



## Report on IT tools for behavioural change

(Deliverable 5.1)

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## 1. Executive Summary

Antimicrobial resistance (AMR) is a growing global health threat, requiring integrated responses that combine public policy, technological innovation, and professional training. This report, developed under the European project AMR EDUCare, provides a foundation for identifying and developing key skills needed to prevent and manage AMR. It focuses on two connected domains: behavioural change and IT tools, both essential for effective training and stewardship.

This report identifies, classifies, and evaluates IT tools that enable behaviour change relevant to AMR prevention and management across healthcare settings, and proposes selection and adoption criteria for AMR-EDU Care.

Key contributions of the report include<sup>1</sup>:

- An analysis of behavioural change models, with emphasis on the COM-B<sup>2</sup> model and the Behaviour Change Wheel<sup>3</sup>, which provide a framework for understanding and influencing clinical practices related to antibiotic use.
- Identification of effective interventions in hospital and primary care settings, highlighting the value of multi-component strategies that combine education, restriction, enablement, and environmental restructuring.
- Emphasis on digital health literacy as a cross-cutting competency for professionals and the public, essential for the critical and ethical use of digital technologies in combating AMR.
- A structured taxonomy of IT tools relevant to behaviour change, ranging from educational platforms and mobile apps to AI-powered systems, and evaluates them using criteria such as effectiveness, accessibility, scalability, interoperability, safety, privacy and user engagement.

This report recommends prioritising Clinical Decision Support Systems (CDSS), feedback dashboards, mobile apps and gamified tools, and e-learning platforms as key IT solutions to strengthen antimicrobial stewardship (AMS). These tools support knowledge, motivation, and real-time prescribing decisions, while emerging technologies like AI, VR, and AR offer

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<sup>1</sup> In this report, the term 'IT tools' includes digital solutions such as mobile apps and dashboards, as well as institutional systems like CDSS and audit platforms

<sup>2</sup> COM-B model as the core of the **Behaviour Change Wheel (BCW)** framework and is the most widely cited source for both academic and applied. See work of Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 42. <https://doi.org/10.1186/1>

<sup>3</sup> Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, 6(1), 42. <https://doi.org/10.1186/1748-5908-6-42>

additional opportunities where infrastructure allows. Their effectiveness depends on integration into clinical workflows, user acceptance, and strong digital health literacy to ensure equitable use. Overall, the findings highlight that AMR prevention and management are best advanced through multi-component digital strategies that combine education, decision support, and continuous feedback.

## 2. Introduction

Antimicrobial resistance (AMR) is a major global health threat that undermines effective treatment, raises costs, and increases mortality. In 2019, bacterial resistance was associated with an estimated 1.27 million deaths worldwide (Antimicrobial Resistance Collaborators, 2022). AMR now sits centrally within international public health agendas, including pandemic preparedness and One Health.

In response, many countries have adopted National Action Plans (NAPs) to tackle AMR. These plans provide strategic frameworks to improve AMS, regulate antimicrobial use in healthcare and agriculture, strengthen surveillance systems, and raise public awareness. However, the success of NAPs depends on behavioural and institutional change within health systems. Healthcare professionals also play a main role in this effort, in prescribing, patient communication, and the effective use of digital tools aligned with evolving standards of care. practices but also in how they communicate with patients, engage with IT tools, and adapt to evolving standards of care. This report addresses that implementation gap by focusing on behaviour change supported by IT tools.

The AMR EDUCare project promotes a pedagogical framework designed to equip healthcare professionals with the skills necessary to combat AMR through evidence-based clinical practice and effective public engagement. Here, behavioural change skills are essential for promoting responsible antibiotic prescribing, effective patient communication, and adherence to stewardship principles.

This report examines how IT tools can support behaviour change in the prevention and management of antimicrobial resistance (AMR). It is part of the AMR EDUCare project that aims to strengthen the competencies of healthcare professionals through digitally enabled education and training. It constitutes one of two deliverables within Work Package 5 (WP5), which was responsible for the development and implementation of behavioural change and IT tools in educational materials for AMR stewardship. Deliverable 5.1 identifies stakeholder needs, behavioural models, digital health frameworks, and IT tool types relevant to stewardship behaviours. Deliverable 5.2 translates these findings into training materials and practical recommendations for healthcare workers.

Thus, this report provides a foundation for designing future AMR education and training tools, supporting the broader goal of the AMR EDUCare project, which is equipping the health workforce with both behavioural insights and IT tools needed to address the AMR crisis through informed, adaptive, and collaborative practice.

Information was collected through a review of literature and stakeholder consultations. The analysis is guided by behavioural science (particularly the COM-B model and the Behaviour Change Wheel) and digital transformation. We use these frameworks to identify enablers and barriers across capability, opportunity, and motivation, and to characterise how different IT tools can influence practice. The report outlines how various IT tools, from clinical decision support systems and mobile applications to gamified platforms and AI-powered technologies, can support AMS by informing decisions, shaping habits, and reinforcing best practices.

We consider IT tools used by healthcare professionals and health systems in hospital and primary care settings in Europe, with relevance to broader contexts. The primary audience is educators, health leaders, and practitioners implementing AMS.

The following section outlines the methodology that guided development of behaviour change and IT tools in the AMR EDUCare project.

### 3. Methodology

This section explains the approach used to identify relevant IT tools for behaviour change in AMR, including the literature review and stakeholder consultations. To guide the development and integration of behaviour change and IT tools in the AMR EDUCare training materials (which are described in deliverable 5.2), a scoping review of the existing literature was conducted in parallel with stakeholder consultations.

#### 3.1 Literature review objectives

The literature review had three core objectives:

- To identify behavioural theories and models commonly applied in AMR-related interventions.
- To identify and map effective tools, techniques, and programmes already in place; and
- To identify knowledge gaps and areas where behavioural strategies and IT tools had limited reach or impact.

We systematically searched scientific and grey literature using databases such as PubMed, Scopus, and Google Scholar, and targeted reports from WHO, ECDC, and OECD. Keywords included ‘antimicrobial resistance,’ ‘behaviour change,’ ‘digital skills,’ ‘digital tools,’ and ‘healthcare professionals.’ The search included peer-reviewed studies, policy reports, and evaluations of digital interventions.

#### 3.2 Stakeholder consultations

To complement the literature, empirical data was collected with the goal of identifying the needs of the target population of AMR EDUCare, ensuring practical relevance. A diverse range of stakeholders were consulted:

- Healthcare professionals (physicians, nurses, pharmacists and hospital managers)

- Patients and informal carers
- Policy makers, health authorities and representatives of international organizations
- Members of the general public (with a focus on responsible antibiotic use)

In total, 90 professionals contributed insights.

Engagement involved a combination of methods that included workshops, semi-structured interviews, focus groups, document analysis and stakeholder surveys.

The feedback gathered from these consultations directly informed the selection of behavioural science frameworks and IT tools, ensuring that the materials developed (see deliverable 5.2) were aligned with the real-world training needs of healthcare workers.

### 3.3 Tool selection criteria

Each behavioural model was mapped to antimicrobial prescribing and infection prevention behaviours to highlight relevant barriers, facilitators, and change mechanisms in real-world AMR scenarios. A broad range of IT tools were identified and classified according to a custom taxonomy based on functionality, user type, and behavioural target.

Tools were assessed using the following criteria:

- Effectiveness (evidence of impact)
- Accessibility (ease of use and reach)
- Scalability (potential for broader deployment)
- Interoperability (integration with existing systems)
- User engagement (motivation and usability)
- Data safety and privacy (compliance with GDPR and ethical use)

Findings from the literature and consultations inform the theoretical framework presented in the next section.

## 4. Behavioural Analysis in the AMR Context

### 4.1 Behavioural determinants

This section summarises behavioural determinants relevant to AMR and outlines the frameworks (COM-B and BCW) used to guide the analysis of IT tools.

Understanding and influencing behaviour is essential to tackling antimicrobial resistance (AMR). Despite the availability of clinical guidelines, inappropriate antibiotic use remains widespread across healthcare systems. Behavioural science helps explain this gap between knowledge and practice, offering tools to design interventions that address the underlying drivers of prescribing behaviour.

Behavioural change models in healthcare have evolved over several decades, starting with early psychological theories such as the Health Belief Model, the Theory of Planned Behaviour, and Social Cognitive Theory (1950s-1970s). These frameworks aimed to explain how individual beliefs, perceived risks, and social norms influence health-related decisions. More recently, “nudge” theory, popularised by Thaler and Sunstein (2008), has drawn attention to low-cost, subtle interventions that guide behaviour without restricting choice.

In the context of AMR, behavioural approaches gained traction in the early 2010s as it became clear that policy directives and clinical protocols alone were insufficient. For example, a study by Meeker et al. (2016) demonstrated that a simple behavioural nudge, such as posting commitment letters with accountable justification for prescribing by physicians, could significantly reduce inappropriate antibiotic prescribing rates. The strength of this approach lay in its simplicity, affordability, and ease of replication, sparking a broader wave of behavioural research and interventions.

Before exploring specific models, it is important to clarify what is meant by “behaviour change.” In everyday language, the term often refers to a modification or shift in behaviour. However, such definitions tend to be vague, offering little insight into the direction, drivers, or consequences of that change. In psychology, behaviour change has a more established and nuanced foundation. Traditionally, it has been defined as “a systematic approach to changing behaviour through the use of operant conditioning,” or more clinically, as “any alteration or adjustment of behaviour that affects a patient’s functioning, brought about by psychotherapeutic or other interventions, or occurring spontaneously” (APA, n.d). The reference to operant conditioning is particularly noteworthy, as it highlights the role of learning through consequences, where positive reinforcement strengthens a behaviour, and punishment suppresses it (APA, n.d). Closely related is the concept of “behaviour modification,” which applies learning techniques, often including operant conditioning, to alter harmful or maladaptive behaviours.

We can thus begin to understand behaviour change as a process that often involves learning, and one that encompasses both the adoption of desirable behaviours and the discontinuation of less desirable ones. But this leads us to a more practical question: how does behaviour change occur, and how can it be effectively influenced? Addressing this question is central to the AMR EDUCare approach, which embeds these theoretical models into the design of training modules that translate knowledge into concrete clinical practices, supported by the strategic use of digital tools.

## **Understanding the COM-B Model and the Behaviour Change Wheel**

As previously mentioned, psychology has a long-standing tradition of developing models, theories, and frameworks to explain behaviour and guide behavioural interventions. A widely used framework in this field is the COM-B model, developed by Michie et al. (2011). It defines behaviour (B) as a function of three interacting components: Capability, Opportunity, and Motivation. If one or more of these elements is lacking, the desired behaviour is unlikely to occur. COM-B serves as the foundation for the Behaviour Change Wheel (BCW), which

links behavioural drivers to nine intervention functions (such as education, persuasion, or enablement) and supporting policy strategies. These frameworks formed the foundation of the work conducted on behavioural change in the context of AMR within Work Package 5 (WP5) of the AMR EDUCare project. In Work Package 5 (WP5) of the AMR EDUCare project, the COM-B model and Behaviour Change Wheel (BCW) were applied to systematically design and evaluate IT tools aimed at fostering behavioural change in AMS. By mapping the Capability, Opportunity, and Motivation components of COM-B, WP5 identified key barriers to appropriate antibiotic prescribing, such as limited clinician knowledge (capability), time constraints in clinical workflows (opportunity), and habitual prescribing practices (motivation). Using the BCW, targeted interventions were developed, including educational platforms to enhance capability, clinical decision support systems to improve opportunity, and feedback mechanisms to boost motivation. Concrete outcomes included the creation of a taxonomy of IT tools (Section 6.1) tailored to these behavioural drivers, with preliminary insights indicating improved prescribing accuracy in pilot settings where multi-component interventions were tested, particularly those combining education and real-time decision support. These findings informed the selection criteria for scalable, user-centered digital solutions (Section 6.2), emphasizing the need for context-specific adaptations.

Each component of COM-B captures a different dimension of human behaviour:

1. Capability refers to an individual's psychological and physical capacity to engage in the desired behaviour. This includes knowledge, reasoning, memory, attention, and physical skills. For example, a healthcare provider may lack the pharmacological knowledge needed to select the most appropriate antibiotic.
2. Opportunity encompasses external factors that make the behaviour possible or prompt it. This includes physical opportunity (e.g. access to diagnostic tools or time within clinical workflows) and social opportunity (e.g. cultural expectations or professional norms).
3. Motivation includes all brain processes that energise and direct behaviour, both reflective (e.g. conscious planning, beliefs about consequences) and automatic (e.g. emotions, habits, cues). In antibiotic stewardship, a clinician's motivation may be shaped by a desire to meet patient expectations or by routine habits built over time.

While COM-B offers a conceptual model of individual behaviour, it also serves as the foundation for designing targeted interventions. By understanding which component(s), capability, opportunity, or motivation, are lacking or misaligned, one can begin to develop more effective strategies for behaviour change. This is where the Behaviour Change Wheel becomes particularly useful. Surrounding the COM-B core, the BCW provides a taxonomy of intervention functions, such as training, modelling, incentivisation, coercion, and environmental restructuring, that can be strategically deployed. These are further supported by policy categories, such as guidelines, regulation, fiscal measures, or service delivery systems, that enable or reinforce behaviour change at the systemic level.

In Figure 1, these three domains mentioned, Capability, Opportunity, and Motivation, are represented as overlapping sections around a central “Behaviour” circle. For example, to achieve behavioural change, one might enhance capability (the core layer) through training (the intervention layer), supported by official guidelines or service delivery mechanisms (the policy layer). This structured, integrative approach has been applied in various public health domains, such as the English Department of Health’s 2010 tobacco control strategy and NICE’s guidance on reducing obesity (Michie et al., 2011).

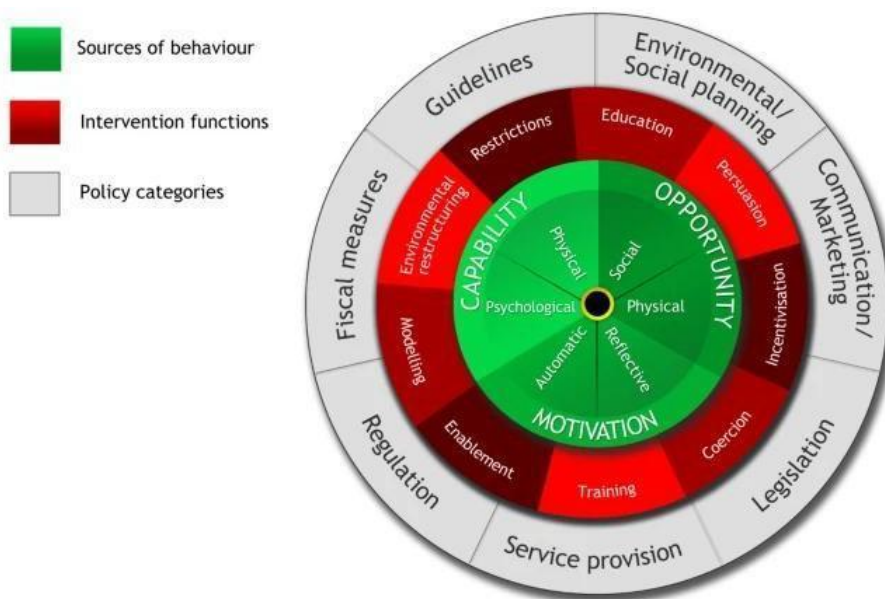


Figure 1 COM-B model and the Behaviour Change Wheel (Michie et al., 2011)

## Evidence from Behavioural Interventions in AMR

To better understand the mechanisms through which behaviour change interventions can improve antibiotic use, this section briefly summarises findings from four recent systematic reviews. These studies offer insight into how different behavioural strategies, grounded in models like COM-B, are applied in clinical and public health contexts and what factors contribute to their success or failure.

A 2021 systematic review analysed 43 studies on AMS interventions in low- and middle-income countries (LMICs; Cuevas et al., 2021)

The review found that:

- 69.8% of interventions had a positive impact on responsible antibiotic use.
- 62.8% specifically improved prescribing practices, though most improvements were modest (often under 20%).
- Multi-component interventions, especially those combining education, restriction, and enablement, were more effective than single strategies.

- Stand-alone restriction-based interventions consistently showed statistically significant improvements.
- Education was the most frequently used and impactful component, particularly when paired with training.

The authors concluded that education enhances both capability and motivation, thereby amplifying the effects of other strategies. Interventions aligned with policy functions, such as context-specific guidelines or structural planning, showed the greatest promise. Cost analyses also indicated potential savings from optimised prescribing and reduced drug overuse.

Pouly et al. (2022) reviewed 123 multimodal AMS interventions in hospital settings. Their analysis found that:

- 64% of interventions were categorised as effective in improving prescription quality or reducing use.
- The most effective function was restriction, but enablement, environmental restructuring, and education were the most common components in successful interventions.
- Under enablement, tools like real-time recommendations, algorithms, and alerts were highly impactful.
- For environmental restructuring, introducing new tasks and physical resources produced the greatest improvements.

Prescribing was the dominant target behaviour in these settings. The review also stressed the importance of multidisciplinary collaboration and involving healthcare professionals in intervention design to enhance effectiveness and acceptance. These insights directly support addressing opportunity and motivation through system-level change and user engagement.

A review by Suttels et al. (2022) covered 30 studies of AMS interventions in primary care. It examined both individual- and collective-level change strategies and reported the following:

- Educational efforts targeting patients alone were largely ineffective.
- GP education was often used as a supporting component, but its independent effect was hard to isolate.
- Communication skills training (e.g. shared decision-making) had moderate success in reducing antibiotic use.
- Delayed prescribing was well-accepted and effective, especially when supported by training and clear guidelines.
- Point-of-care diagnostics (e.g. POC-CRP, POC-PCT) showed promise, but long-term effects remained unclear.

At the organisational level:

- Guideline dissemination had mixed outcomes, particularly among older GPs.
- Multifaceted quality improvement programmes, such as those based on CDC stewardship principles, led to modest reductions in prescribing.

- Provider feedback was more effective when informed by behavioural science, but was resisted in time-constrained settings or by GPs already aware of their prescribing patterns.

Public campaigns and regulatory measures were widely implemented but showed limited standalone effectiveness. In contrast, in countries like Sweden, combined interventions involving benchmarking, tailored guidelines, reimbursement restrictions, and public education produced sustained declines in antibiotic use. Across studies, time pressure and workflow constraints were key barriers, emphasising the need for flexible, low-burden interventions.

Craig et al.'s (2023) review covered 290 AMS interventions in human healthcare, offering a broad view across settings. Key findings include:

- The most common interventions were audit and feedback, education, and guideline implementation.
- While relatively few studies reported large-scale reductions in antimicrobial use, most showed improvements in adherence to treatment guidelines.
- Among studies reporting on AMR outcomes, just under 50% documented positive changes.
- Critically, only a minority of studies employed behavioural theory in their design. This gap suggests that many IT tools and interventions missed opportunities for stronger impact through theory-informed approaches.
- The review called for standardised evaluation methods and metrics, which are essential for scaling and adapting successful strategies.

The lack of consistent behavioural foundations in digital AMR tools reinforces the need for frameworks like COM-B in designing effective, context-sensitive solutions.

Across all four reviews, several clear patterns emerge:

- Multi-component interventions consistently outperform single strategies, especially when combining education with structural and motivational elements.
- Contextualisation is important: tailoring interventions to local practices, resource levels, and user expectations enhances adoption and effectiveness.
- IT tools show promise, but many lack behavioural grounding and long-term engagement strategies.
- Stakeholder participation, sustained feedback, and alignment with institutional priorities are essential for real-world success.

The AMR EDUCare project builds on these lessons by using a behaviourally informed, multi-component approach targeting capability and motivation, supported by IT tools. In doing so, it recognizes that no single actor or intervention can shift entrenched prescribing patterns or public behaviours alone. Instead, coordinated, theory-informed efforts are needed across all levels of the healthcare system.

## 4.2 Stakeholder needs assessment

Stakeholder consultations revealed behavioural priorities and actionable recommendations to support responsible antibiotic use. Participants highlighted Antibiotic Prescribing, Patient Education and Duration of antibiotic prophylaxis as critical behaviours requiring targeted intervention to combat AMR. Specific actions requiring change to reduce AMR were also identified:

- Prescribing guidelines
- Preoperative prophylaxis guidelines
- Discontinuation of prolonged or wrong prescriptions of antibiotics
- Frequent antibiotics review
- Incorporation of a One Health perspective
- Increase interdisciplinary care and communication
- Patient and population health literacy

Participants also indicated barriers and difficulties regarding responsible antibiotic practices. These included interoperability, behaviour change, time pressure, organisational culture, limited access to diagnostics, regulatory challenges and digital literacy gaps. On the other hand, training opportunities, institutional support and feedback mechanisms were identified as facilitators of positive behaviours.

Together, these insights highlight the multifaceted nature of AMS and underscore the importance of interventions targeting different domains of behaviour change (e.g., capability, motivation and opportunity) to support sustainable improvements in practice.

## 4.3. Mapping of behavioural needs

The analysis of stakeholder input enabled the identification of priority behaviours that directly influence AMS. To translate these insights into a targeted intervention, behavioural needs from each group were mapped against the COM-B model:

- Healthcare Professionals are central to prescribing decisions. Effective interventions for this group often focus on improving capability (e.g. through clinical guidelines, decision-support tools), reinforcing motivation (e.g. feedback systems, peer comparison), and enhancing opportunity (e.g. access to diagnostics, supportive institutional policies).
- Patients influence prescribing through expectations, treatment adherence, and health-seeking behaviours. Communication training for providers, public-facing educational materials, and shared decision-making tools are key to shifting both social norms and individual habits.
- Policymakers shape the broader environment through regulatory, financial, and policy instruments. Interventions here include guideline development, enforcement mechanisms (e.g. prescription control), and investments in system-level enablers such as surveillance infrastructure.

- The General Public is the audience for mass awareness campaigns. Strategies typically focus on raising understanding of AMR risks, discouraging self-medication, and encouraging trust in evidence-based care. Social marketing, behavioural nudges, and school-based education have all been employed with varying success

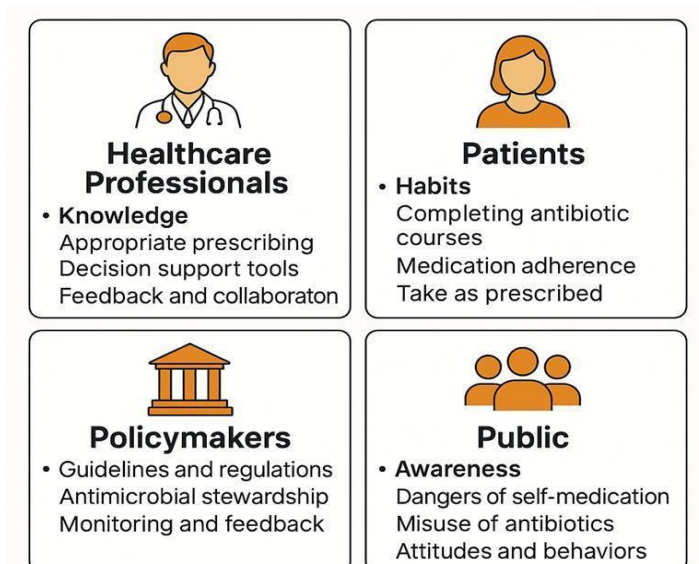


Figure 2 Targeting Stakeholders to Combat Antimicrobial Resistance (AMR)

In summary, the analysis of stakeholder input, evidence from behavioural interventions, and mapping of priority behaviours has highlighted several key gaps and needs in AMS. Among healthcare professionals, critical gaps include inconsistent adherence to prescribing guidelines, insufficient treatment review practices, and limited patient-provider communication.

The intersection between behavioural needs and digital competences is particularly significant. IT tools offer opportunities to reinforce knowledge, support adherence to guidelines, and provide real-time feedback. However, their effectiveness depends on users' capability to engage with these technologies, the availability of supportive infrastructure, and alignment with behavioural motivators. Recognising this intersection highlights the need for future interventions to not only target behavioural change but also leverage digital solutions and focus on digital skills.

Deliverable 5.2 will expand on these insights, translating them into actionable performance and change objectives for the development of AMR EDUCare training materials.

The next section explores how IT-based interventions can enhance stewardship efforts, improve guideline adherence, and support informed decision-making in clinical practice.

## 5. Digital Transformation in the Governance AMR

### 5.1 Role of IT tools as enablers of opportunity and behaviour change

Digital interventions have become central to modern strategies for promoting behaviour change in AMS. These tools, ranging from mobile apps and decision-support systems to AI-driven nudges and gamified learning platforms, support more accurate prescribing, increase awareness of AMR risks, and improve engagement among both healthcare professionals and patients.

At the global level, the World Health Organization (WHO) and the OECD emphasise the role of digital solutions in strengthening surveillance systems, improving data exchange, and supporting public engagement. In Europe, the EU Digital Health Strategy and the European Health Data Space highlight interoperability, secondary use of health data, and the integration of digital tools into healthcare delivery. These initiatives provide the policy foundation for the development and deployment of IT tools relevant to AMR prevention and management.

For AMR governance, digital transformation has three main implications:

- Surveillance and data integration. Systems such as WHO's GLASS (2022) platform or national antibiotic consumption databases show how digital infrastructures enable cross-country monitoring of resistance and prescribing trends.
- Clinical decision support. Embedding stewardship alerts and prescribing guidelines into electronic health records (EHRs) provides real-time influence on prescribing behaviour.

Care delivery models. Telemedicine and digital consultations shape antibiotic use in outpatient settings, while AI and big data applications can detect emerging resistance patterns and support resource allocation. In this case, evidence from across global settings (US, UK, Southeast Asia, and parts of Africa) shows that well-designed digital interventions can meaningfully change prescribing behaviour. For example, tele-AMS programmes have allowed remote hospitals to access infectious disease specialists, improving prescribing accuracy in underserved areas. Mobile apps have provided real-time access to local guidelines and dosage calculators at the point of care, reducing inappropriate antibiotic use. Gamified platforms have enhanced learning and adherence among students and professionals, while AI-based alerts and peer comparison tools have successfully nudged prescribers toward evidence-based decisions.

However, the success of these tools is not solely dependent on technological innovation. Their impact relies heavily on integration into clinical workflows, alignment with cultural and professional norms, and responsiveness to the specific needs of users. Challenges such as alert fatigue, information overload, increased workload, and digital inequality underscore the importance of thoughtful design, ongoing support, and cultural sensitivity.

In this respect, behavioural science frameworks such as the COM-B model and the Behaviour Change Wheel (BCW) are essential. They help identify which components of behaviour,

capability, opportunity, and motivation are being targeted by a tool, and what kinds of support (e.g. education, enablement, persuasion) are needed to make change sustainable.

## 5.2. Digital health literacy as a cross-cutting competence

A key facilitator of AMS is Digital Health Literacy (DHL). Defined as the capacity to access, understand, appraise, and apply digital health information (WHO, 2023), DHL blends traditional health literacy with digital and media literacies. It allows professionals and patients alike to engage meaningfully with tools like EHRs and mHealth apps (Lee et al., 2021; Van Den Broucke et al., 2020). DHL plays a foundational role in determining the effectiveness of digital interventions. Tools that are difficult to navigate, poorly contextualised, or fail to engage users with varying levels of digital proficiency are unlikely to deliver behavioural impact, even if technically sound. This is particularly relevant in AMR contexts, where both clinicians and patients need to understand and act on complex information about infection risks, treatment guidelines, and resistance data. Clinicians with stronger digital literacy are better equipped to monitor antibiotic use, recognise resistance trends, and implement stewardship practices effectively (European Commission, 2018). In this context, DHL is not an optional skillset but a foundational competency for safe, informed, and effective AMR governance.

Despite these benefits, digital skills acquisition remains uneven across the workforce. Studies show that adoption levels are strongly influenced by age, professional specialisation, and access to training opportunities (Mežnarec & Bogataj, 2021). For example, younger professionals often display greater adaptability to new IT systems, while older or less digitally literate colleagues may struggle with complex platforms. These disparities risk deepening the “digital divide” within healthcare delivery. During the COVID-19 pandemic, vulnerable groups, including older adults, rural populations, and low-income communities, faced disproportionate digital exclusion (Coulby et al., 2020; Milanti et al., 2023). These gaps limit both individual and system-level resilience against AMR.

Barriers to integration include:

- **Time constraints:** Heavy workloads leave little space for training (Borges Do Nascimento et al., 2023; Caton et al., 2024).
- **Lack of structured training:** Few institutions have systematic digital skills programmes, leading to inconsistent competency levels (Kaihlainen et al., 2024).
- **Institutional gaps:** Inadequate IT infrastructure, interoperability issues, and limited technical support hinder implementation (Borges Do Nascimento et al., 2023; Oudbier et al., 2024).
- **Privacy and security concerns:** Widespread apprehension about data breaches can reduce trust and willingness to use digital platforms (Oudbier et al., 2024).

These broader digital health transformations provide the context for IT tools specifically targeting behaviour change in AMR, described in the next section.

## 6. IT tools for Behaviour Change (preliminary mapping)

### 6.1 Taxonomy of IT Tools

Understanding how IT tools contribute to behaviour change in AMS requires a clear classification system. We present a taxonomy of IT tools based on their primary function and the behavioural mechanisms they are designed to influence. Drawing on behavioural science (particularly the COM-B model and the Behaviour Change Wheel), persuasive technology design, and existing AMS interventions, the tools are grouped into six overlapping categories:

- Educational Platforms

These tools aim to improve psychological capability by increasing knowledge and awareness of AMR and appropriate antibiotic use. Examples include:

- Online learning modules
- Interactive webinars
- Multimedia toolkits and e-courses

Educational platforms support reflective motivation by encouraging deliberate reasoning and informed decision-making. When integrated with peer learning or feedback mechanisms, they can also reinforce social norms and professional identity (Charani et al., 2019).

- Clinical Decision-Support Systems (CDSS)

CDSS are typically embedded within electronic health records (EHRs) and provide tailored, context-specific prescribing recommendations. They address both reflective and automatic motivation, by prompting clinicians at the point of decision and reducing cognitive load.

When CDSS incorporate local resistance data or are updated in real-time, they can reduce broad-spectrum antibiotic use, support timely de-escalation, and promote adherence to guidelines (Cresswell et al., 2017). They also enable environmental restructuring by embedding stewardship directly into clinical workflows.

- Mobile Applications

Mobile apps serve multiple behavioural functions: they can reinforce capability through education, opportunity through reminders, and motivation through feedback. Typical features include:

- Guideline access
- Dose calculators
- Shared decision-making tools
- Push notifications for review or stop dates
- Data Feedback Systems and Dashboards

These tools offer real-time visualisation of prescribing patterns, benchmarking against peers, and institutional performance tracking. Rooted in social influence and feedback loops, dashboards help normalise responsible prescribing behaviour and can motivate change by promoting transparency and accountability (Hallsworth et al., 2016). They are especially effective when tailored to specific user roles (e.g. department heads vs individual prescribers) and when linked to performance improvement targets.

For example, the ARK Dashboard is part of the [Antibiotic Review Kit \(ARK\)](#) intervention, a stewardship programmes rolled out across 39 UK hospitals. The dashboard provides real-time visualisation of antibiotic prescribing patterns, including rates of review and discontinuation at 48–72 hours. It supports multiple user roles:

1. Frontline prescribers receive immediate feedback on their antibiotic prescriptions.
2. Department heads and antimicrobial leads access aggregated benchmarking data across wards and with national performance.
3. Hospital leadership can monitor progress toward institutional targets, such as reducing broad-spectrum antibiotic use.

This intervention was evaluated through a stepped-wedge cluster-randomised controlled trial published in *Lancet Infectious Diseases*, which found that ARK led to a 4.8% reduction in antibiotic use per admission without negatively impacting 30-day mortality (Glover et al., 2023). Most participating hospitals integrated dashboard insights into ongoing improvement efforts.

For example, a mobile clinical decision support app was implemented as part of an AMS initiative at a university hospital in Brazil. The app aimed to optimize antibiotic prescribing by providing locally tailored guidance at the point of care. It included:

1. Access to guidelines based on local epidemiology to reduce inappropriate use of broad-spectrum agents.
2. Dose calculators and treatment optimization tools.
3. Shared decision-making support, offering real-time prescription recommendations.
4. Push notifications reminding prescribers to review and de-escalate therapy when appropriate.

This intervention was evaluated in a longitudinal before-and-after study over 12 months. Use of the app was associated with a statistically significant reduction in

the consumption of piperacillin/tazobactam and meropenem, improved antimicrobial susceptibility profiles for key pathogens, and a cost saving of over USD 296,000 in antibiotic expenditure. The study highlights how mobile apps can reinforce capability (via education), opportunity (via reminders), and motivation (via feedback on antibiotic use and outcomes) to support responsible prescribing practices in the fight against antimicrobial resistance.

## 5. Gamified Tools

Gamified platforms use game mechanics, points, levels, competition, and rewards, to promote engagement, learning, and habit formation. They are especially effective for early-

career professionals, students, and community education initiatives (Subhash & Cudney, 2018). Gamification supports automatic motivation by stimulating curiosity, reinforcing desired behaviours through repetition and reward, and reducing resistance to learning (Sardi et al., 2017). These tools often enhance affective engagement, a critical but underused mechanism in AMS efforts.

One great example here is Micro-Combat, a cooperative card-based simulation developed by ISGlobal under the EU-JAMRAI initiative, available both as a physical card game and a mobile app. In this game, players take on the roles of healthcare professionals tasked with protecting a city from a pathogen outbreak. Through decision-making, balancing treatment options, hygiene measures, and prevention tactics, players are exposed to real-world challenges such as drug resistance and limited resources. Designed for learners aged 10 and up, Micro-Combat has been used in classrooms and health awareness campaigns across Europe, providing an interactive, fast-paced learning experience that reinforces the importance of AMR prevention.

## 6. Emerging Technologies: AI, VR, and AR

Frontier technologies such as artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) offer powerful new modes of behavioural influence. Their contributions include:

- AI-based prescribing recommendations and resistance forecasting
- VR simulation of prescribing scenarios or infection control training
- Personalised interventions based on predictive analytics

These tools target multiple behavioural domains simultaneously, building capability (through realistic rehearsal), motivation (via adaptive prompts), and opportunity (by integrating with broader health system infrastructure) (Topol, 2019).

A summary of the selection process is provided in Table 1.

<b>TOOL TYPE</b>	<b>FUNCTIONALITY</b>	<b>TARGET USERS</b>	<b>AMR RELEVANCE</b>
E-learning Platforms	Deliver structured training and interactive content	Health professionals, students	Foundation for knowledge acquisition
Mobile Apps	Provide just-in-time information and reminders	Physicians, nurses	Promotes point-of-care learning and engagement
Clinical Decision Support Systems (CDSS)	Assist clinicians with guideline-based prescribing	Prescribers, pharmacists	Reduces inappropriate prescriptions through nudging
Gamification Tools	Reinforce correct behaviour through game mechanics	All health professionals	Motivates behavioural change via incentives
Feedback Dashboards	Visualize prescribing patterns and resistance trends	Hospital and primary care teams	Supports audit-feedback cycles in stewardship
EHR-integrated Stewardship Modules	Embed AMR prompts and alerts into clinical workflow	Clinicians in digital health settings	Enables real-time intervention during prescribing

*Table 1 Overview of IT tools evaluated in the context of AMR EDUCare, including functionality, target users, and relevance to antimicrobial stewardship training*

## 6.2 Selection Criteria for Tools

In evaluating IT tools aimed at addressing antimicrobial resistance (AMR), several key criteria are used to assess their effectiveness and potential for widespread use. These criteria help determine whether the tools are likely to have a lasting impact on improving antibiotic stewardship and combating resistance across different healthcare environments. The theoretical foundations for these criteria draw upon established behavioural and technology adoption models that explain how digital interventions can influence health-related behaviours and be effectively integrated into clinical and public health systems.

To guide this process, we propose a selection framework grounded in behavioural science, technology adoption theory, and systems thinking. This framework draws on the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), the COM-B model and Behaviour Change Wheel (BCW) (Michie et al., 2011; 2014), Persuasive System Design (Oinas-Kukkonen & Harjumaa, 2009), and the WHO's Tailoring Antimicrobial Resistance Programmes (TAP) guidance (WHO, 2022). These models offer both explanatory depth and practical utility, enabling the assessment of tools based on their potential for sustained, meaningful impact.

### Theoretical Foundations

- UTAUT helps explain the conditions under which users adopt and continue using IT tools, with a focus on performance expectancy, effort expectancy, social influence, and facilitating conditions. These dimensions inform criteria such as interoperability and user engagement.
- COM-B frames behaviour as a function of capability, opportunity, and motivation. Tools should enhance knowledge and skills (capability), embed into practice settings (opportunity), and trigger or sustain behavioural intention (motivation).
- BCW maps tool functions to intervention types (e.g. education, persuasion, enablement), linking them to concrete behaviour change techniques (BCTs) such as prompts, feedback, or reinforcement.
- Persuasive System Design (PSD) provides a lens to evaluate how tools promote engagement through design elements like reduction of friction, credibility cues, and real-time feedback loops.
- The TAP framework and One Health-informed systems approaches (Loh et al., 2023) underscore the need for context-sensitive, equity-oriented tools that adapt across healthcare settings, including low-resource environments.

### Selection Criteria

Drawing on the above, we define five core criteria for selecting IT tools in AMS and AMR contexts:

#### 1. Effectiveness

*Does the tool reliably change antimicrobial-related behaviours?*

This refers to the tool's demonstrated ability to reduce inappropriate prescribing, improve adherence to guidelines, or enhance health-seeking behaviours. Effectiveness should be supported by empirical evidence (e.g. controlled studies, real-world data) or strong theoretical justification.

## 2. Scalability

*Can the tool be deployed across diverse contexts and systems?*

Scalability includes both technical replicability and behavioural adaptability. A scalable tool works in different settings, urban or rural, high- or low-resource, without compromising functionality or user relevance. This aligns with TAP's emphasis on contextual tailoring (WHO, 2022).

## 3. Accessibility

Is the tool usable by diverse populations, including those at risk of digital exclusion?

This includes compatibility with various devices and platforms, multilingual options, and intuitive design. Accessibility reflects an equity lens, ensuring tools can reach users regardless of geography, digital literacy, or socioeconomic status (Oinas-Kukkonen & Harjumaa, 2009).

## 4. Interoperability

*Does the tool integrate with existing digital infrastructure?*

Effective tools should work seamlessly with EHRs, prescribing systems, or surveillance databases. Interoperability reduces duplication, supports real-time data exchange, and facilitates institutional uptake (Venkatesh et al., 2003).

## 5. User Engagement

Does the tool promote consistent, meaningful use over time?

Engagement reflects both initial adoption and sustained use. Tools that are easy to use, personally relevant, and offer feedback or incentives tend to achieve higher retention and impact. Engagement can be reinforced through persuasive design features such as reminders, gamification, and personalisation (Michie et al., 2014).

Together, these criteria: effectiveness, scalability, accessibility, interoperability, and user engagement, are grounded in behavioural and technology adoption frameworks (van Dort et al., 2022; Loh et al., 2023). They provide a robust basis for evaluating IT tools designed to promote AMS, improve healthcare practices, and ultimately reduce the global burden of AMR.

We've included a series of tables below to visually aid the interpretation of the aforementioned selection criteria across models and tools. The three tables below provide a comprehensive analysis of these tools across different dimensions: technical and operational performance (Table 2), user adoption factors (Table 3), and alignment with behavioural change models (Table 4).

TOOL CATEGORY	EFFECTIVENESS	SCALABILITY	ACCESSIBILITY	INTEROPERABILITY	USER ENGAGEMENT
Educationa l Platforms	Improves knowledge and antibiotic prescribing (Charani et al., 2019)	Accessible via online platforms; replicable globally	Accessible with internet and multimedia support	Can link to LMS and online repositories	Interactive modules promote sustained use
Clinical Decision Support Systems (CDSS)	Reduces broad-spectrum antibiotic use and improves timing (Cresswell et al., 2017)	Deployable across EHR-integrated systems; updates can be centralised	Requires system integration; moderate literacy needed	Strong integration with EHRs and prescribing tools	Real-time feedback increases repeated usage
Mobile Applications	Enhances adherence and clinician behaviour (Car et al., 2017)	Widely accessible via smartphones and adaptable to various settings	User-friendly with basic tech literacy; offline functions possible	Potential for integration with alerts and decision trees	Reminder features enhance routine use
Data Feedback Systems and Dashboards	Enables benchmarking and behaviour adjustment (Hallsworth et al., 2016)	Customisable dashboards for local or national use	Requires basic digital skills; visual dashboards increase usability	Links with prescribing databases and institutional targets	Peer comparison enhances motivation
Gamified Tools	Boosts protocol adherence and retention (Sardi et al., 2017)	Can be deployed through online games or training modules	High engagement; appealing across education levels	Less integrated; typically standalone	Reward systems increase engagement and learning retention
Emerging Technologies (AI, VR/AR)	Simulates decision-making and forecasts resistance (Topol, 2019)	Growing infrastructure allows expansion across simulation labs and cloud services	May require high digital literacy and institutional access	Dependent on AI model integration and platform compatibility	Immersive environments encourage repeat usage

Table 2 Technical and operational performance

Table 2 assesses IT tools based on five core criteria: effectiveness, scalability, accessibility, interoperability, and user engagement.

- Educational Platforms stand out for their global accessibility and ability to enhance knowledge through interactive modules.
- Clinical Decision Support Systems (CDSS) are effective in improving prescribing practices, with strong integration into electronic health systems.
- Mobile Applications offer high adherence rates and usability across settings, with potential for integration into clinical workflows.
- Data Feedback Systems and Dashboards support behavioural change through peer benchmarking and real-time data.

Gamified Tools encourage knowledge retention and protocol adherence via rewards and engagement strategies.

- Emerging Technologies (AI, VR/AR) simulate complex clinical scenarios, though they require significant infrastructure and digital literacy

TOOL CATEGORY	PERFORMANCE EXPECTANCY	EFFORT EXPECTANCY	SOCIAL INFLUENCE	FACILITATING CONDITIONS
Educational Platforms	Improves clinical knowledge and prescribing accuracy	Easy-to-navigate interfaces with multimedia support	Peer forums and shared modules encourage participation	Needs stable internet and institutional support
Clinical Decision Support Systems (CDSS)	Supports evidence-based prescribing in real-time	Varies by system integration and UI complexity	Institutional norms influence use in clinical practice	Requires IT infrastructure and system compatibility
Mobile Applications	Improves health behaviour and decision-making	Intuitive design tailored to non-specialists	Endorsements and social proof drive use	Depends on smartphone access and app deployment
Data Feedback Systems and Dashboards	Reinforces data-driven improvement in prescribing	Requires data literacy but often user-friendly	Benchmarking against peers promotes social accountability	Needs integration with health data repositories
Gamified Tools	Enhances motivation through interactive content	Gamified simplicity supports ease of use	Team-based play or leaderboards encourage social motivation	Simple tools with minimal setup requirements
Emerging Technologies (AI, VR/AR)	Personalises decision-making and simulates complexity	Can be technically demanding to use	Less direct influence, more expert-driven adoption	High dependency on hardware, bandwidth, and institutional support

Table 3 Adoption factors

Table 4 evaluates tools in terms of performance expectancy, effort expectancy, social influence, and facilitating conditions.

- Educational Platforms are user-friendly and supported by peer interaction, though reliant on stable internet and institutional backing.
- CDSS deliver high clinical value, with usage influenced by integration quality and institutional norms.
- Mobile Applications are intuitive and benefit from social endorsements and widespread smartphone use.
- Feedback Systems/Dashboards drive data-informed improvements and encourage accountability through peer comparison.
- Gamified Tools combine motivational appeal and ease of use, with minimal technical requirements.
- Emerging Technologies offer personalised and complex simulations, but pose usability challenges and require advanced infrastructure.

TOOL CATEGORY	COM-B ALIGNMENT	BCW ALIGNMENT	PERSUASIVE SYSTEM DESIGN	WHO TAP ALIGNMENT
Educational Platforms	Enhances psychological capability through knowledge acquisition	Education, Training, Enablement	Tailored messaging, reduction, suggestion	Strengthens professional training at national scale
Clinical Decision Support Systems (CDSS)	Supports reflective and automatic motivation via clinical prompts	Persuasion, Environmental restructuring	Real-time feedback, self-monitoring, dialogue support	Customisable for local prescribing practices
Mobile Applications	Strengthens physical opportunity and motivation via reminders	Enablement, Incentivisation	Reminders, personalization, credibility support	Useful for regional public health campaigns
Data Feedback Systems and Dashboards	Influences reflective motivation with feedback and social norms	Feedback, Monitoring, Enablement	Social comparison, praise, self-monitoring	Enables continuous quality improvement with data
Gamified Tools	Drives automatic motivation through reward-based engagement	Incentivisation, Persuasion, Training	Simulation, praise, rewards, tunneling	Scalable for youth engagement in targeted settings

Emerging Technologies (AI, VR/AR)	Builds capability and motivation through immersive simulations	Training, Modelling, Environmental restructuring	Simulation, personalization, rehearsal	Adaptable to national and institutional simulations
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*Table 4 Alignment with behavioural change models*

Table 4 examines how each tool aligns with the COM-B model, Behaviour Change Wheel (BCW), persuasive system design principles, and the WHO’s TAP framework.

- Educational Platforms enhance psychological capability and support national-scale professional development.
- CDSS influence both reflective and automatic motivation via real-time prompts and feedback.
- Mobile Applications target physical opportunity and motivation, using reminders and credible content to influence behaviour.
- Feedback Systems/Dashboards shape reflective motivation through social norms and continuous performance monitoring.
- Gamified Tools drive automatic motivation using rewards and interactive experiences, especially effective for youth engagement.
- Emerging Technologies build both capability and motivation through immersive simulations, well-suited for institutional training contexts.

The combined analysis of the three tables highlights that there is no universally superior tool; rather, a combination of complementary solutions should be tailored to specific contexts, clinical goals, and user profiles. Educational platforms and mobile apps offer broad accessibility and are well-suited for large-scale, low-cost interventions. CDSS and dashboards are particularly effective in institutional settings with robust health IT infrastructure, while gamified tools and emerging technologies provide innovative avenues for engaging targeted audiences and simulating complex scenarios. Tool selection should be guided by behavioural science principles and existing system capabilities to maximise impact and ensure sustainable improvements in antibiotic prescribing practices.

Based on the synthesis of literature, tool evaluation criteria (effectiveness, accessibility, scalability, interoperability, user engagement, safety, and privacy), and the educational goals of AMR EDUCare, we recommend prioritising the following categories of tools for implementation and further piloting in AMR contexts:

- Clinical Decision Support Systems (CDSS) integrated into Electronic Health Records (EHRs): These tools offer high impact at the point of care by guiding prescribers with real-time, evidence-based recommendations and alerts. They are particularly useful for reducing inappropriate antibiotic prescriptions and can be embedded in clinical training simulations.

- Feedback Dashboards: Visual, data-driven feedback loops (e.g., antibiotic use, resistance patterns) support audit-and-feedback strategies that are proven to influence prescriber behaviour. They are also valuable pedagogical tools in educational modules focused on data interpretation and stewardship outcomes.
- Gamified Learning Tools and Mobile Apps: These tools promote user engagement and can help reinforce knowledge and behaviours in a flexible, accessible format. They are particularly relevant for junior professionals and learners in resource-constrained settings.
- E-learning Platforms: Foundational for knowledge dissemination, e-learning platforms support structured, modular training and can be adapted to different languages and professional contexts across Europe.
- While all tool categories offer relevant contributions, those that combine real-time decision support, data visualisation, and interactive learning—while maintaining strong privacy and usability standards—are especially recommended for AMR EDUCare.

Future steps include tailoring these tools to specific user groups (e.g., hospital vs. primary care professionals), ensuring alignment with local governance and interoperability standards, and embedding them into the broader training and evaluation framework of AMR EDUCare.

## 7. Conclusion

This deliverable set out to identify IT tools that support behaviour change in the prevention and management of AMR, and to provide preliminary guidance on their relevance and potential adoption. Using behavioural frameworks (COM-B, BCW) and stakeholder input, we mapped six main categories of IT tools: clinical decision support systems (CDSS), dashboards, mobile applications, gamified learning, tele-AMS platforms, and emerging AI applications.

The literature consistently highlights that successful digital interventions are those grounded in behavioural science. COM-B demonstrates that tools are most effective when they strengthen *capability* (knowledge, skills), enhance *opportunity* (workflow integration, system resources), and sustain *motivation* (norms, engagement). Our review shows that digital solutions often underperform when they focus only on information provision without addressing opportunity or motivation.

Based on available evidence and among the tools analysed, we recommend prioritising Clinical Decision Support Systems (CDSS) and Data Feedback Systems and Dashboards, particularly audit–feedback dashboards, as the most effective and evidence-based interventions for behaviour change in AMR. These tools directly influence prescribing behaviour at the point of care and provide actionable feedback, aligning with COM-B capability and opportunity mechanisms. Mobile applications and gamified learning can be valuable complements, particularly for training, motivation, and sustaining engagement among healthcare workers. Tele-AMS and AI-based tools hold future promise but currently

face barriers of maturity, scalability, and governance, and should be monitored for integration in later phases.

Findings from this deliverable suggest that training is essential to ensure digital tools are effectively adopted in practice. In particular, healthcare professionals will need support to develop digital literacy, confidence in using IT solutions such as CDSS and dashboards, and awareness of how these tools align with stewardship behaviours. Ensuring equitable access to training opportunities, especially in resource-constrained settings, is also critical to avoid widening healthcare inequities.

Choosing the right IT tools requires evidence of effectiveness and alignment with practical criteria. This deliverable highlights six critical dimensions for evaluation: effectiveness, accessibility, scalability, interoperability, user engagement, and governance (including privacy and ethics). These criteria provide a structured way to compare tools and ensure they are fit-for-purpose in diverse healthcare settings.

On a final note, a recurring theme is that successful implementation of digital solutions for AMR depends on complementing technology with supportive policies, training, and systems thinking. Future initiatives should focus not only on technological innovation but also on closing these systemic gaps to fully integrate digital advancements into the fight against AMR.

Building on this foundation, Deliverable 5.2 will set out how multimodal digital tools can be integrated into training modules and present recommendations based on the lessons from the implementation of the training programme. By aligning behavioural science with digital transformation, the project will move from identifying needs to developing a practical, scalable, and sustainable intervention that strengthen professional competencies and support responsible antimicrobial use.

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