SmartINNO

BEGINNER LEVEL

COURSE 1: DEFINITIONS, TYPES, AND INTERDISCIPLINARY APPROACH OF SMART TEXTILES IN DIFFERENT INDUSTRY FIELDS

Task: WP1

Responsible partner: TITERA d.o.o. Slovenia

Participating partner(s): SmartTex Netzwerk Germany, Textile ETP Belgium

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Project Number: 2024-1-DE02-KA210-VET-000253979
KA210-VET - Small-scale partnerships in vocational education and training (KA210-VET)

Skills for Smart Textiles: Identification of required skills in the smart textile industry and development of online training content in two levels.

COURSE 1: DEFINITIONS, TYPES, AND INTERDISCIPLINARY APPROACH OF SMART TEXTILES IN DIFFERENT INDUSTRY FIELDS

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Introduction

Welcome to **Course 1: Introduction to Smart Textiles.**

This document complements the accompanying PowerPoint video on our YouTube site. It's introductory and provides a basic level of awareness of smart textiles, their classifications and their cross-industry application. This document covers two main topics:

- Definition and Types of Smart Textiles & Core Technologies Used – A discussion of what smart textiles are, the different types of smart textiles, and the core technologies used.
- Interdisciplinary Applications within Industries – Examining how smart textiles interact and influence industries such as healthcare, fashion, sport, and more.

After reading this paper, you will be well-versed in the evolving landscape of smart textiles and how they will shape the future of different industries.

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Definition and Types of Smart Textiles & Core Technologies Used

This chapter introduces smart textiles, their classifications, and the fundamental technologies behind them.

Smart textiles include a wide range of materials designed to interact with their environment through embedded technologies. Smart textiles include a wide range of materials designed to interact with their environment through embedded technologies. Depending on their level of functionality and responsiveness, they can be classified into three main categories: passive, active, and ultra-smart textiles.

Passive smart textiles are the simplest form, offering enhanced properties without reacting to external stimuli. These include UV-protective fabrics, antibacterial textiles, and moisture-wicking materials often found in sportswear. While they do not change or adapt dynamically, they provide essential benefits such as comfort, protection, and durability[1].

Active smart textiles take functionality a step further by responding to changes in their surroundings. They incorporate technologies that allow them to alter their properties based on environmental conditions. For instance, thermochromic pigments change colour with temperature variations, while photochromic fabrics react to sunlight, shifting shades when exposed to UV rays. Shape-memory alloys embedded in textiles can adjust their form when activated by heat, offering applications in medical and performance wear. These materials allow garments to be more interactive and adaptable to user needs[2].

At the most advanced level, **ultra-smart textiles** not only sense and react to external stimuli but also process information and respond intelligently[3]. These textiles often integrate conductive fibres, flexible circuits, or even self-healing materials. Some ultra-smart fabrics are capable of biometric monitoring, collecting real-time data on heart rate, body temperature, or hydration levels. Others can store and transmit information, creating possibilities for interactive clothing and wearable technology in healthcare, sports, and even military applications.

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Figure 1: Smart textiles use different conductive yarns depending on the application — each type serves a unique purpose based on what the textile needs to do. Image courtesy of ITP GmbH, Germany.

The functionality of smart textiles is made possible by a variety of specialized materials and embedded technologies. Thermochromic and photochromic pigments enable colour-changing effects based on heat or light exposure. Conductive fibres, infused with metallic or carbon-based materials, facilitate electrical conductivity, making it possible for textiles to generate heat, detect movement, or even transmit data. Phase-change materials help regulate temperature by absorbing and releasing heat, making them valuable for extreme weather conditions or high-performance sportswear[4].

Electroluminescent textiles, which emit light through embedded materials, are increasingly used in fashion, safety clothing, and artistic designs, making garments more visible and interactive[5].

Through these advancements, smart textiles are revolutionizing industries such as healthcare, sports, fashion, and even defence. Their ability to sense, adapt, and respond to external conditions is paving the way for innovative applications that go far beyond traditional fabric functions, bringing us closer to a future where clothing and textiles seamlessly integrate with digital and interactive technologies.

A significant category within this field is electronic textiles (e-textiles), textiles integrated with electronic components such as batteries, lights, sensors, and microcontrollers. These components can be embedded at various levels, including fibres, yarns, fabrics, coatings, and embellishments.

A complete e-textile system typically consists of five key components:

- Sensors: Detect environmental changes (e.g., pressure, temperature, humidity)
- Actuators: Respond to stimuli, such as heating or light emission
- Energy Components: Power the system, including batteries or energy-harvesting units
- Data Processing Units: Analyse and interpret signals from sensors

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- Communication Devices: Enable data transmission and connectivity

E-textiles are highly adaptable and customizable for various applications, from wearable health monitoring to interactive fashion. Integrated technologies such as LED lighting, heating and cooling systems, and sensor-based monitoring enable these textiles to collect, process, and transmit data in real time, making them invaluable in multiple industries.

To integrate technologies like electronics, conductive inks, or embroidered sensors into fabrics, these components must be applied to a textile carrier. The textile carrier acts as the base material that holds and supports the electronic components while maintaining flexibility and comfort. These carriers can be made from a variety of materials, such as synthetic fibres like nylon and polyester, or natural fibres like wool and cotton. Common types of carriers include fabrics like jerseys, bands, or even special textiles like spacer fabrics.

The choice of carrier material depends on the specific needs of the application. For example, the material needs to be lightweight, flexible, and durable to ensure that the integrated electronics function properly while also providing comfort and wearability.

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Sensor types

A textile sensor is a type of sensor embedded into fabrics to detect and react to changes in the environment, such as pressure, temperature, humidity, or movement. These sensors can be flexible and lightweight, making them ideal for applications like health monitoring, wearable tech, and smart clothing. Made from conductive or sensitive materials, they gather data and send it to a processor, which analyses and responds in real-time. Essentially, textile sensors turn everyday fabrics into "smart" materials that interact with their surroundings or the wearer [6, 7, 8].

Temperature sensors in smart textiles are integrated devices that monitor and respond to temperature changes on the skin or within the surrounding environment. These sensors are integrated or attached to fabrics, enabling continuous temperature monitoring for different applications, including healthcare, sports, and environmental sensing.

Figure 2: Demonstration of a cooling textile in action, linked to a temperature monitoring device, clearly displaying the real-time temperature of the object undergoing cooling. Image courtesy of ITP GmbH, Germany.

In a similar manner, **humidity sensors** in smart textiles are integrated devices that detect and measure moisture levels in the environment or on the skin. It is possible to continuously monitor humidity for applications such as construction, athletic performance optimization, and medical applications. The development of textile-based humidity sensors involves selecting appropriate integration techniques to ensure durability, flexibility, and accuracy.

Pressure sensors in smart textiles detect force, weight, or touch applied to the fabric. They are used in healthcare, sports, and human-computer interaction (smart gloves).

There are many more sensor types used in smart textile applications such as optical sensors, strain sensors, pH sensors, biochemical or motion sensors and many more. As technology progresses, the sensors are also developed, and the potential applications are researched[9].

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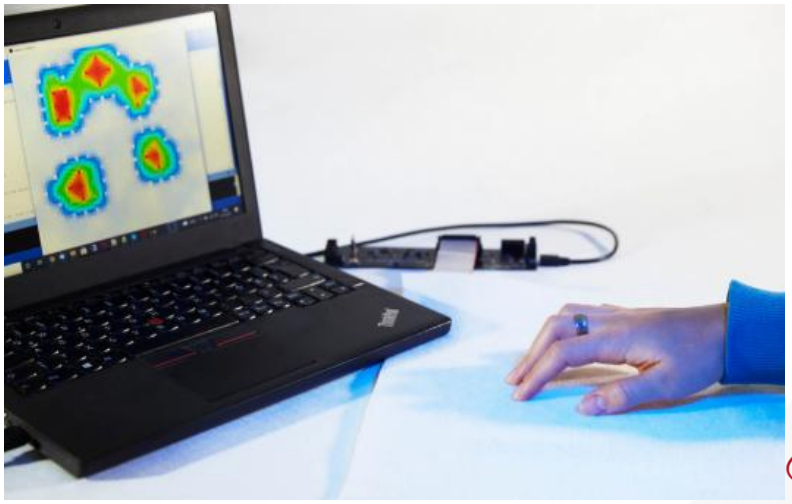

Figure 3: An advanced pressure-sensing textile system linked to a computer unit, mapping and displaying localized pressure points across the fabric surface. Image courtesy of ITP GmbH, Germany.

Technologies used

Various technologies can be used to bring smart textiles to life. Different technologies allow textiles to respond to environmental factors, monitor the wearer's health, or even interact with other devices. The process of making smart textiles can also involve a combination of different methods, depending on the type of textile, its intended use, and the functionality desired. Smart characteristics can be integrated at various stages of textile production, starting from the yarn itself and extending to the application of smart components onto the finished fabric or final textile product.

Textile surfaces and products can be upgraded with conductive yarns through, for example, embroidery. Embroidery allows for the integration of conductive yarns. This enables the application of components like sensors, conductive paths, or heating wires to the fabric. This method offers a stable way to integrate sensors.

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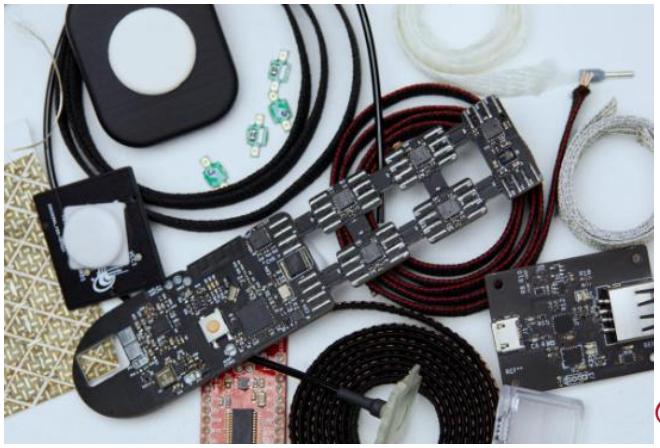

Figure 4: Smart textile products bring together multiple elements, and knowing the right technology to connect them is key to making it all work. Image courtesy of ITP GmbH, Germany.

Conductive ink printing enables the integration of intelligent functions into textiles with high resolution[10]. One of the main challenges is ensuring washing resistance and preventing cracking under mechanical stress. Conductive ink can be applied to textiles using various methods, such as a screen or stencil printing, or inkjet printing. Screen printing requires curing in an oven to maintain conductivity and secure the ink to the fabric. Inkjet printing, on the other hand, is a digital process that applies small drops of ink directly onto the textile without contact, eliminating the need for a stencil[11].

The incorporation of conductive yarns into conventional textile threads can be done manually by sewing conductive yarns or automatically through techniques such as embroidery, weaving, knitting, and braiding machines. Similarly, conductive, luminous, optical, or shape-memory yarns can be used as warp threads in weaving or inserted as weft threads to create various effects.

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Interdisciplinary Applications within Industries

Smart textiles have found use in multiple industries through interdisciplinary innovation. By combining materials science, electronics, and advanced manufacturing techniques, these textiles are transforming sectors such as healthcare, sports, automotive, aerospace, and fashion. Their ability to sense, react, and adapt to environmental conditions makes them valuable for applications ranging from monitoring health parameters to enhancing performance and safety. In this section, we present some of the areas where smart textiles are already used and explain how they integrate knowledge from multiple disciplines to create innovative solutions across different industries.

Medicine

Healthcare is one of the most promising areas for smart textile applications. Wearable healthcare devices are used in diagnostic and therapeutic processes. ECG sensors, to continuously measure heart rate, are integrated into the garments like smart t-shirts[12]. Interestingly, new wound care technologies have been introduced to overcome the limitations of conventional treatments. These include bioengineered skin substitutes and smart dressings equipped with sensors and drug delivery systems. For example, smart wound dressings can track wound conditions in a real-time, offering crucial data that helps healthcare providers make better treatment decisions. These cutting-edge products not only accelerate the healing process but also aim to shorten hospital stays and enhance overall patient recovery outcomes.

A Switzerland based company Xsensio[13] has developed a groundbreaking wearable device that tracks biochemical data from the interstitial fluid (Interstitial fluid -ISF- is the fluid that surrounds and fills the spaces between cells in tissues throughout the body), unlike traditional devices that monitor physical data. At the core of this device lies a sensing chip, which uses advanced nanotechnology, biochemistry, and microfluidics to analyse the biochemical composition of the body in real-time. This chip can include multiple sensors targeting specific biomarkers like metabolites, proteins, ions, and hormones, enabling detailed, multiparametric analysis. The data is wirelessly transmitted to users, caregivers, or healthcare providers via a secure app.

Denmark-based company, ABENA Nova[14] combines innovative sensor technology with high-quality incontinence products to improve care by providing real time data on product saturation. This allows caregivers to change products exactly when needed, allowing for more personalized care. The integrated sensors track where and how urine spreads. The wearable clip then transmits this information via Bluetooth and 4G to the monitor app, indicating caregivers to take action.

The company Sensoria Health[15], USA, developed a foot protection solution in collaboration with a leading podiatrist and former Nike shoe designer, aimed at better protecting diabetic

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foot wounds with a design patients will want to wear. The shoe reduces foot pressure by up to 50% compared to other protective boots, promoting healing. It features a durable, abrasion-resistant sole and offers support and pressure relief. The Sensoria Diabetic Foot Ulcer Boot App tracks steps, activity, and boot usage, sending real-time updates to the physician's cloud system to guide treatment and track monitoring time for potential reimbursement.

Construction and Interior (or decoration)

Smart textiles can significantly improve indoor environmental quality. This addresses the quality of a building's indoor environment. This parameter (the indoor environmental quality-IEQ) is determined by multiple factors like lightening, air quality, temperature, humidity and space acoustics[16].

Eschler GmbH[17], Germany based company is shaping the future of textile engineering by developing smart textiles that integrate lighting, heating, and sensors. By merging electronics with textiles, they create innovative solutions like ambient lighting, wall panel heating, and interactive wall systems.

IKEA[18], Sweden based company, has developed air-cleaning textiles to improve indoor air quality and help people live healthier lives. The product GUNRID an air-purifying curtain, developed with universities and innovators across Europe and Asia, uses a unique mineral-based photocatalyst coating that breaks down common pollutants like formaldehyde and odours when activated by both indoor and outdoor light. With air pollution being a major health risk, IKEA aims to raise awareness of indoor air pollution, which can be just as harmful as outdoor air. The curtain offers a simple, affordable solution that fits seamlessly into homes, improving air quality without taking up extra space.

Diffus[19] is a Copenhagen based design studio developing industrial innovations and material research. Their ELAC product uses advancements in OLED and LED technology to enhance acoustic ceiling tiles. Unlike traditional methods that require removing acoustic material for lighting installation, ELAC integrates light and circuitry directly onto the textile tiles, making the process very simple. Through a soft embroidery technique, the tiles are easily installed. The system works with a central "brain" tile that controls up to 8 surrounding tiles, and multiple sets of tiles can be combined to create a larger light surface. The brain tile also includes sensors for wireless interaction, allowing the system to adapt to its environment.

Sports

Athletic apparel is no longer just a simple layer of fabric, but it has become an advanced tool that connects athletes to their environment.

Advanced Sports Textiles are revolutionizing how athletes train, compete, and interact with their gear by integrating technology into the fabric itself. These textiles can monitor key

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metrics like pressure, muscle activity, foot pressure, hydration, temperature, and movement, offering valuable insights into an athlete's performance and health.

With technologies like real-time biometric monitoring and sensor-embedded clothing, the sportswear industry is evolving rapidly, providing athletes with smarter gear that enhances comfort, performance, and fit.

Alpina, a Slovenian company produces ski boots and hiking boots with integrated heating systems to provide comfort to the users in cold conditions. The system operates at full power for the initial warm-up and then automatically returns to normal power, ensuring optimal warmth without overheating. The entire system, including batteries and heating elements, is fully integrated inside the boot for the user's convenience.

French company clim8 produces heating clothing for outdoor and sport applications.

German company Rico Wappler – Lederhandschuhmanufaktur produces heating gloves: https://handsching.com/en/measure-gloves/album/15-heizende-handschuhe-1

WANT TO LEARN MORE?

Websites:

- **SmartX Innovation Hub:** https://www.textile-platform.eu/innovation-hub-smartx
- **Wearable technologies:** https://wearable-technologies.com/

Exhibitions, Fares:

- **Smarttex Netzwerk Workshops and Symposiums, Jena, Germany:** https://smarttex-netzwerk.de/de/
- **Smart Textiles Showroom, Boros, Sweeden:** https://smarttextiles.se/en/smart-textiles-showroom/?utm
- **Techtextil Fare, Frankfurt, Germany:** https://techtextil.messefrankfurt.com/frankfurt/en.html

Interesting companies to explore:

- **ITP GmbH, Germany:** Home - ITP - smart textiles engineering
- **EMBRO GmbH, Germany:** https://embro.de/en/
- **SensingTex, Spain:** Sensing Tex - Stretchable Electronics, Smarter Connectivity
- **SunFibre, Czechia:** https://sunfibre.com/

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