studies on interactive whiteboards suggest that tools like OpenBoard enhance lesson clarity, improve student focus, and foster deeper understanding particularly in visually intensive subjects such as mathematics and science.

III.4.6. Relevance to Our Platform

OpenBoard has influenced the design of our system, especially in terms of usability and visual simplicity. While our GUI includes more specialized features such as AI-driven interactions, the core philosophy remains consistent: enable seamless interaction without distracting from learning objectives.

OpenBoard exemplifies how open-source educational software can significantly impact teaching quality without incurring high costs. By drawing inspiration from its strengths and integrating advanced technologies like computer vision and real-time feedback, our system aims to offer a locally built alternative tailored for Algerian education. OpenBoard shows that meaningful, scalable educational innovation can indeed emerge from freely accessible tools.

III.5. Kahoot

Kahoot! is a game-based learning platform that uses interactive quizzes to boost student engagement. It's popular in schools and universities because it turns regular review sessions into fun competitions, with students answering questions on their devices while the teacher hosts. Designed for formative assessment, it includes features like leaderboards and music to make learning more playful. Kahoot! encourages active participation, especially from shy students, and is grounded in ideas of motivation and game-based learning. It replaces traditional polling tools with a more engaging format and has been adopted by millions of teachers and students worldwide.

FIGURE III.4 - School Year With Kahoot

III.5.1. Review Methodology

Wang and Tahir conducted a comprehensive literature review to synthesize research on the effects of using Kahoot! for learning. They identified **93 studies** that met their criteria, drawing from both quantitative experiments and qualitative case studies that focused on classroom implementations of Kahoot! (including face-to-face and online environments). The inclusion criteria emphasized **relevance** (studies that directly investigated Kahoot! use), **academic rigor**, and **methodological credibility**. In practice, this meant selecting research papers (including journal articles, conference papers, and theses) where Kahoot! was explicitly used as a learning tool, often in controlled or observational classroom settings. The authors categorized the reviewed studies into five broad themes: effects on learning outcomes, effects on classroom dynamics, effects on student anxiety, student perceptions, and teacher perceptions. Of the 93 studies, they counted 48 that examined **learning outcomes** (e.g. test scores), 34 on **classroom dynamics and engagement**, 14 on **student anxiety**, and many studies on **student perceptions** (over 80 in total, reflecting that students' reactions were often surveyed). Very few studies explicitly explored **teachers' attitudes** toward Kahoot, indicating a gap in the literature. The review was narrative rather than statistical: it summarized results across studies rather than performing a meta-analysis.

III.5.2. Impact on Learning Performance

A major focus of the literature is whether Kahoot improves student learning and achievement. In the reviewed studies, performance was typically measured by quizzes, test scores, or course grades. The overwhelming finding is that using it generally leads to better outcomes compared to traditional teaching. About 70% of studies with statistical tests reported significant improvements in grades or test scores. For instance, classes using Kahoot often had higher exam averages or larger pre- to post-test gains. One study noted that, on average, performance increased by a full letter grade in meta-analyses. These gains are credited to active rehearsal through game-based quizzes, helping students review material without the feel of a routine drill.

The positive impact was observed across education levels, from K-12 to higher education. Both young students and undergraduates showed improved results. The effect was also consistent across subjects, including languages, science, and engineering. While part of the impact is due to increased motivation and engagement, the immediate feedback from Kahoot also plays a key role. Students see right away whether their answers are correct and can view rankings, which helps them adjust and learn in real time. Overall, it's shown to enhance learning outcomes in a variety of settings.

III.5.3. Classroom Engagement and Dynamics

Many studies report that Kahoot! makes lessons more lively—attendance and participation rise, peer interaction increases, and even shy students feel safe to join in under anonymous nicknames. Teachers note that, instead of passive lectures, students eagerly grab devices to answer quiz questions. This boost in confidence and active involvement correlates with better concentration and understanding.

III.5.4. Student and Teacher Perceptions

An important theme in the literature is how users perceive Kahoot. Over 80 studies surveyed students, and nearly all reported very positive attitudes. Students described Kahoot! as fun, motivating, and engaging often noting it made them want to pay attention and study to succeed in the game. Compared to traditional lectures, Kahoot made them feel more involved. These positive perceptions often correlated with improved academic performance.

Teacher perceptions were studied less frequently, but available evidence shows they also appreciated the platform. Instructors noted it saved time, provided immediate feedback, and made classes more dynamic. They valued its ability to engage learners and serve as a useful assessment tool. While some expressed concerns about time constraints, most viewed it as a beneficial teaching aid.

III.5.5. Anxiety and Confidence

A somewhat surprising and important finding is that Kahoot! tends to **reduce anxiety** and boost confidence in students. Some educators initially worried about the competition and speed aspects of Kahoot! might stress students, especially if they answered slowly or incorrectly. However, the research reviewed indicates the contrary. In most studies where anxiety was measured, students using Kahoot! reported feeling *less* anxious about quizzes and more comfortable participating. Factors contributing to this include the anonymous play option and the game-like atmosphere, which together create a low-stakes feeling. Students felt free to make mistakes in a game context without fear of embarrassment. One student is quoted saying the quiz format made them “feel more confident answering questions” since it was just a game. Teachers in these studies also observed that even typically reserved students participated more, suggesting their classroom anxiety had lessened. Thus, far from raising anxiety, Kahoot! appears to alleviate it, giving students the confidence to answer and the freedom to learn from mistakes.

III.5.6. Comparative Contexts

The review also examined how Kahoot!’s effects might vary across different educational settings. The core conclusion was that **positive effects were evident in both K–12 and higher education**. In K–12 schools (elementary through high school), Kahoot! was often used to review lesson material at the end of class or week. Here it boosted engagement and motivation among younger learners who respond well to game elements. In universities and colleges, Kahoot! was used in large lectures and seminars; even adult learners reported high enjoyment. The consistent finding is that regardless of age, students showed improved performance and attitude when Kahoot! was included. No studies reported negative effects unique to one level or subject.

III.5.7. Limitations and Critiques

While the literature review paints a strong positive picture, several limitations should be noted. First, the review itself is not a meta-analysis with effect sizes, it qualitatively summarizes diverse studies. The 93 studies vary widely in design quality. Many were small classroom studies without random assignment or control groups. Thus, there is a risk of **publication bias**: teachers and researchers who saw good results may have been more likely to write up and publish their findings. The review did not report any cases where Kahoot! had negative effects, but this could reflect reporting bias rather than reality.

Second, because most studies used quasi-experimental or observational designs, some confounding factors cannot be ruled out. For instance, teachers who choose to use Kahoot! may also be more engaging instructors overall, so student gains might not be solely due to the tool. Third, the review covers a relatively short period of time after Kahoot! was introduced (studies from roughly 2015–2020). There may be a novelty effect: the excitement of a new tool can boost motivation temporarily. Over time, students might become accustomed to Kahoot! and the effect might diminish.

Finally, few studies addressed potential drawbacks of Kahoot!. The review mentions connectivity issues (if Wi-Fi fails) and the possibility that students come to expect only game-like learning, which could be problematic if mismanaged. It also notes that the majority of data comes from student self-reports and classroom observations; rigorous assessments of long-term learning or critical thinking skills are scarce. In short, while the existing evidence is overwhelmingly positive, it is not conclusive. More controlled, long-term studies would help confirm the extent of Kahoot's benefits.

III.5.8. Conclusion

Wang and Tahir's (2020) review of nearly 100 studies shows that Kahoot! consistently enhances student learning, engagement, and motivation across K–12 and higher education. Its competitive, game-like format drives higher attendance, active participation, and confidence, while surprisingly reducing quiz anxiety. Both teachers and students report enjoying the platform, and most studies document measurable gains in test scores and course grades.

Overall, Kahoot! proves to be a valuable active-learning tool rather than a mere gimmick. When integrated thoughtfully aligning quiz questions with learning objectives and complementing traditional instruction it can strengthen educational outcomes. The research underscores that combining play with pedagogy fosters a positive classroom climate and deeper learning. Further long-term and controlled studies are needed, but current evidence strongly supports "fun and learning" working together to boost achievement.

IV. Project Implementation

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IV.1. Introduction

This chapter provides a comprehensive overview of the practical realization of the EduVision system. Following the conceptual and theoretical foundation established in the previous chapters, the implementation phase translates the design into a functional and interactive educational software. EduVision is composed of three core components, each developed with distinct technologies and methodologies to address specific pedagogical and technical challenges, a graphical user interface (GUI) for lesson creation and presentation, a smart pen for seamless interaction, and an AI-based vision system that enables real-time recognition and response to user gestures.

The chapter begins by detailing the development of the presentation GUI, which empowers educators to craft rich, interactive lessons enhanced with multimedia content and dynamic elements. Next, it explores the design and assembly of the smart pen, a custom-built hardware device integrated with motion sensors and Bluetooth communication to enable wireless interaction with the projected content. Finally, it delves into the AI vision system, the intelligent backbone of the platform, describing how it was trained to detect the smart pen in live video feeds, classify gestures, and accurately interpret user actions on the projection surface.

Each section elaborates on the tools and technologies used, implementation processes, challenges encountered, and solutions adopted. Special emphasis is placed on how these components interact in real time to create a cohesive and intuitive user experience. Screenshots, hardware illustrations, model architectures, and performance metrics are included to support the narrative and demonstrate the system's reliability and effectiveness in real-world classroom environments.

Through this implementation, EduVision aims to bridge the gap between traditional teaching methods and modern interactive technologies, offering a forward-thinking solution that enhances both teaching delivery and student engagement.

IV.2. GUI Presentation

In the context of modern education, delivering course content effectively requires more than just static slides and one-way communication. To address this need, the EduVision system includes a custom-built presentation tool designed specifically to support dynamic and interactive teaching. This graphical user interface (GUI), developed using **PyQt5** and associated Python libraries, empowers educators to create rich, multimedia-enhanced lessons that engage students and encourage participation.

IV.2.1. Technology Stack and Design Rationale

The GUI was implemented using **Python 3.11** with **PyQt5**, a comprehensive set of Python bindings for the Qt application framework. PyQt5 was chosen for its flexibility, mature ecosystem, and seamless support for custom widgets and multimedia components. Additional Python libraries such as **OpenCV**, **NumPy**, **Matplotlib** , **flask** etc … .were integrated to support features such as image rendering, and 3D object manipulation, vote systems ...

The design follows the **Model-View-Controller (MVC)** paradigm, ensuring modularity and maintainability. Each component of the interface from the slide canvas to the multimedia toolbar is developed as a separate class or module, facilitating code reuse and future expansion.

IV.2.2. Core Features and Functionalities

The GUI offers a wide range of features that go far beyond conventional presentation software. These include:

1. Slide Creation and Management

The core of the GUI revolves around a **slide-based interface**, enabling teachers to create structured lesson content. Users can add, delete, duplicate, or reorder slides with ease via a slide panel. Each slide acts as a flexible canvas on which various elements can be placed and arranged.

The slide editor includes **drag-and-drop functionality**, allowing educators to add content elements intuitively. Each slide's content is saved in a structured format (JSON), making it easy to export, reload, or integrate into other parts of the EduVision system.

2. Multimedia Embedding

A key strength of the system lies in its support for **multimedia content**. Educators can embed:

- **Text** blocks with full formatting (font, size, color)
- **Images** from local storage or drag-and-drop from file explorer
- **Shapes**, including rectangles, ellipses, arrows, and custom annotations

Each media item can be resized, rotated, or moved interactively on the slide. This flexibility allows instructors to tailor the presentation to match the flow of the lesson.

3. Interactive Elements

To promote interactivity and keep students engaged, the GUI supports embedding **interactive objects** such as:

- **Clickable 2D cards** where you can transform an image into an interactive info card.
- **Quizzes and questions** with real-time feedback.
- **Vote system** where the classroom can vote on a topic or answer questions more effectively.

These interactive components are not passive visuals but **functional controls**. For instance, clicking a region on a map could display population data, or rotating a cube could demonstrate geometric transformations.

The teacher can define specific responses to these interactions, such as loading additional content or changing slide context making the experience both instructive and immersive.

4. State Management and Undo/Redo

The application includes a robust **state management system** to track changes made to the slide content. Users can freely undo and redo actions, a critical feature when building complex slides or correcting mistakes during live instruction.

Each user interaction from moving an object to changing text is recorded as a state event. This allows not only undo/redo but also the potential for **session playback or history tracking**, which can be useful for debugging or tutorial demonstrations.

5. Exporting and Sharing Features

Once a presentation is complete, it can be:

- **Saved in a proprietary project format** for future editing
- **Exported as a standalone presentation file**
- **Shared to the cloud** (planned feature for the future)

Exported presentations preserve multimedia and interactive behavior where supported, ensuring students receive the full experience if reviewing after class.

6. Real-Time Annotation Mode

While this feature is tightly coupled with the AI vision system, the GUI also includes a mode where teachers can write, draw, or highlight elements during a presentation using the **smart pen**. These annotations are saved along with the presentation, providing an accurate record of live teaching moments.

IV.2.3. User Experience and Interface Design

The GUI is designed with a **teacher-first philosophy**, emphasizing ease of use, clarity, and minimal distraction. Key interface elements include:

- A **side panel** for slide thumbnails
- A **top toolbar** with common actions (add text, insert image, etc.)
- A **canvas area** for slide design
- A **properties panel** for selected object customization
- A **preview pane** to simulate the final student-facing presentation

The application supports customizable shortcut keys, and scalable UI components to adapt to various screen resolutions and projection environments.

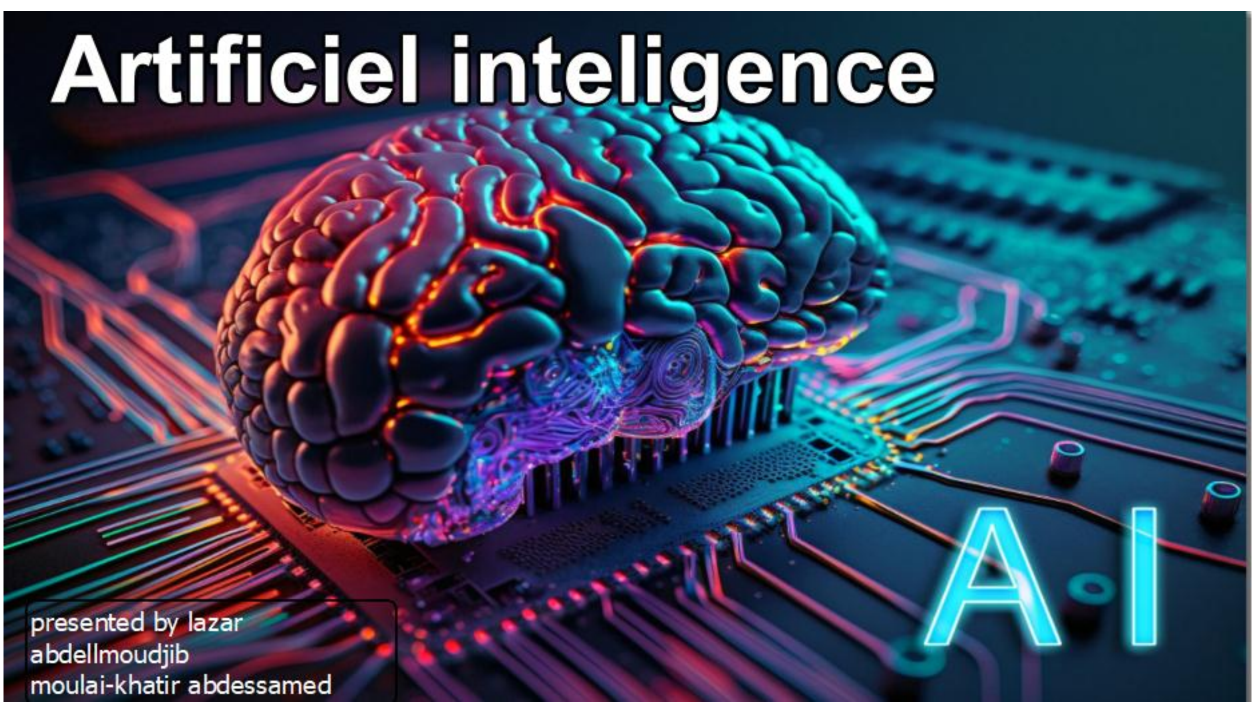

Figure IV.1 - a simple slide made in Eduvision

IV.2.5. Conclusion

The presentation GUI developed for EduVision represents a significant step forward in how digital content can be delivered in the classroom. By combining traditional presentation features with advanced multimedia, interactivity, and live annotation, the tool bridges the gap between lecture and dialogue turning passive content delivery into an engaging and participatory experience. This module also lays the foundation for integration with the AI-driven pen tracking system, making it a central pillar in the EduVision ecosystem.

IV.3. Smart Pen Hardware

In the pursuit of a truly interactive and hands-on teaching environment, EduVision introduces a **custom-engineered smart pen,** a compact, wireless device that enables teachers to interact naturally with projected course content as if they were writing on a traditional whiteboard. This smart pen plays a critical role in bridging the physical and digital classroom experiences by enabling annotation, navigation, and manipulation of on-screen elements in real time.

IV.3.1. Concept and Objective

The smart pen was conceptualized with the objective of enhancing mobility and intuitiveness during classroom presentations. Traditional presentation tools such as laser pointers or wireless remotes offer limited interaction. In contrast, the EduVision smart pen functions as a digital stylus for projection-based surfaces, enabling teachers to:

- Write or draw annotations directly on the projected screen.
- Interact with elements such as quizzes or buttons embedded in slides.
- Navigate between slides without returning to the computer.
- Exercise full control over the computer system remotely, including actions such as launching applications, switching windows, or interacting with the interface.

This hardware solution significantly reduces reliance on external input devices, allowing the teacher to remain fully engaged with the class and the content, while maintaining control over the entire presentation environment from a distance.

FIGURE IV.2 - Smart Pen external Design Side View

IV.3.2. Hardware Components and Architecture

The image below (see Figure IV.5) illustrates the physical structure and internal wiring of the smart pen prototype. The pen integrates several miniature components onto a compact PCB (printed circuit board), all enclosed within a lightweight, pen-sized form factor. Below is a breakdown of the key components and their roles:

1. Microcontroller (Arduino Nano)

At the core of the device lies a **microcontroller unit (MCU) Arduino Nano** is selected for its small footprint, low power consumption. This component manages sensor input, processes user actions, and handles wireless communication with the EduVision system.

2. Motion and Orientation Sensors (IMU)

The smart pen is equipped with a **6-axis Inertial Measurement Unit (IMU)** consisting of an **accelerometer** and **gyroscope**. These sensors track:

- Orientation (pitch, yaw, roll) .
- Acceleration (in the 3 axis) to deduce its motion through space .

These motion readings are processed in real-time and transformers in various task such as the air mousse functionalities where you can control the cursor without the need of the actual mousse .

3. Push Buttons / Control Switches

Three **push buttons** are placed along the body of the pen, giving users control over presentation functions. Typical bindings include:

- Mouse left/right presses
- Changing modes.
- Triggering different actions

These buttons are directly wired to the MCU and debounce-filtered in software to ensure responsive interaction.

4. Bluetooth Module

Wireless communication is achieved through an external bluetooth module(HC-05), allowing the smart pen to transmit motion data and button events to the host computer running the EduVision software. This wireless approach ensures **mobility and freedom** of movement, with a range of over 10 meters.

5. Power Supply

The pen is powered by a **rechargeable lithium-ion battery** connected directly to the heart of the mcu.Power management circuitry ensures safe voltage regulation and efficient energy consumption. And the battery could be deattached easily for charging or replacing .

6. PCB Layout and Wiring

The internal wiring, as seen in the figure, connects all components through a two-layer PCB with careful attention to signal integrity and wire length. Thin gauge wires were used to maintain flexibility and minimize weight, while the overall casing was designed to mimic the size and ergonomics of a traditional pen.

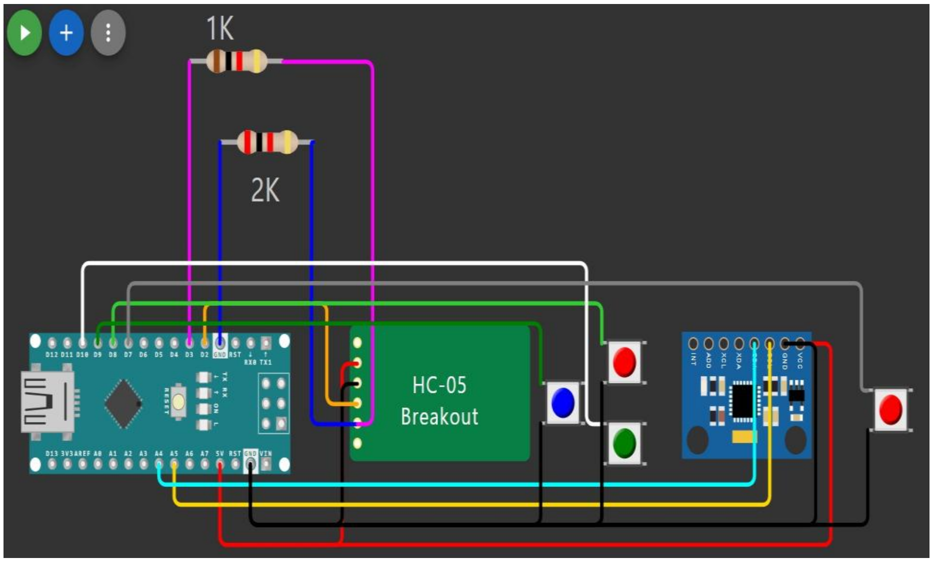

FIGURE IV.3 - Functional Block Diagram of Smart Pen

7. plastic casing :

Modeled using SolidWorks and Tinkercad, the chassis was designed to be simple, ergonomic, and lightweight for extended use. Using 3D printing technology, we transformed the digital model into a physical casing to securely house the delicate electronic components.

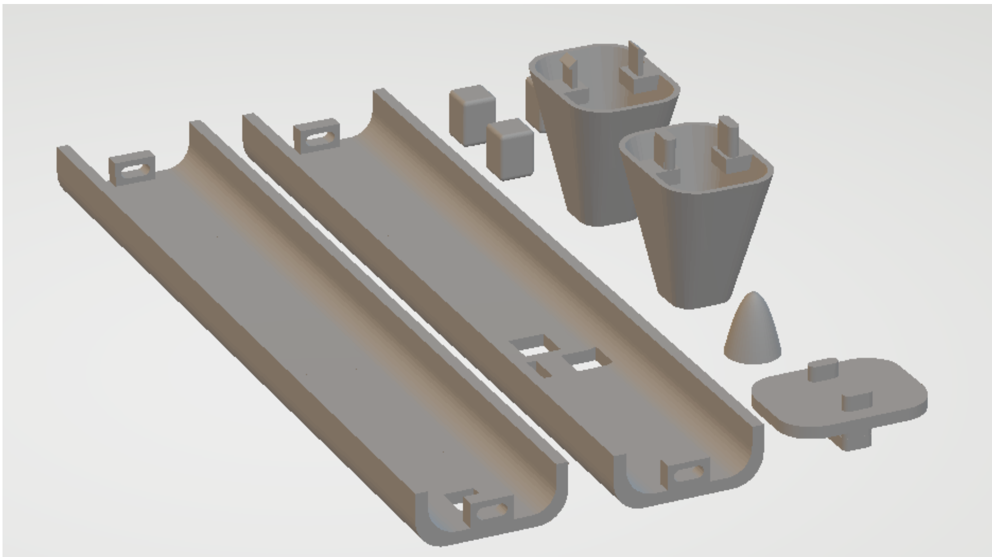

FIGURE IV.4 - plastic casing for the smart pen

IV.3.3. Functionality and Operation

When the smart pen is powered on, the motion sensors initialize and begin collecting orientation and position data. Upon detecting a specific motion (e.g., pointing or tapping), the pen transmits the data to the host system, where the Eduvision app processes the information

The data is being sent using packets at 38400 baud rate , which ensures smooth movements and fast response time .

Teachers can perform the following actions:

- **Write annotations** that are mirrored live on the slide canvas.
- **Interact with interactive elements** like clickable maps or quizzes.
- **Navigate slides** using button combinations or gestures.

The handwriting, gestures, and interactions are all digitally recorded and saved within the session file, creating a **complete trace of the live lesson**.

System Integration and Communication Protocol

The smart pen communicates with the EduVision system via a **Bluetooth Low Energy (BLE) protocol**, ensuring:

- Low latency (<50ms)
- Efficient power usage
- Robust reconnection on disconnection

A simple custom protocol defines the message structure (sensor values, button codes), allowing the receiver application to interpret and act upon each input. Additionally, calibration routines are built into the system to align the pen's sensor space with the projection area.

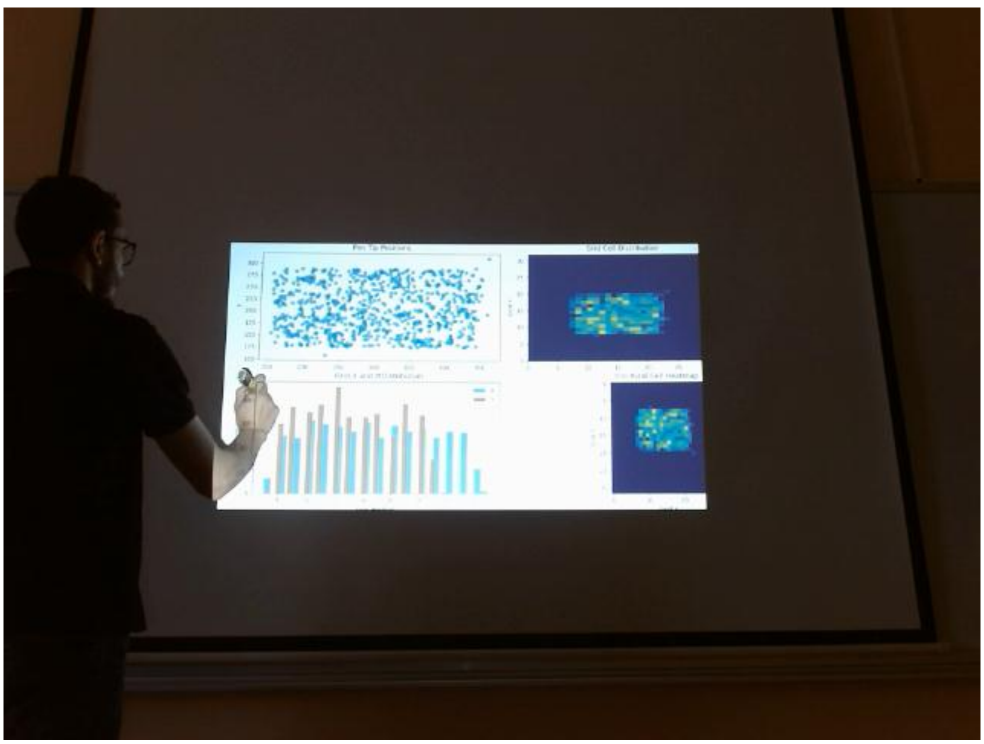

FIGURE IV.5 - Real Example of Using the Smart Pen

IV.3.5. Conclusion

The smart pen represents a core innovation within the EduVision ecosystem, enabling a new level of freedom and interactivity in the classroom. By combining embedded hardware, motion sensing, and wireless communication, the pen transforms any flat surface into a digital workspace. More importantly, it allows educators to focus on teaching not on controlling software and offers students an experience that feels natural, dynamic, and deeply engaging.

IV.4. AI Vision Model

The AI vision model constitutes the intellectual core of the EduVision platform, responsible for detecting and interpreting the instructor's smart-pen interactions on the projected display in real time. In this section, we describe in detail the data collection, model architecture, training procedure, evaluation methodology, and experimental results, together with an interpretation of system performance.

The goal of this model is to detect the pen tip position in a live feed camera input by operating on each frame of it , this is achieved by training a deep neural network (Unet) to predict the probable location of the pen tip.

IV.4.1. Data Acquisition and Annotation

To train a robust detection model, we assembled a dataset of over **3,000 annotated images**.by developing a capture system combining a **projector, a camera** and a **custom annotation tool**. This setup enables fast collection of training data with known pen-tip positions projected into camera images

1. **Capture Setup**

    - Used an HD webcam (logitech C920X pro) positioned above the projector to capture frames from the same field of view

    - Acer X118AH as a projector to display interactive targets onto a flat surface .

    - The Smart pen we discussed earlier.

    - Classrooms and conference rooms from our faculty to simulate real classroom conditions .

    This configuration simulated the real conditions of a lecture which ensures realistic lightning , shadows and visibility

2. **Annotation tool :**

    The capture interface was developed using **PyQt5** and **openCV** consisting of two primary windows :

    - Control panel (camera view) : displays the live camera feed in real-time while allowing for manual calibration of the projected region.

- Projected window (target display) : Shown on the projection , this window displays randomly placed colored dots (targets) that switch their location after every pen click

3. **Annotation Process**

   - The system projects a random target on the wall (via the projector).
   - The user places the pen tip on that spot , and uses the built in button which triggers an action to take an image using the camera.
   - The corresponding (x,y)coordinates of the target are mapped into the camera image via inverse homography (by knowing the target's location on screen as well as the projected area on camera).
   - The image and annotation are saved automatically in their corresponding folder .

Each capture saves:

- An RGB **image** file (.png) with a fixed size . (640 x 480)
- An **annotation.json** file , with a structure inspired by the COCO format which is widely used json format for structuring image datasets in computer vision .


```json
"annotations": [
    {
        "image": "images\\captured_20250521_104402378.png",
        "width": 640,
        "height": 480,
        "keypoints": [
            191.20484924316406,
            159.1839141845703,
            2
        ]
    },
```


FIGURE IV.6 - annotation.json format

4. **Data Augmentation**

   To increase generalisation , several augmentations are applied :

   - Random rotations
   - Color Jitter.
   - Horizontal flip.
   - Random crop and resize.

These augmentations simulate different lighting conditions and pen orientation which increase the original 3003 images to well over 100,000 samples

IV.4.2. Model Architecture

To achieve real-time detection and gesture classification, we adopted a modified version of the U-net architecture , which is well suited for dense prediction tasks like segmentation and localisation , utilizing encoder-decoder structure with skip connections enables both fine localization and global context understanding .

The objective of this U-Net is **pen tip localization** in input images by generating a 2D heatmap. The brightest point in the predicted heatmap represents the predicted location of the pen tip . rather than directly regressing (x, y) coordinates, the model learns to predict a 2D Gaussian distribution centered at the ground-truth pen tip, which:

- Provides spatial uncertainty.
- Is robust to annotation noise.

Allows the model to leverage convolutional structure better than coordinate regression.

1. **Detailed Structure**

- **Encoder** : This part reduces spatial resolution while increasing feature depth, allowing the network to extract contextual features from the input data.
  This step consist of 3 stages in which the model passes through :

  - Two 3×3 convolution layers with padding .
  - Batch normalisation .
  - Relu activation .

  Each stage followed by a 2x2 Max pooling layer to down sample the resolution .

Reducing spatial resolution and increasing feature depth.

- **Bottleneck :** The deepest part of the network, which captures the most abstract features.

    - A convolution block with 512 filters.
    - Captures deep features before upsampling .

- **Decoder:** This path upsamples the feature maps back to the original size using transposed convolutions, and concatenates the corresponding encoder feature maps via skip connections to recover spatial details.

    - 4 transpose convolution stages (Up-convolution).
    - Each upsampled output is concatenated with the corresponding feature map from the encoder via skip connections.
    - Then passed through Convolution Blocks to refine .

2. **Output**

    - The model compresses the 32 feature maps into a single-channel heatmap, which is later interpolated to the final output size of 64×64 used in the heatmap mask .
    - The output represent the probability of the smart pen tip coordinates , where the highest value significate the highest probability of pen tip position

3. **Total parameters**

    - `Total ≈ 7.8 million parameters`

Which make it light enough to sustain **about 24 FPS** on a mid-range usage device, satisfying the system’s real-time interactivity requirement .

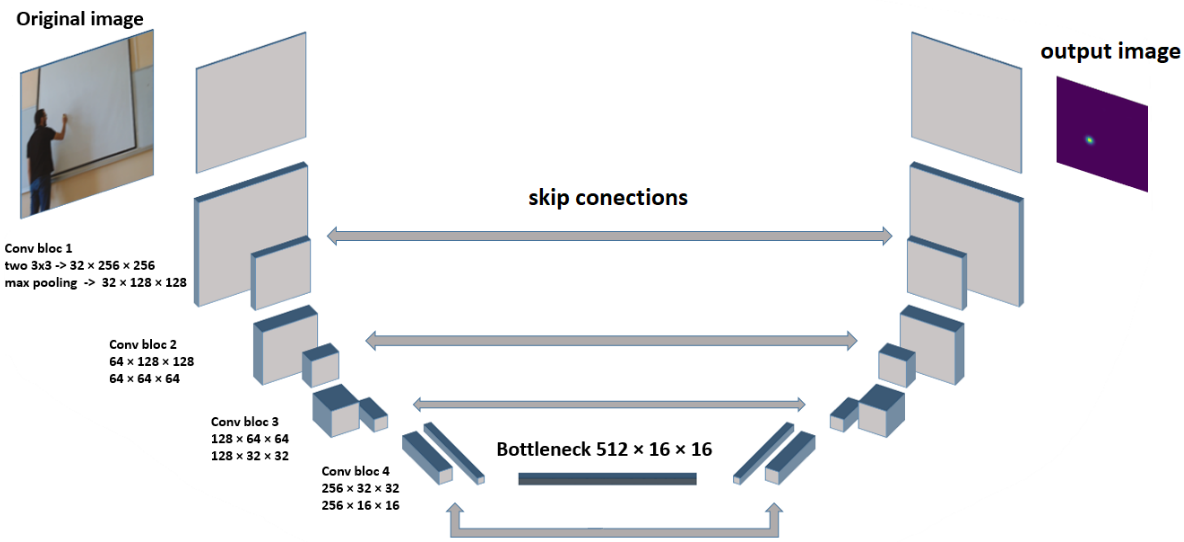

FIGURE IV.7 - model architecture diagram

IV.4.3. Training Procedure

1. **Loss function** :

   The model is trained using Mean Squared Error (MSE) between the predicted and ground truth which encourages the network to focus its output near the true coordinates values **.**

2. **Optimiser :**

   with an initial learning rate of 10^{-3} , we used the adam optimiser to help with fast convergence and handle noisy gradients well .

3. **Evaluation Metrics :**

   Mean squared error between predicted coordinates and ground truth ,

   Root mean squared error to penalize larger errors more robustly

4. **Accuracy thresholds :**

   We used three percentages of predictions to help quantify precision and robustness of the model

   ≤ 5 pixels , ≤ 10 pixels , ≤ 20 pixels .

5. **Prediction :**

given an image (live feed frame) the model output a heatmap

The point of maximum intensity is taken as the predicted location

The heatmap transform the 64×64 back to the original input image (640×480)

6. **Hyper parameters :**

Input image	height : 480px	Width : 640px
Heatmap resolution	64px × 64px	
Batch size	= 16	
Number of epochs	= 100	
Learning Rate	= 1e-3	
Train split	= 0.8	
Validation split	= 0.2	

7. **Hardware:**

training was performed on a NVIDIA 3090ti with 24go Vram .

Total training time was approximately 38mn 22s (personel pc i5 7th gen with 16go of ram took over 10h to train on cpu).

IV.4.4. Evaluation and Testing

1. **Dataset Splitting :**

The full dataset of annotated pen images was split as follows:

Training set: 80% of the dataset

Validation set: 20% of the dataset

This split ensures the model is evaluated on unseen examples during training, giving insight into generalization.

2. **Evaluation procedure :**

During each epoch, after the model is trained on the training set, it is evaluated on the validation set using both heatmap similarity and coordinate accuracy:

- **Heatmap Accuracy:**

  The model outputs a 64×64 heatmap. Mean Squared Error (MSE) is computed between the predicted and ground-truth heatmaps.

- **Coordinate Estimation**:

  The predicted pen tip location is obtained by taking the pixel with the highest intensity value in the heatmap. These coordinates are then rescaled back to the original image size (640×480) and compared to the ground truth.

3. **Results** :

Train MSE : 0..0000 **Val MSE** : 0.0001

MAE : 7.61px **RMSE** : 32.29px

Accuracy :

<=5 px: 69.3% **<=10 px** : 96.8% **<=20 px** : 97.8%

IV.4.5. Results Interpretation

- The detection model achieves **high precision** (96.8%) within the 10px range , which is suitable for our projection interactive board project .
- The heatmaps are sharp and centered, as MSE loss converges to a small value.
- Nearly all predictions fall within 20px, indicating good robustness.
- In addition to numeric metrics, visual tests confirm correct localization overlaying predicted heatmap peak on live feed shows close alignment with the pen tip.

  Operate at ~24 FPS on CPU.
  Accurately follow the pen tip across various lighting conditions and backgrounds.

- **Failure modes**:
    - **Low-contrast scenarios** : eg, in extreme light conditions whether the light is too bright or too dark , the model struggles to predict the pen tip.
    - **Rapid motion blur :** can degrade accuracy when the pen moves too quickly.
    - **Tight conditions for training data sample :** due to the lack of diversity in the dataset many images were captured in the same condition with the same person which limits the overall performance of drastically new data (eg, big image with a small person).

These results validate the AI vision system's suitability for live classroom deployment, offering both accuracy and responsiveness that underpin the EduVision promise of seamless, pen-driven interactivity.

IV.4.6. Figures and Illustrations

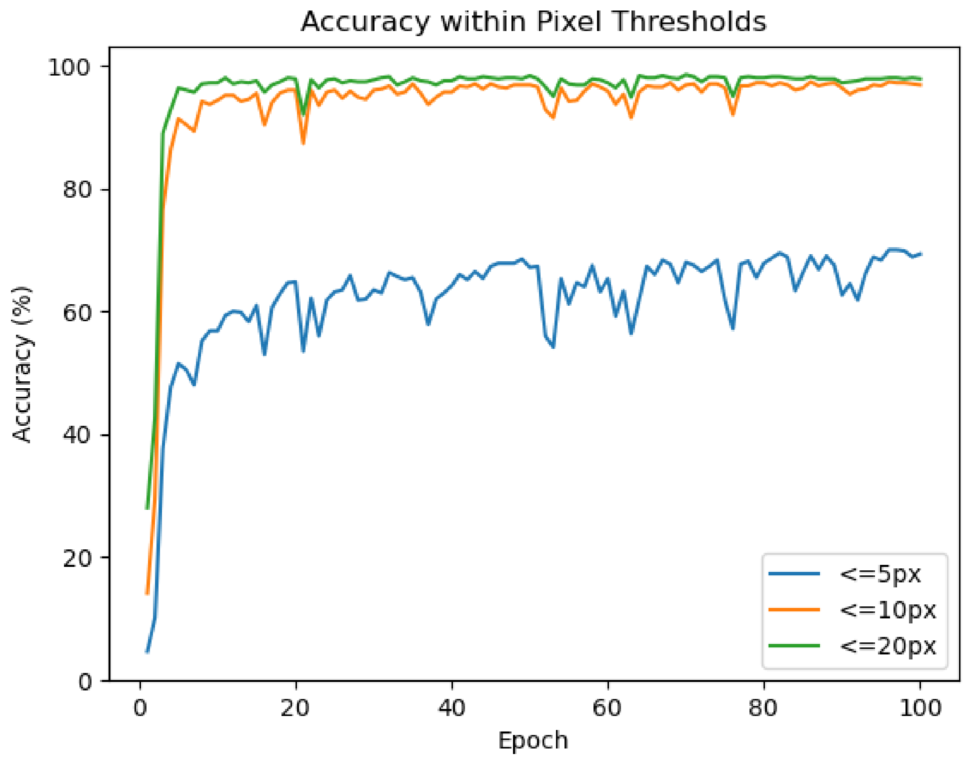

FIGURE IV.8 - plot displaying the the accuracy increase during training

Fast convergence all three curves shoot up within the first 10 epochs. By epoch 10 the model accuracy was already above 90 % for both the ≤10 px and ≤20 px criteria.
After ~20 epochs the model stabilizing around **95–98%** accuracy for ≤20 px, **92–95%** for ≤ 10 px and **55-70%** for <5px

a bit of noise after epoch 20 suggesting that fine-grained localization is still somewhat unstable from epoch to epoch.

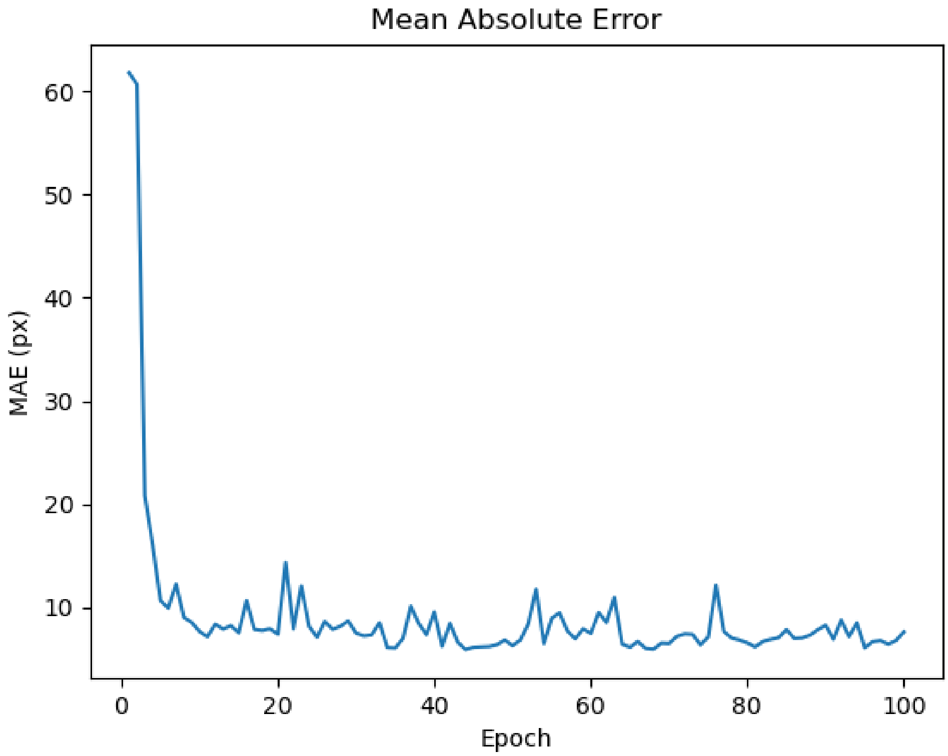

FIGURE IV.9 - Mean absolute error across training epochs

Steep initial drop , MAE falls from ~60 px down to ~10 px very fast, Because the model compute MAE in image pixels (640×480), the initial high MAE (~60 px) is just the untrained model's "random guess," then by epoch 10 its around 8–10 px on average.

Leveling off around 6 –10 px: After that initial drop, it stays in the 6 – 10 px range for the rest of training. With only ~600 validation images per epoch the results are good hitting low values , Small spikes: Occasional bumps (up toward 12–14 px) correspond to moments when the ≤5 px accuracy also dipped—probably due to outlier batches or a temporarily too-high learning rate.

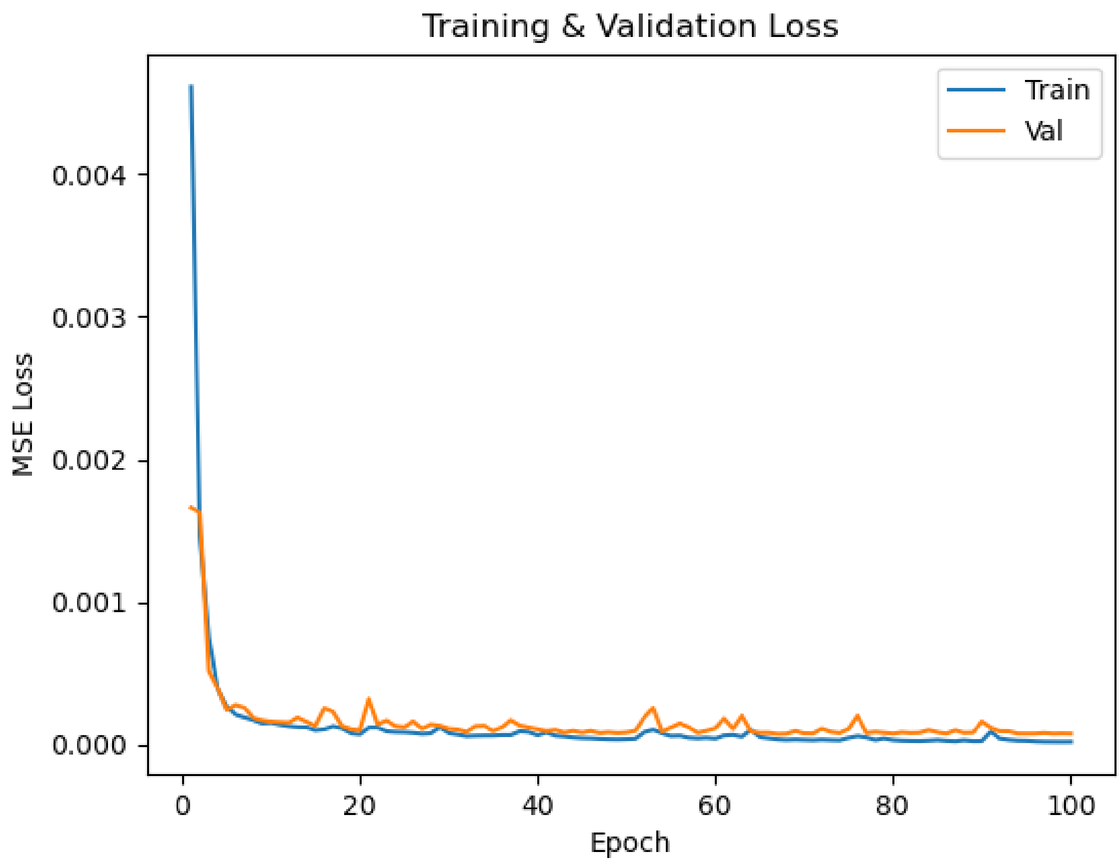

FIGURE IV.10 - training and validation loss

After an initial drop, the training loss stabilizes around 0.0002, and the validation loss stabilizes around 0.0003, with only minor fluctuations for the remaining epochs.

This ensures stability, implementing early stopping could reduce training time without changing the model's effectiveness.

IV.4.7. Conclusion

With the AI vision model successfully implemented and validated, the EduVision software is now capable of translating natural pen movements into precise, real-time digital interactions, forming the cornerstone of the system’s interactive presentation capabilities.

General Conclusion

This thesis explored the development of **EduVision**, an AI-powered interactive presentation system designed to transform conventional classroom lectures into dynamic, engaging experiences. The focus was on three tightly integrated components, a **PyQt5-based GUI** that lets instructors build multimedia-rich slides with text, images, and a various set of interactive widgets, a **custom smart pen** equipped with motion sensors, buttons, and Bluetooth that allows teachers to navigate and annotate directly on the projected display, and an **AI vision model** that processes live camera input to detect the pen tip, classify gestures, and map actions to on-screen interactions.

The first chapter dives into the depths of **Learning Theories** exploring the various techniques and challenges to understand how people acquire knowledge with the aim to enhance and build more effective teaching methods .

The second chapter details a collection of related works conducted beforehand ,adding into the inspiration for our project .

The third chapter covered the implementation, building the GUI , prototyping the smart pen hardware, and training/testing the U-net detection model, including dataset collection and performance metrics.

Through this project, we've gained hands-on a variety of technical skills such as GUI development , embedded systems , computer vision and training machine learning models from data collection to designing an architecture to train and test the models while also diving into the hardware side with electronic soldering and sensor integration .

The prototype met real-time accuracy and latency targets, demonstrating the feasibility of pen-driven, AI-enhanced teaching tools and the ability to upscale in terms of quality and efficiency.

Looking ahead, we plan to make lessons accessible online allowing for easier sharing and accessing previous works . We also aim to build and enhance the unique interactive file format with the goal of securing a patent to protect and formalize its innovation, ensuring it's protected and recognized as an original contribution. Future updates will include support for modifying existing DOCX and PDF files by embedding interactive elements directly into them, as well as introducing more dynamic and engaging components to enhance the teaching experience—all while maintaining focus exclusively on this project’s continued innovation.We also plan to redesign the smart pen both its physical structure and internal electronics to meet the requirements of mass production, ensuring reliability, affordability, and ease of manufacturing at scale.

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ملخص
تقدّم هذه الأطروحة تصميم وتطوير EduVision، نظام عروض تقديمية تفاعلي مدعوم بالذكاء الاصطناعي يهدف إلى تحديث أساليب التعليم في الفصول الدراسية. يدمج النظام واجهة مستخدم رسومية غنية بالأدوات التفاعلية ، وقلمًا ذكيًا مزودًا بحساسات للحركة و الاتجاه مزودا بتقنية البلوتوث للاتصال اللاسلكي ، بالإضافة إلى نموذج ذكاء اصطناعي يمكّن من تتبع التفاعلات مع شاشات العرض.

يتيح EduVision للمعلمين إنشاء عروض تقديمية ديناميكية، وتدوين الملاحظات على المحتوى مباشرة، وتفعيل عناصر تفاعلية مثل التصويت او اسئلة سريعة ، دون الحاجة للعودة إلى جهاز الحاسوب.

تم تدريب نموذج الذكاء الاصطناعي باستخدام مجموعة بيانات مخصصة لاكتشاف القلم الذكي وتفسير حركاته، مما يمكّن من تفاعل سلس بين المعلّم و المحتوى المعروض.

يمثل هذا المشروع نقطة التقاء بين البرمجيات والأجهزة الذكية والذكاء الاصطناعي، لتقديم تجربة تعليمية متكاملة.

الكلمات المفتاحية: الذكاء الاصطناعي في التعليم، التفاعل بين الإنسان والحاسوب، الرؤية الحاسوبية، القلم الذكي، العروض التقديمية التفاعلية، التعلم العميق، الأنظمة المدمجة, .

Abstract

This master’s thesis presents the design and development of **EduVision**, an AI-powered interactive presentation system aimed at modernizing classroom instruction. The system integrates a multimedia-rich **graphical user interface (GUI)** , a custom-designed **smart pen** equipped with motion sensors and Bluetooth, and an **artificial intelligence model** that enables real-time tracking of gestures and interactions projected on classroom screens. EduVision allows educators to create dynamic presentations, annotate live content, and trigger interactive elements such as maps and quizzes—all without returning to the computer. The AI model was trained using a custom dataset to detect the smart pen and interpret its movements, enabling seamless interaction between teacher and content. This project bridges software, hardware, and artificial intelligence to deliver a cohesive, hands-free teaching experience.

Keywords: AI in Education, Human-Computer Interaction, Computer Vision, PyQt5, Smart Pen, Gesture Recognition, Interactive Presentations, Deep Learning, Embedded Systems.

Résumé

Ce mémoire de master présente la conception, le développement et l’évaluation de **EduVision**, un système de présentation interactif basé sur l’intelligence artificielle, visant à moderniser l’enseignement en présentiel. La solution repose sur l’intégration d’une **interface graphique** riche en contenus multimédias ,d’un **stylo intelligent personnalisé** doté de capteurs de mouvement et de connectivité Bluetooth, ainsi que d’un **modèle d’intelligence artificielle** capable de suivre en temps réel les gestes projetés à l’écran. EduVision permet aux enseignants de créer des leçons interactives, d’annoter en direct les contenus projetés, et d’activer des éléments interactifs tels que des votes ou des quiz, sans avoir à retourner à l’ordinateur. Le modèle d’IA a été entraîné sur une base de données personnalisée pour détecter et interpréter les mouvements du stylo intelligent. Ce travail allie logiciels, matériel embarqué et intelligence artificielle pour offrir une expérience d’enseignement immersive, intuitive et engageante.

Mots-clés : Intelligence Artificielle, Vision par Ordinateur, Interaction Homme-Machine, Éducation Numérique, Stylo Intelligent, Reconnaissance de Gestes, Présentations Interactives, apprentissage profond.