Health Translation Queensland

Mapping the Health Research Digital Ecosystem

Health Research Digital Ecosystem Capability Statement and Blueprint for the Future

The University of Queensland, Queensland Digital Health Centre (QDHeC), CSIRO Australian e-Health Research Centre (AEHRC)

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Executive summary

Iterative improvement and innovation are essential to underpin the safe and effective evolution of our health care system to meet a rapidly changing health care environment. To achieve a learning health system, a mapping of Queensland's health research digital ecosystem is required. Supported by Health Translation Queensland (HTQ), together the Commonwealth Scientific and Industrial Research Organisation Australian e-Health Research Centre (CSIRO AEHRC) and The University of Queensland (UQ) Queensland Digital Health Centre (QDHeC) developed this health research digital ecosystem capability statement and blueprint for the future to highlight the efforts underway supporting digital health and medical innovation in Queensland.

The aim of the HTQ Health Research Digital Ecosystem project is to articulate the interconnections within the health and medical research digital ecosystems, and to develop information, tools and resources for end users navigating the digital ecosystems, and to guide relevant stakeholders for leading and investing in it. To support this overarching aim, this capability statement has been developed for our stakeholders to demonstrate the health research digital capabilities operational in Queensland.

Digital health is increasingly recognised around the world as the backbone of optimal health care delivery, opening new ways to deliver care to more people, more efficiently. Digital transformation enables the use of routinely collected data to continuously monitor and improve health care outcomes, facilitating what is known as a learning health system. In turn, a learning health system, one that is cohesive and cross-enterprise, platforms and boundaries, can better equip organisations to achieve the quadruple aim of health care which is better outcomes, improved patient experience, improved clinician experience and lower costs.

Due to its continuous investment into digital health capabilities, Queensland is well placed to progress towards a learning health system and cultivate translational and impactful health and medical research, with key investment across multiple key digital initiatives including integrated electronic records, consumer portal, telehealth, clinician health portal (The Viewer), Remote Patient Monitoring, Clinical and Business Intelligence, My Health Record (national electronic health record), and the use of agile development and cloud platforms. In particular, the integrated electronic Medical Record (ieMR) is used in Queensland Health (QH) digital hospital sites, delivering 48% of all acute public inpatient health care, providing a rich repository of data with the potential for use by QH and external researchers both internal and external to QH.

Numerous works are currently underway across key research institutions, united in developing digital and technology innovations to drive better health service delivery and health outcomes. These projects work closely with QH, leveraging the QH system capabilities described above, along with other health and emergency service providers within the broader health ecosystem. These work programs span areas including health data semantics and interoperability, system analytics providing real-time clinical and system-level decision support, digital therapeutics and care, bioinformatics and finally, infrastructure and platforms that allow researchers to use clinical and health data with appropriate levels of security and governance.

Health care delivery is changing rapidly. The use of technology and data is accelerating, and we need to ensure our clinical and broader workforce has the skills to effectively and safely lead this transformation.

1. Introduction

Over the course of Queensland's pandemic response, multi-disciplinary teams across QH, public and private hospitals and health services, other government departments, and research and industry partners worked collaboratively within and across organisational boundaries. The success of Queensland's response to the pandemic demonstrated the opportunities that could be realised when organisations work collaboratively to co-produce and implement innovative solutions to pressing health care challenges.

QH established a Reform Planning Group for a limited time period to prepare advice to the QH Director-General and the Deputy Premier and Minister for Health and Ambulance Services on system-wide reform activities for Queensland's health system arising from the COVID-19 pandemic. The final report highlighted that, enabled by technology, health and medical services, research and industry partners worked together and created a more open and equitable health system. Specifically, clinicians reported being able to work to their full scope of practice, sectors engaged more deeply, community-controlled organisations responded with incredible speed to their communities[1]. Consequently, consumers were provided with real-time advice and insight, and decisions were made quickly and at lower levels, with technology helping provide care closer to home.

Iterative improvement and innovation are essential to underpin the safe and effective evolution of our health care system to meet a rapidly changing health care environment. For research and innovation to thrive and to achieve an open, equitable and sustainable health system, end users across the ecosystem require appropriate and timely access to high-quality (linked) data. Specifically, secure and timely access to high-quality (linked) and real-time (or as much as possible) data enables the system to:

1. Co-produce knowledge and insights with key research and industry partners to drive health service and system improvements
2. Establish the foundational digital infrastructure for precision medicine, enabling the system to identify and effectively address waste, harm, and reduced/low-value care and
3. Effectively engage consumers in how their health care is delivered.

To realise these benefits and bring about a learning health system, a mapping of Queensland's health research digital ecosystem is required. Supported by HTQ, CSIRO Australian e-Health Research Centre and the UQ Queensland Digital Health Centre developed this capability statement to highlight the efforts underway supporting digital health and medical innovation in Queensland.

An 'innovative ecosystem' has been defined as "an evolving set of actors, activities, and artifacts, and the institutions and relations…that are important for the innovative performance of an actor or a population of actors"[2]. Within the context of this report, the health and medical research digital ecosystem is defined as the set of actors and artifacts, and the institutions and relations that are important for driving digital health and medical research in Queensland.

The aim of the HTQ Health Research Digital Ecosystem project is to articulate the interconnections within the health and medical research digital ecosystems, and to develop information, tools and resources for end users navigating the digital ecosystems, and to guide relevant stakeholders for

[1] Unleashing the potential: an open and equitable health system. Healthcare for Queenslanders in a pandemic ready world. Reform Planning Group: Final Report.(2020). The State of Queensland (Queensland Health), August 2020.
[2] Granstrand, O., & Holgerson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. Technovation, 90, 102098.

leading and investing in it. The outputs will enable effective translation of research into better health outcomes through data-driven health care practices inclusive of both health system capability, and research capabilities.

To support this overarching aim, this capability statement has been developed for our stakeholders to demonstrate the health research digital capabilities operational within CSIRO AEHRC and UQ QDHeC, to foster greater collaboration and represent Queensland's capability to further research funding appeal. This statement will also help ensure that ongoing activities and investments by relevant stakeholders can be considered within the broader requirements of the digital ecosystem to support the translation of research to clinical practice.

2. The role of digital health research and innovation

Health care, as it is currently delivered in Australia, is not sustainable. Health systems are straining under rising costs, increasing demand and consumer expectations, as well as growing wait times. The data needed to make complex health care decisions is stored in both paper and electronic records, making it hard to access and connect with. Currently, health research lacks the capability and capacity to translate this data into knowledge that can rapidly transform the health care system and improve health care outcomes.

Digital health is increasingly recognised around the world as the backbone of optimal health care delivery, opening new ways to deliver care to more people, more efficiently. A 2019 study by Ernst and Young Health Sciences and Wellness on the value of data in health care concluded that harnessing this information would seed innovation, advance medical research, and improve patient care[3]. As identified in the Digital Health 2031: A digital vision for Queensland's health system[4],

The use of technology and innovation to deliver and enable health care services includes, but is not limited to:

- supporting consumer engagement and capturing consumer health information
- enabling predictive modelling to support prevention and point of care decision making
- providing intelligence to inform strategic and operational decisions on models of care
- reporting on outcomes and supporting system governance
- enabling health research and education.

Indeed, a broad range of works are underway to continue developing predict-prevent models of health care to improve service delivery and support patient demand management (see Section 6).

Queensland is a national and international leader in many areas of digital health. Digital transformation is underway in practice, research, and training across the health system in this state.

In terms of research, there are 2 main types of data used, designed data and real-world data:

- **Designed data** is created using specialised methods by the user, often as point-prevalence disease snapshots, administrative datasets, and disease registries. Designed data is bespoke – It has been designed for a specific purpose and is often single-use, or repeated use for the same purpose[5].
- **Real world 'organic' data** is repurposed data that is automatically and routinely collected in real time from clinical or social systems, not through a specific research design[6].

Contemporary research techniques include the use of real-world data for research. This form of research meets clinical practice in digital health care.

[3] Ernst and Young. Realising the value of health care data: a framework for the future 2019.
[4] Digital Health 2031: A digital vision for Queensland's health system. (2021) The State of Queensland (Queensland Health).
[5] Groves, R. Designed data and Organic Data USA: United States Census Bureau 2011
[6] Xu H, Zhang N, Zhou L. Validity concerns in research using organic data. Journal of Management. 2019; 46; 1257-74.

3. Learning health system capability

When health care organisations embark on digital transformation (horizons framework – see Figure 1), they are taking the first steps toward becoming a learning health system[7]. Such a system collects all data from each episode of patient care, permits real-time analyses of the data by researchers and accelerates the translation of research findings into improved clinical practice and patient outcomes. Organisations start their transformation by routinely collecting large amounts of data in digital format for every patient, every time they interact with the system in real-time (Horizon 1). Organisations can leverage the data to create analytics (Horizon 2) and develop new models of care using the data and digital technology (Horizon 3). Going forward organisations can establish continuous learning cycles and care improvement, thus enabling a learning health system.

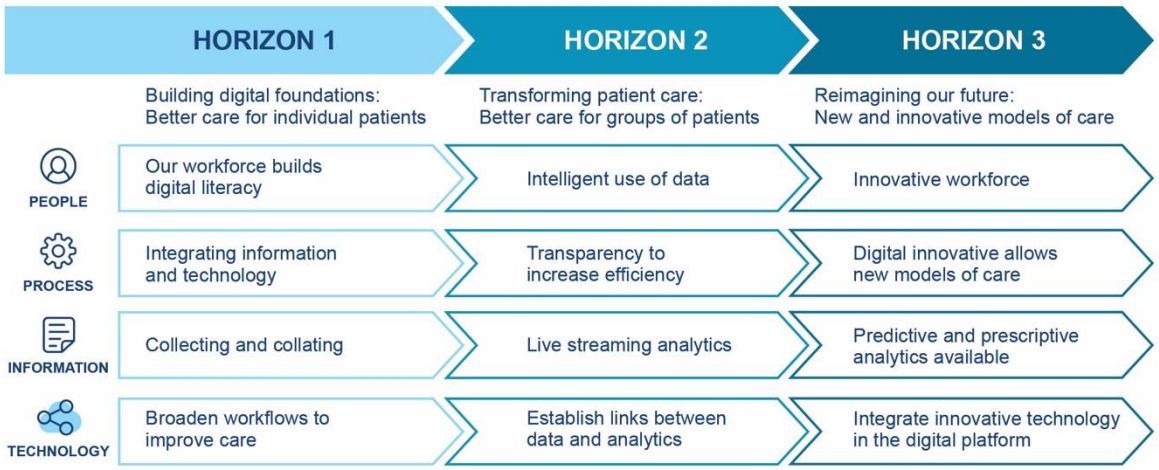

Figure 1. Three horizons framework for digital health transformation[8]

A learning health system "is designed to generate and apply the best evidence for the collaborative health care choices of each patient and provider; to drive the process of discovery as natural outgrowth of patient care; and to ensure innovation, quality, safety, and value in health care". Such a system aims to gather health information from clinical practice and information systems to improve real-time clinical decision making by clinicians that enables better quality and safety of patient care.

In Queensland, many initiatives are underway as the state continues to progress towards a learning health system. In 2017, the Princess Alexandra Hospital was the first hospital site to go live with the full suite of ieMR applications Since then, numbers have steadily increased to the current 16 sites, 14 of which have a full suite of advanced capability (see Figure 2). Over the past 5 years, the public hospital system has built digital foundations (Horizon 1), establishing good digital workflows within ieMR facilities and the routine collection of large amounts of digital data for each patient.

[7] Sullivan, C. S., Staib, A., McNeil, K., Rosengren, D., & Johnson, I. (2020). Queensland Digital Health Clinical Charter: A clinical consensus statement on priorities for digital health in hospitals. Australian Health Review, 44, 661-665.

[8] Sullivan C, Staib A, McNeil K, Rosengren D, Johnson I. Queensland Digital Health Clinical Charter: a clinical consensus statement on priorities for digital health in hospitals. Aust Health Rev. 2020;44(5):661-5

4. Integration of digital health research and health system

In order to complete the virtuous cycle of the learning health system, insights and knowledge gleaned from research and innovation needs to be integrated back into the health ecosystem, ultimately driving service improvements and better system outcomes. The UQ SMART project was established in Aug 2021, as a vehicle to enable a learning health system through accelerated and streamlined data extraction from the QH ieMR for research, innovation, and operations. A series of standard operating procedures (SOPs) have been created to map the processes from navigating the ethics and governance procedure to extract ieMR data for research purposes, to data linkage requests, to data extraction and validation procedures to maintain data privacy, integrity and fit within current legislative frameworks. Section 6 below outlines the work currently underway within Queensland as it continues its digital transformation, leveraging real-time data collected during routine care to create analytics products using aggregated data (Horizon 2) and establishing new models of care using the data and digital technology, for example, machine learning, artificial intelligence and predictive and prescriptive analytics.

5. Queensland's health system capability

Due to its continuous investment in digital health capabilities, Queensland is well-placed to progress towards a learning health system and cultivate translational and impactful health and medical research.

The health system in Queensland is well established, delivering world-class, quality care across multiple health domains. The 2031 Queensland population is projected to be approximately 3,207,000 persons, with 19.2% of those aged 65 and older. To support the health care needs of the population, almost $40 billion was spent on health in Queensland in 2018-19[9].

As identified in Queensland Health's Digital Health 2031 vision, digital and technology serve as fundamental enablers for the health system. Specifically, digital enables consumers greater access and control of their health information, and supports the delivery of integrated models of care and health system operations across vast geographical locations, while providing clinicians and system administrators the insights and intelligence to make better, more effective decisions.

Over $725 million has been expended on digital investments over the past 5 years. Key investments across multiple key digital initiatives over the past 5 years include:

- **Integrated electronic records** – deployment of a connected health record capability at 16 hospitals and 3 community facilities across Queensland (see Section 0)
- Consumer portal – providing the QH portal for consumers to coordinate referrals and appointments
- **Telehealth** – delivery of one of the largest managed telehealth networks in Australia, including video conferencing at more than 200 facilities
- **Clinician health portal** (The Viewer) – delivery of a portal for internal clinicians and external care partners that collates relevant consumer information from multiple health systems
- **Remote Patient Monitoring** – providing remote solutions to enable care in the appropriate setting

[9] Digital Health 2031: A digital vision for Queensland's health system. (2021) The State of Queensland (Queensland Health).

- **Clinical and Business Intelligence** – bringing our large complex data sets together and generating insights
- **My Health record** (national electronic health record) – better integration with nationally-shared consumer health information
- **Use of agile development and cloud platforms** – enabling rapid responses including the COVID-19 response and automating workflows.

These initiatives and systems provide a fertile foundation for digital health research and innovation that deliver improvements in health care safety, quality, and efficiency, and revolutionise the consumer experience through how and where they access health care services.

5.1 Queensland Health's integrated electronic Medical Record (ieMR)

Queensland has the largest digitally integrated health care delivery system in the nation. The integrated electronic Medical Record (ieMR) is used in QH digital hospital sites, covering approximately 48% of all acute inpatient beds. Currently, 16 QH sites use the ieMR, 14 of which use the full stack of advanced ieMR capability including electronic medications management, anaesthesia, and clinical trials applications (see Figure 2). An additional 3 community centres have rolled out the advanced ieMR solution. Remarkably, this ieMR is a single instance, spanning from far north Queensland to the Gold Coast, a distance of more than 1,500km. A recently announced $300 million investment by the Queensland Government over the next 5 years in the continued roll-out of the ieMR and $90 million over 3 years for the next tranche of the Infrastructure Maintenance Program will ensure that digital delivery of health care is business as usual in Queensland[10].

The ieMR offers a range of digitally enabled applications that permit clinicians and support staff to centrally document patient care. This complex, adaptive system integrates with multiple health systems such as external QH radiology and pathology programs, feeding information directly into a patient's electronic medical record. Consequently, the ieMR provides a rich pool of health data with the vast potential for research capability to guide new, improved models of care with the potential for use by QH and external researchers both internal and external to QH.

As Queensland health care undergoes rapid digital transformation, it is important that decision-makers hear the priorities and needs of consumers and clinicians. The Queensland Digital Health Consumer Charter[11] and Clinical Charter[12] have been created to clearly articulate these expectations.

[10] The Queensland Health and Hospitals Plan (2022) Queensland Government.
[11] Health Consumers Queensland. Queensland Digital Health Consumer Charter. Available from: https://www.hcq.org.au/qdhcc-full/
[12] Sullivan C, Staib A, McNeil K, Rosengren D, Johnson I. Queensland Digital Health Clinical Charter: a clinical consensus statement on priorities for digital health in hospitals. Aust Health Rev. 2020;44(5):661-5

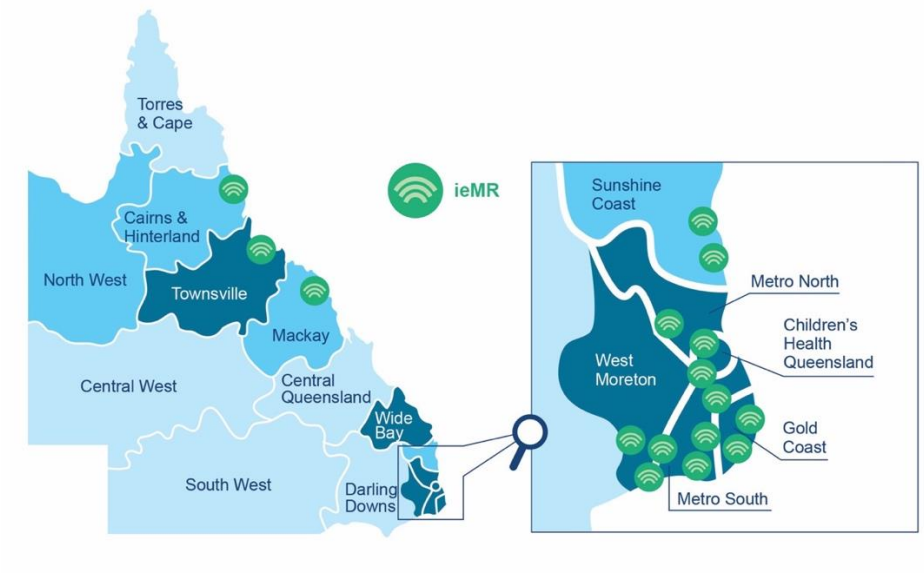

Figure 2. ieMR sites across Queensland

5.1.1 Usage

Around 27,000 users log into the ieMR system each business day. They place an average of 2.9 million electronic orders each month and sign more than 285,000 clinical notes per month. Information is stored in approximately 8,500 back-end data tables; the clinical event table, for example, consists of more than 4,000,000,000 rows. This volume of data requires a huge storage capacity, and the database currently sits at 50 terabytes plus 97 terabytes for scanned documentation.

5.1.2 Structured versus unstructured data

Data can be structured or unstructured in nature. Structured data includes codified information that is entered using standardised terminology (for example SNOMED-CT). This type of data can be readily navigated and extracted because of the way back-end tables are linked. While data extraction is traditionally undertaken by trained data analysis, other users will be able to extract data using new applications being developed by UQ and QH. Unstructured data includes free text clinical notes. This type of data is much more difficult to extract and requires specialist resources. UQ and QH have work underway to help streamline unstructured data extraction.

5.1.3 Encounters

The way patient information is entered into the ieMR is known as an encounter. Each time a patient makes contact with an ieMR hospital, an encounter is generated in their electronic medical record. Encounters include treatment in emergency and outpatient departments, as an inpatient, for chronic disease and in community health settings. An encounter will contain all documents, orders and results relating to a visit, which are filed together. Clinicians can retrieve data for all encounters for each patient.

5.1.4 Diagnoses

Alerts and problems are documented to help capture a patient's medical conditions and diagnoses. SNOMED-CT terminology, a standardised clinical terminology used in the electronic exchange of health care data, is used to help document a diagnosis – for example, to assist with clinical decision support and data retrieval, alongside any problems the patient may be experiencing – for example the patient may be at risk of falls, or an interpreter may be required. SNOMED-CT diagnoses codes are not mandatory fields within the ieMR and more work is needed to improve

documentation of alerts and problems. Therefore, researchers seeking cohorts defined by diagnoses may wish to use ICD-10 codes from another source in addition to ieMR data.

5.1.5 Histories

ieMR data permits documentation of histories surrounding 4 areas for each patient: family, procedural, pregnancy and social. Family history includes medical conditions of the patient's family members relevant to their own treatment or risk factors. These are categorised into common conditions within the systems of the body, such as cardiovascular, respiratory, and psychiatric.

Procedural history will include any procedure the patient has undergone at an ieMR facility. Users can also record procedures that pre-date the ieMR or were performed at another facility. Social history enables documentation of daily habits such as alcohol and tobacco use, diet, and exercise. Pregnancy history documents current or previous pregnancies and their outcomes.

5.1.6 Clinical documentation

Clinical data can be documented either through direct entry of information or scanning of documents. The ieMR includes templates that assist with documentation. In patient progress notes, for example, data will be unstructured. The 'ad hoc' section of the ieMR includes forms with a series of questions that consists of checkbox (structured) answers but may also require some free text (unstructured) information. Certain fields of the form may be mandatory to complete and will be indicated in yellow, for example, completing the height and pre-pregnancy weight on an antenatal booking form. Mandatory fields may offer significant volumes of information when looking to extract health data for research purposes.

5.1.7 Results

The ieMR interfaces in real-time with multiple external QH radiology and pathology programs. It provides access to radiology reports but does not display radiology images.

The ECG result section will only display integrated ECGs which have been transferred electronically from the ECG cart and the ieMR. Scanned ECG results can be uploaded to and viewed in other sections of the ieMR.

The interactive view or 'I-view' section of the ieMR is commonly used by nursing staff to chart results and observations. The fluid balance chart, where intake and outputs are documented and balances can be calculated, is one frequently used section of I-view. Many results recorded within I-view may be pulled into other areas of the patient chart, such as 'managing deterioration' or 'results' or 'lines, tubes and drains'.

There are numerous ways to enter vital signs in the ieMR. Vital signs monitors can be integrated with the ieMR, enabling results to be electronically uploaded into the chart once they've been verified by the clinician. Clinicians can manually enter this data. A section on managing deterioration displays a graphical representation of a patient's observations so clinicians can quickly identify patient trends. In addition to plotting results, the ieMR will calculate an Early Warning Score (EWS) whenever a complete set of observations is recorded. The EWS is determined using the Queensland Adult Deterioration Detection System, the Queensland Maternity Early Warning Tool, or the Children's Early Warning Tool. When results fall outside of the normal range, clinical decision support, such as pop-up alerts, will display advising the clinician to consider action or to escalate.

5.1.8 Orders

Clinical staff can place a variety of orders in the ieMR including medication, pathology, radiology, patient care and consultation orders. These have predefined instructions (known as order sentences) to help guide best practice.

Clinical decision support systems within the ieMR match individual patient characteristics to a computerised clinical knowledge database to generate patient-specific assessments or care recommendations. These systems include (but are not limited to):

- drug interaction alerts that reference the ieMR drug database, known as Multum. QH developed custom alerts, such as renal alerts for patients with impaired kidney function
- dose range checking alerts to guide prescribing within usual reference ranges for individual medication dosages
- therapeutic substitution to help guide prescribing in line with the list of approved medications at QH
- dose capping to help prevent the prescribing of excessive doses, and calculators to suggest weight-based dosing orders.

Clinicians have various ways of interacting with the ieMR to place orders and view results and documentation. These include M-pages, which are interactive pages that gather and consolidate patient information that can feed into other areas of a patient's chart. Order sets, also known as power-plans, are a form of clinical decision support system whereby groups of orders can be pre-designed to help clinicians follow best practice guidelines. For example, indication-based order sets can contain laboratory, patient care, consultation, and medication orders. These order sets can also contain phases to guide decision-making based on a particular outcome of a patient. For example, a heparin infusion order set may contain several phases based on the patient's most recent activated partial thromboplastin time (aPTT) result.

Plans of care are designed to facilitate optimal outcomes for patients during their inpatient stay by enabling an interdisciplinary team to share assessments, goals, and interventions in one place within the ieMR.

Once placed, medication orders will display on the Medication Administration Record (MAR). Nursing staff will document medication administration either manually via the MAR or via barcode scanning using the Medication Administration Wizard (MAW).

5.1.9 Allergies

Patient allergies are recorded in the ieMR using codified data to assist clinicians when they place orders for known allergens. Allergy information includes the substance known to cause a reaction, the type of reaction which occurs and the severity of the reaction. There is the ability to audit when clinical decision support has fired to flag a potential allergy and the response which was taken by the attending clinician.

5.1.10 Acute resuscitation plan

The ieMR can document an adult or paediatric resuscitation plan, including a clinical assessment of the patient, an assessment of the patient's capacity to consent to such a plan, whether the patient wishes to be resuscitated, and the patient's wishes for end-of-life care.

5.1.11 Advanced growth chart

The Advanced Growth Chart for children contains 6 types of growth measures including the Clinical Growth Chart (CDC), and World Health Organisation (WHO) and the Fenton growth charts. These record paediatric measurements, such as an infant's weight, height and head circumference, and plot measurements on appropriate charts according to the patient's age.

5.1.12 Maternity

The Pregnancy Health Record contains information relating to a patient's pregnancy and is printed and given to the patient at each visit. The Pregnancy Summary Report provides a summary of the patient's pregnancy.

5.2 Moving forward

The ieMR is a rich repository of data with the potential for use by QH and external researchers both internal and external to QH. To ensure that new digital health innovations are co-designed with stakeholders and take a human-centred approach, QH has commissioned numerous projects, such as the current work upgrading the Deteriorating Early Warning Tool (DEWT-US). In addition, new opportunities are emerging for upskilling the workforce to lead digital health transformation (see Section 7).

6. Digital health and related research capability

Numerous works are currently underway across key research institutions, united in developing digital and technology innovations to drive better health service delivery and health outcomes. These projects work closely with QH, leveraging the QH system capabilities described above, along with other health and emergency service providers within the broader health ecosystem. They include but are not limited to:

- public health surveillance systems
- primary and community health care providers (e.g. general practitioners and allied health practitioners)
- aged care and disability services
- first responder services such as fire and emergency services as well as Queensland Ambulance Services, and
- private health care providers.

6.1 CSIRO Australian e-Health Research Centre

The CSIRO Australian e-Health Research Centre (CSIRO AEHRC) is CSIRO's digital health research program, which aims to drive innovations that enable the digital transformation of health care to improve services and clinical treatment for Australians. The CSIRO AEHRC has a long-standing relationship with QH through a Joint Venture funding agreement between the organisations (currently in the fifth funding cycle). With offices nationally across Brisbane, Melbourne, Sydney, and Perth, the CSIRO AEHRC undertakes research and develop technologies that:

- transform health systems with data and artificial intelligence
- transform health care delivery with virtual care
- improve health system efficiency and readiness with digital health
- speed the transition to precision health.

CSIRO AEHRC works with many collaborators across the digital health care system to improve diagnosis and treatment across Australia and internationally.

The CSIRO AEHRC delivers its research through the activities of 5 research groups:

- Health Data Semantics and Interoperability Group
- Health System Analytics Group
- Health Services Group
- Bioinfomedical Informatics Group, and
- Transformational Bioinformatics Group.

6.1.1 Health data semantics and interoperability

Patient data is often captured in disparate electronic systems, different formats, and described using different clinical terminologies or 'languages'. The development of standard clinical terminology to describe the care and treatment of patients, to allow full interoperability between

electronic health systems enables meaningful transfer of health information between various clinical systems within the health ecosystem.

The CSIRO AEHRC health data semantics and interoperability group is answering the call for real-time clinical information to be shared between individual health practitioners, health care provider organisations and state and territory health departments to improve patient outcomes and health system performance through a number of interoperability related initiatives.

This group has created solutions and tools that underpin the continued development of SNOMED CT – a global clinical terminology – and its implementation for use in Australia. The tools allow improvements in the use, interoperability, and effectiveness of patient data captured in electronic medical records. Key platform technologies include Snorocket[13], which for the first time enabled semi-real time authoring of very-large-scale clinical ontologies like SNOMED CT, and Ontoserver[14], which is a world leading clinical terminology server implementing HL7's Fast Healthcare Interoperability Resources (FHIR) Terminology Services, and supporting syndication–based content distribution.

CSIRO AEHRC and QH have initiated a project to stand up Ontoserver as a Qld Clinical Terminology Service to help standardise all code systems across QH. eHealth Queensland has now initiated a policy that the QCTS will be the central point for this clinical content.

This group supports the implementation of the Queensland Clinical Terminology Service and the ongoing adoption of SNOMED CT across a number of QH projects. Currently, the CSIRO AEHRC is working with QH and other partners to develop a project to use an FHIR server as a Health Information Exchange between QH and community and allied health external to QH. In addition, a number of strategic projects in collaboration between CSIRO AEHRC and QH will use the Qld Clinical Terminology Service to embed its use within key areas of the business (e.g. Clinical and Business Intelligence, and the Queensland Health Smart Referrals team) to support health care delivery and meaning health information transfer.

Through enhancing Health IT standards, these solutions further the maturity of our health research digital ecosystem, thereby maximising the value in health data, including electronic health records and administrative data sets.

The health data semantics and interoperability group also work with Cancer Alliance Queensland to support the development of the Queensland Cancer Registry and the Queensland Oncology Online System, as well as the addition of mandatory cancer reporting by radiology by working with the 4 main private radiology companies on AI based reporting.

6.1.2 Health system analytics

The CSIRO AEHRC Health System Analytics group focuses on optimising the use of the variety of data sources available within the broader health ecosystem to support system level decisions, and ultimately improve system sustainability and outcomes. This group focuses on supporting and improving health service delivery by utilising data to generate insights, and support intelligent decisions in the design, implementation, and evaluation of health care service delivery. For example, using Artificial Intelligence and Machine Learning tools for prediction and simulation of the health system, including syndromic surveillance, health service demand and patient risk.

[13] Snorocket is fast and able to classify SNOMED CT at least an order of magnitude faster than other known classifiers. Snorocket was extended with new Description Logic features to support AMT and further improve performance.
[14] Ontoserver is a terminology server designed to support the requirements of SNOMED CT tooling, including the ability to manage multiple SNOMED CT extensions, subsumption queries, and SNOMED CT Reference Sets. It includes support for the Australian Medicines Terminology (AMT) and reasoning with numbers as well as LOINC, and ad hoc taxonomies.

Projects include developing and deploying analytics, prediction, optimisation, and operational and clinical decision support tools that can help improve and streamline the delivery of care and improve impatient experience and outcomes.

Utilising a mix of data from Queensland Ambulance Services, Queensland Health and Hospital and Health Services, the work between CSIRO AEHRC and QH to develop a digital twin of their Queensland Patient Access Coordination Hub state-wide control room, enables the dynamic modelling of patient flow management.

Other health system analytics projects between the CSIRO AEHRC and QH include the development of longitudinal individual patient journeys to track long-COVID and advance precision health and consumer engagement, as well as the prediction of patient risk of deterioration and data driven decision support tools for an Emergency Department.

As an example, researchers from this group collaborated with Metro South Health developed a machine learning tool which provides an early warning to medical professionals of a patient's deteriorating condition[15]. By providing early warning deterioration alerts that could be set to monitor patients 2-8 hours before they are triggered by current clinical criteria, this tool warns medical staff when a patient is at risk of deterioration leading to possible death, cardiac arrest, or unplanned admission to ICU. The tool can notify of the need for clinical intervention. Clinical decision support tools such as these are a pre-emptive solution that can provide medical staff with an opportunity to intervene earlier to prevent adverse patient outcomes.

6.1.3 Health service delivery

Mobile health service delivery enables care to be delivered where and when the consumer requires it, such as virtually or in their community. The use of smart devices to enhance remote health monitoring enables clinicians to have a near-real-time view of consumers and allows them to detect trends or concerns and intervene early. As such, remote health monitoring through the use of these smart devices enhances the quality of care and empowers consumers to be actively engaged in their care. These technologies can be particularly beneficial in the realm of service delivery to the elderly, people living with disability, and the chronically ill.

The health services group leverages the advantage of emerging sensor systems, digital technologies, data access, and analytics to accelerate the health care evolution, catalysed by the COVID-19 pandemic. This group works with clinicians through developing cutting-edge mobile phone-based models of care, with a number of new trials in areas such as cancer. These mobile health platforms will be FHIR native reference platforms for mobile health, thereby enhancing the interoperability of these platforms.

Researchers at CSIRO AEHRC have co-developed and trialled a mobile platform with Redland Hospital, part of Metro South Health, to help patients with gestational diabetes, and their treating clinicians, better monitor and track their condition. The application, called MoTHer, replaces a traditional paper-based diary system. Patients can record information in the app such as blood sugar levels, blood pressure, weight, diet, and exercise. This information is then uploaded to the linked clinician portal, so their dietitian, diabetes educator, midwife and obstetrician are able to monitor their progress in real-time and intervene if required – such as calling a patient to give specific, immediate advice if their blood sugar levels have changed too much. In addition, the

[15] Brankovic, A., Hassanzadeh, H., Good, N. *et al.* Explainable machine learning for real-time deterioration alert prediction to guide pre-emptive treatment. *Sci Rep* **12**, 11734 (2022).

application also includes educational resources to help patients understand and manage gestational diabetes.

The implementation of the MoTHER mobile health for gestational diabetes program is underway across a number of hospitals:

- Mater Health moved from trial to a 'business as usual' model of the platform with a software as a service license being signed by Mater Health. Mater Health has used the program with more than 3,000 women
- Redlands and Logan Hospitals have used the program for more than 1,000 women
- Royal Brisbane and Women's Hospital commenced using the program in late June 2022
- A trial of the MoTHER platform with the Cairns diabetes service for the Indigenous population.

The 'Smart foot monitoring for diabetic foot care and amputation prevention' program has been completed with the trial of a prototype 'smart sock'. This has been trialled with patients at the Mt Isa Hospital diabetic clinic.

6.1.4 Biomedical Informatics

The CSIRO AEHRC Biomedical Informatics group is the leading medical image analytics group in Australia – providing medical image analytics and biostatistics to large clinical research trials and studies with key partners around Australia. This group use medical imaging biomarkers with statistical techniques that enable precision health (prediction staging, and treatment) when used in combination with various 'omics, neuropsychology, smart sensing, and clinical phenotypes.

The developed techniques are deployed in clinics, hospitals and on our cloud informatics platform where they are used in a wide range of large observational and randomised controlled trials across the human lifespan (from pregnancy to ageing) and across the disease spectrum (including osteoarthritis, cerebral palsy, cancer, and dementia).

This group serves as a key partner in many clinical trials and studies in Australia and internationally where we contribute to the collection and analysis of data and interventions with our clinical and research partners.

The Biomedical Informatics group is developing key platform technologies including:

- AI driven medical imaging tools for precision medicine and clinical research
- cloud based imagine services to support large imaging and cohort studies, such as in areas of Alzheimer's diseases and Cerebral Palsy
- biostatistics and bioinformatics analysis for large cohort studies.

6.1.5 Transformational Bioinformatics

The CSIRO AEHRC Transformational Bioinformatics group enables scientists and industry partners to deliver scalable research outputs using cloud-computer and machine learning. This group focuses on delivery impact in 3 disciplines: genomic analysis, genome engineering, and therapeutics as well as biosecurity. The group has developed a competitive suite of solutions in the CRISPR space, supporting medical applications such as GeneTherapy and biosecurity applications such as detecting antimicrobial resistance.

The Transformational Bioinformatics group is developing key platform technologies including:

- **VariantSpark** suite of tools for big data analytics on cloud platforms, targeting whole genome sequences
- **sBeacon** for sharing genome information
- **GT-scan** suite for genome engineering.

Currently, this group is also working with clinical researchers on clinical research for pre-term births at risk of Cerebral Palsy.

6.1.6 Other CSIRO initiatives

CSIRO AEHRC supports a wide range of national CSIRO health initiatives with digital health expertise. These include:

- **Infectious Disease Resilience (IDR) Mission**

The COVID-19 pandemic has awakened the world to the dangers of zoonotic infectious diseases impacting human health, and the dangers posed by pathogens with no test to identify them, vaccines to prevent them, or therapeutics to treat them. The Indo-Pacific is a hotspot for infectious diseases. Recently this has included SARS, COVID-19, MERS, and Influenza. However, many countries in the region remain vulnerable because their laboratory and detection systems could be advanced.

As part of CSIRO's Mission Program to tackle Australia's national challenges, the CSIRO AEHRC is involved in developing the Infectious Disease Resilience (IDR) Mission. Working with regional partners, the IDR mission aims to enhance the Indo-Pacific region's ability to detect – and respond to – infectious disease threats by 2030. Supporting regional partners in strengthening laboratory capabilities and data analytics, we will introduce fit for purpose science and technology solutions to provide laboratories with the tools and knowledge they need. By enhancing infectious disease resilience in the Indo-Pacific, the IDR mission will help safeguard human health, promote economic growth, and minimise the risk of infectious diseases reaching Australia.

- **Antimicrobial Resistance (AMR) Mission**

Another major challenge to human health is Antimicrobial Resistance (AMR) – bacteria that cannot be treated by antibiotics. To tackle this problem, a 'One Health' approach is needed, which recognises the contribution of humans, animals, plants, and the environment to AMR. Hence, as part of CSIRO Mission Program to tackle Australia's national challenges, the CSIRO AEHRC is involved in developing the Antimicrobial Resistance (AMR) Mission.

The Queensland AMR Hub will work with QH and the Herston Infectious Diseases Institute (HeIDI) stakeholders to develop AI-driven tools for One Health surveillance and decision support. The surveillance and decision support platform will capture and integrate data across the health sector, agriculture, and the environment to provide a more comprehensive picture of AMR. This data will support applications that enable time and location-specific trends of AMR to be better measured, analysed, and managed, and AI-assisted decision support for antimicrobial stewardship.

The first application to use this data is a tool to alert emergency department doctors of drug-bacteria mismatches and hence when a change of antibiotic treatment might be needed. This application has been developed in conjunction with The Prince Charles Hospital with initial results

already published16. The tool reconciles information from microbiology test results and patient discharge summaries and uses the SMART on FHIR health care interoperability standard to provide a decision support app.

This tool supports hospital Antimicrobial Stewardship programs by ensuring that appropriate antibiotic prescription continues through the treatment of the infection.

The second application uses de-identified and aggregated data to create a dashboard of information about antimicrobial resistant infections and their location, which can give early indications of AMR hotspots. This dashboard will use disparate data sources from HL7 microbiology test results and Antimicrobial Stewardship Data, which contain antibiotic susceptibility, utilisation, and genetic testing results; ED information systems, which contain hospital interaction and antibiotic prescription information; and environmental data through the collection, monitoring, and assessment of AMR pollution in wastewater ecosystems.

These tools can expedite the response to infectious disease outbreaks in hospitals and the community to provide an early warning system for escalating pathogens and resistance threats. As such the Queensland AMR Hub aims to demonstrate that early surveillance can help protect Australians from antimicrobial resistant infections, reduce hospital admissions, and reduce related health care costs.

Ultimately, this will help minimise the development and spread of AMR and ensure the continued availability of effective antibiotics for fighting bacterial infections.

- **Precision Health Future Science Platform**

CSIRO's Future Science Platforms (FSP) represent investment in science that underpins innovation, with the potential to help reinvent and create new industries for Australia. CSIRO's FSPs are multi-year, multi-disciplinary investments in our collective future – bringing CSIRO and key partners together to work on the big ideas.

The CSIRO AEHRC contributes to a number of CSIRO FSPs, including the Precision Health FSP, the Machine Learning and Artificial Intelligence FSP and the Space FSP. The CSIRO's Precision Health Future Science Platform targets enabling innovative integrated platform to proactively manage a person's health through their life.

6.2 Metro North institutes

6.2.1 Herston Infectious Diseases Institute (HeIDI)

HeIDI's purpose is to deliver innovative infectious diseases research that achieves clinical excellence in the surveillance, diagnosis, management, and prevention of serious infections that impact the community, and aims to create a legacy by training the next generation of infectious disease clinician researchers.

The objectives of HeIDI around enhancing translation and clinical research, improving outcomes for patients with serious infections, and leading the prevention of health care associated infections throughout Queensland are strongly aligned with CSIRO's health and biosecurity strategy,

[16] Nguyen, A., Hassanzadeh, H., Zhang, Y, O'Dwyer, J., Conlan, D., Lawley, M., Steel, J., Loi, K., & Rizzo, P. (2019). A Decision Support System for Pathology Test Result Reviews in an Emergency Department to Support Patient Safety and Increase Efficiency. Studies in Health Technology and Informatics, 264, 729-733.

particularly in relation to the programs of work being planned by the CSIRO Infectious Disease Resilience (IDR) Mission, Antimicrobial Resistance (AMR) Mission, and the CSIRO AEHRC.

Given this alignment, CSIRO AEHRC is playing a key role in developing a larger research collaboration between HeIDI and the CSIRO AMR Mission and IDR Mission. As a mechanism to establish this partnership, the CSIRO AMR Mission and IDR Mission have committed funding to support research in several identified priority areas. This research collaboration fund will foster links between CSIRO and other HeIDI members, as well as contributing to the outputs of the Missions initiated by CSIRO.

6.2.2 Jamieson Trauma Institute (JTI)

The Jamieson Trauma Institute (JTI) aims to revolutionise how trauma services are delivered, bringing together a unique and integrated group of services including intensive care, burns, rehabilitation and military medicine. JTI strives to advance trauma prevention, research, system, and clinical management to deliver the best possible care for people who suffer a traumatic injury, be it those treated at Royal Brisbane Women's Hospital, other trauma centres across Queensland and Australia, or those under the care of the skilled and dedicated workforce who have trained at RBWH.

The Queensland trauma system requires an integrated, efficient, coordinated, and sustainable data solution to meet the strategic and operational needs of contemporary emergency health service providers, trauma clinicians, health administrators and external stakeholders and JTI has established a central data quality and analytics unit for this purpose. The work of the unit is focused on scoping the breadth and depth of data collected on injury across the continuum of care, developing best practice methods, resources, and tools for using linked injury data, and analysing the data to better understand the causes, trends, patterns, burden, costs, and outcomes of injury in Queensland. The JTI team were intricately involved in the QH Clinical Excellence Queensland-led project to scope the business requirements for a Queensland Trauma Data Warehouse solution, a state-wide linked trauma data platform to capture trauma patient journeys, treatment, costs, and outcomes, and support clinical improvement and trauma management. JTI continues to provide advice and support to operationalise this concept into action, utilising the resources, expertise, and tooling developed within the unit. JTI partners closely with the Australian Centre for Health Services Innovation (AusHSI) with many joint positions between JTI and AusHSI. The program is focused on strong, collaborative relationships between academic, clinical, government, and community partners (More information at: https://www.aushsi.org.au/aushsi-research/trauma/).

Metro North HHS is in the final quarter of a 2-year contract between JTI and CSIRO AEHRC to provide seed funding for projects across data analytics, medical imaging, and mobile health. JTI's strong clinical engagement has enabled identification, definition, and sharpening of clinical problems and needs, and enables validation of solutions in the clinical setting. CSIRO e-health research at CSIRO AEHRC has provided expertise in data interoperability and analytics, image analytics, and connected care capabilities to facilitate the deep understanding of problems and healing of the injured patient.

6.3 The University of Queensland (UQ)

UQ is aiming to become a global leader in digital health with the establishment of the Queensland Digital Health Centre (QDHeC).

Over the next 5 years, QDHeC will leverage these achievements to:

- build a hub to facilitate health care requests, educate on best digital health practices, and support adoption and regulatory approval of industry-led digital solutions
- accelerate and drive innovative digital health research linking UQ to industry
- pioneer future data science in health using new digital technologies.

QDHeC is building our digital health care future. It will become an enduring, world-class virtual facility with a self-sustaining group of high-quality researchers who will generate new research capability and capacity. It will accelerate the translation of research findings into clinical practice to deliver better health outcomes and a more responsive and sustainable health care system. It will enable a single focus for digital health at UQ and a single 'front door' for our partners.

QDHeC's vision is for a digitally enabled learning health system which delivers on the quadruple aim of health care: better outcomes, lower costs, better clinician and consumer outcomes. Such a system collects data from each episode of patient care, permits real-time analysis of data by researchers, and accelerates translation of research findings into improved clinical practice and patient outcomes.

QDHeC hopes to become the preferred research partner for health care providers and industry stakeholders seeking digital solutions to complex challenges and, as a result, position UQ as a global leader in digital health.

Queensland is on the cusp of becoming an international leader in digital health. Enhanced and broader access to the rich repository of data within the QH ieMR combined with ground-breaking innovations will accelerate development of the digital health ecosystem, strengthen the digital health workforce, and enable a learning health system.

QDHeC was established to drive and coordinate the pioneering beginnings of a digital health care revolution. Established by the Global Change Institute, QDHeC is comprised of researchers from 6 UQ faculties, from:

- Faculty of Medicine
- Faculty of Science
- Business Economics and Law
- Engineering Architecture and Information Technology
- Health and Behavioural Sciences
- Humanities and Social Sciences
- UQ Centre for Policy Futures
- UQ Centre for Health Services Research
- UQ Frazer Institute.

QDHeC's programs aims to harness the power of the government, industry, clinical and academic sectors to work together with health care consumers in driving data-driven health care improvement in real time.

6.3.1 Real time analytics and product development

An essential step in the maturation to Horizons 2 and 3 is the transition from ieMR data only being used at point of care, to the provision of real-time aggregated ieMR data and analytics as dashboards to clinicians to enable better quality and safety of patient care. To date, a number of analytics products have been produced within QH, for example the Statewide Inpatient Diabetes Dashboard (Figure 3), designed to optimise ordering, minimise dysglycaemia and insulin omission; and the Opioid Inpatient Management Dashboard (Figure 4), designed to identify patients with poor pain control and/or potentially experiencing adverse effects as a result of opioid therapy.

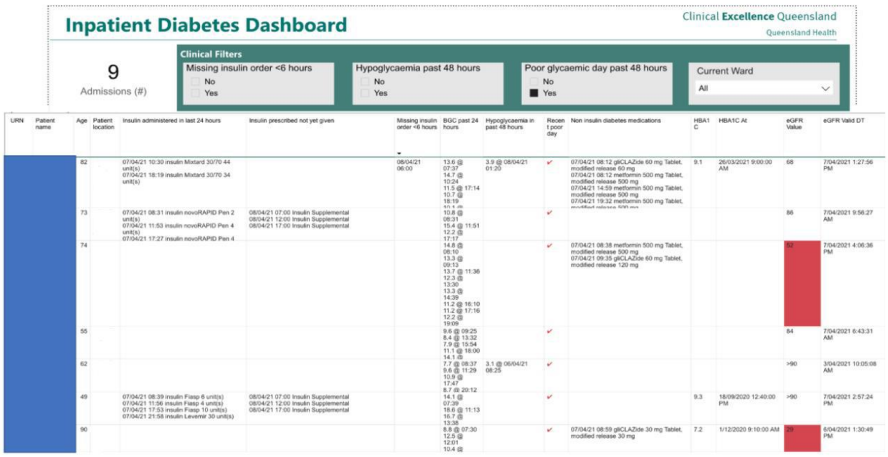

Figure 3. Queensland Statewide Inpatient Diabetes Dashboard

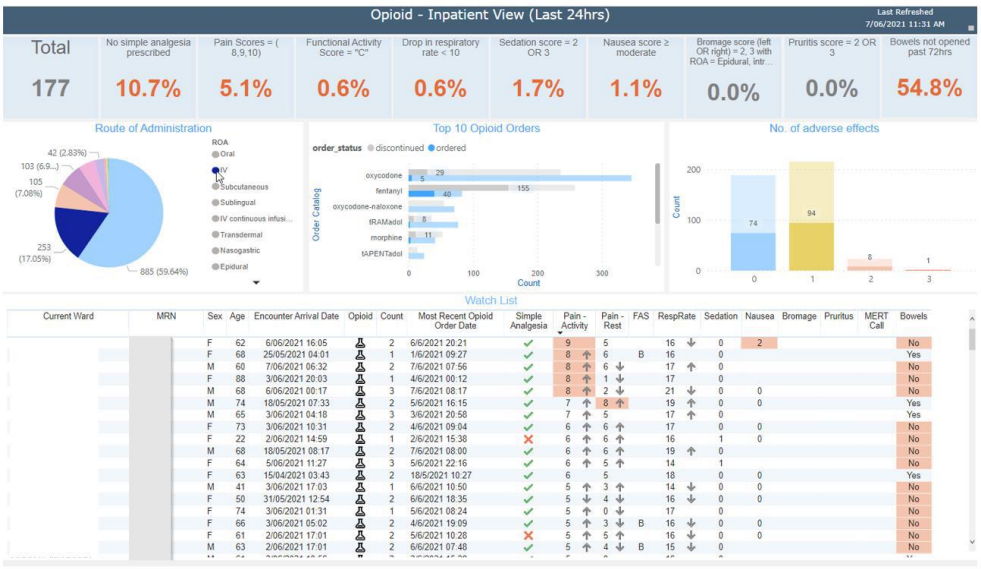

Figure 4. Opioid Inpatient Management Dashboard

6.3.2 Observational Medical Outcomes Partnership (OMOP)

As noted, hospital ieMR data is valuable for research, however, it is often difficult to use and interpret due to its format and structure. To address this, the Observational Health Data Sciences and Informatics (OHDSI) program has adopted the Observational Medical Outcomes Partnership (OMOP) Common Data Model (CDM). This is an international gold standard to transform and standardise data[17], which is widely implemented internationally. Operating under the auspices of the Australian Health Research Alliance, Transformational Data Collaboration the tools, mappings and experience gained will be openly available, as a community of practice is established and continued to support provided for future implementations.

This project will translate data from the QH Cerner ieMR to the OMOP CDM platform, by using synthetic and non-production, non-identifiable ieMR data. This in turn offers cross collaboration both nationally and internationally to address research questions using the OMOP CDM vocabularies to standardise the structure and content of observational data across disparate datasets.

6.3.3 Clinical Artificial Intelligence Research Accelerator (CLARA)

CLARA is a secure research environment which allows researchers to conduct AI experiments using ieMR data while maintaining industry leading levels of data security. CLARA has dedicated compute hardware with the capability of handling complex algorithm training on large health datasets.

Technical researchers will be able to develop their own prescriptive and predictive modelling. Non-technical researchers will be able to use existing models via a web application. Researchers are seeking solutions to clinical problems like identifying patients at risk of sepsis and efficiency problems like predicting length of hospital stay.

6.3.4 KeyPoint

KeyPoint is an e-research platform that enables researchers to manage sensitive research data with approved researchers in a scalable, fully governed, and highly secure environment, whilst maintaining full control of their data at all times. KeyPoint enforces data governance and security consistent with the Five Safes principles as used by the Australian Government for data sharing and release: safe people, safe projects, safe settings, safe outputs, and safe data.

Co-designed with researchers responsible for valuable data assets with a broad range of stringent data governance and analysis requirements, KeyPoint comprises all the infrastructure, software, systems, and analytical tools required by researchers to conduct powerful data analyses on authorised data to address their research questions. By using KeyPoint, researchers can gain the required trust to receive sensitive data for analysis from State and Federal Data Custodians.

KeyPoint is being deployed in a separate, restricted access region on the Queensland node of the Nectar research cloud managed by the Queensland Cyber Infrastructure Foundation (QCIF). KeyPoint's compute infrastructure provides workstation- scale analytics environments, including high-memory virtual desktops for data intensive workloads and graphics processing unit (GPU) enabled virtual desktops for visualisation and/or machine learning and AI workloads.

[17] Observational Health Data Sciences and Informatics. Standardised Data: The OMOP Common Data Model. Available from: https://www.ohdsi.org/data-standardization/

6.4 Queensland University of Technology

6.4.1 Australian Centre for Health Services Innovation (AusHSI)

The Australian Centre for Health Services Innovation (AusHSI) is one of Australia's largest and leading health services research centres and has a large overarching cross-centre program dedicated to Digital Health. This draws on AusHSI's strengths in Health Economics, Implementation Science and Human Factors, Statistics and Data Analytics that are applied across a wide range of clinical contexts in local, national, and international partnerships with health care organisations and industry.

AusHSI enables health service organisations to make changes that bring about greater efficiencies and improved patient outcomes, by combining leading edge health services research with hands on experience, to generate practical insights and independent guidance on how to identify, implement and evaluate innovation for real life health service problems. AusHSI's many Digital Health-related projects include initiatives being carried out in partnerships that span Queensland, Australia and extend internationally. This includes partnerships focused on digital health-related activities with government departments and health services in all Australian states and territories.

7. Digital health workforce

Although many Australian clinicians are already leaders and experts in digital health, there is very limited formal training and much of this is knowledge rather than skills based. Health care delivery is changing rapidly. The use of technology and data is accelerating, and we need to ensure our clinical and broader health and medical workforce has the skills to effectively and safely lead this transformation. This has been recognised by the Australian Government, with the recent release of the National Digital Health Capability Action Plan18. Here, the key components to effectively build digital health capability across the health workforce have been outlined across 4 key themes, comprising 11 pragmatic actions, with the goal to implement over the next 7 years.

7.1 Clinical Fellowship in Digital Health

Australia's digital health workforce capacity will be significantly boosted by a new Clinical Fellowship in Digital Health. UQ is collaborating with the Australasian Institute of Digital Health (AIDH), the Digital Health CRC (DHCRC), and a range of health and medical colleges to develop the curriculum for the Fellowship. Applications for candidacy from health care professionals will open later this year.

The Fellowship is designed to be jointly recognised by AIDH and the relevant professional body, giving clinicians credentials and professional standing similar to other clinical specialties. It will offer an innovative curriculum based on an evidence-based program being pioneered at UQ, cross-health sector engagement, and a national approach to recognition of the importance of digital health and clinical informatics.

In short, the Fellowship means Australian clinicians will be professionally recognised as digital health experts. The clinical leaders of the future need confidence and skills to deliver quality health care at scale with new technology, while maintaining patient care at the heart of every interaction.

7.2 Graduate Certificate in Clinical Informatics and Digital Health (GCCIDH) Program

The Graduate Certificate in Clinical Informatics and Digital Health (GCCIDH) Program was developed in partnership between UQ, QH and the DHCRC. With national and state digital health priorities in mind, UQ launched the Graduate Certificate in Clinical Informatics and Digital Health to build the individual's capability to embrace change and revolutionise digital health care services. The program, led by Professor Andrew Burton-Jones, Business School, and Associate Professor Clair Sullivan, Faculty of Medicine aims to:

- provide a flexible curriculum, developed for modular delivery and micro-alternative credentials
- develop digital health and clinical informatics competency by offering learning opportunities that will enhance practice beyond a basic level
- support the development of clinical informaticians who embrace change and disruptive practice and can become future leaders in health services across Australasia

[18] Australian Digital Health Agency. The National Digital Health Capability Action Plan (2022). Available from: https://www.digitalhealth.gov.au/sites/default/files/documents/national-digital-health-capability-action-plan.pdf

- work towards meeting the competency requirements established by the AIDH and provide an opportunity for accreditation as a clinical fellow of the AIDH.

7.3 Graduate Certificate in Digital Health Leadership and Management Program

The Graduate Certificate in Digital Health Leadership and Management (GCDHLM) program was developed in partnership between the Queensland University of Technology (QUT), Metro North Health, Metro South Health and the DHCRC, supported by digital health experts across QH and other health services. The program was developed to build high-level digital health leadership and management skills in the workforce that are required to fulfil operational and strategic vision to affect change and achieve the quadruple aim in current and future health care systems. The program is led by Associate Professor Amina Tariq (Health Management and Health Information Management) and Professor Steven McPhail (AusHSI and the Centre for Healthcare Transformation). The program aims to:

- address core components of major national and international digital health certification programs including Certified Health Information Australasia (CHIA) and Health Information Management and Systems Society.
- comprise theoretical and practical learning for: Foundations of Clinical Health; Clinical Informatics for Intelligent Healthcare; Implementation Science Theory and Practice; and Leadership in Digital Health Management.
- deliver mixed mode flexible delivery including simultaneous offering of face-to-face and online to meet individual learning needs
- work towards meeting AIDH competency requirements and provide an opportunity for accreditation as a clinical fellow of the AIDH, as well as credit toward QUT post-graduate Health Management degrees.

7.4 Digital health courses within embedded curriculum

In addition to standalone programs, a number of digital health courses are being delivered to existing curriculum (e.g. in areas of Information Technology and Medicine), to enhance system and research capabilities.

7.4.1 Digital Health Software Project course with University of Queensland

The University of Queensland School of Information Technology and Electrical Engineering provides a Digital Health on FHIR course with support from CSIRO AEHRC and a number of QH speakers. Initiated in 2021, this course included 35 students, with several QH hospitals and clinicians proposing projects for the students as well as mentoring for projects selected.

7.4.2 Case Based Learning on FHIR use within University of Queensland Medical Faculty

CSIRO AEHRC is partnering with UQ to develop technology for delivering Case Based Learning to UQ Medical Students. UQ is now using the technology to deliver content to more than 500 medical students. To support this endeavour, CSIRO AEHRC has developed a ‘SimPatients’ application, which is now available on the Android / Apple store. SimPatients is a teaching tool that allows health professionals to interact with simulated patients for better interaction with patients in real life

settings. The simulated patients are a collection of diverse chat-bot personalities with a health complaint that the user must investigate by asking pertinent questions.

8. Blueprint for a learning health system

8.1 Defining a learning health system

Our desired future state is a learning health system. A learning health system is a health system in which internal data and experience are systematically integrated with external evidence, and that knowledge is put into practice. A digital health ecosystem is cocreated between health departments, the broader health system, and universities with world class research capability joining forces to unlock the vast potential of health data now generated. As a result, patients get higher quality, safer, more efficient care, and health care delivery organisations become better places to work.

The principles of a learning health system are:

- Have leaders who are committed to a culture of continuous learning and improvement
- Identify the clinical questions where better data could inform change
- Systematically gather and apply evidence in real-time to guide care
- Employ IT methods to share new evidence with clinicians to improve decision-making
- Promote the inclusion of patients as vital members of the learning team
- Capture and analyse data and care experiences to improve care
- Continually assess outcomes and refine processes and training to create a feedback cycle for learning and improvement.[19]

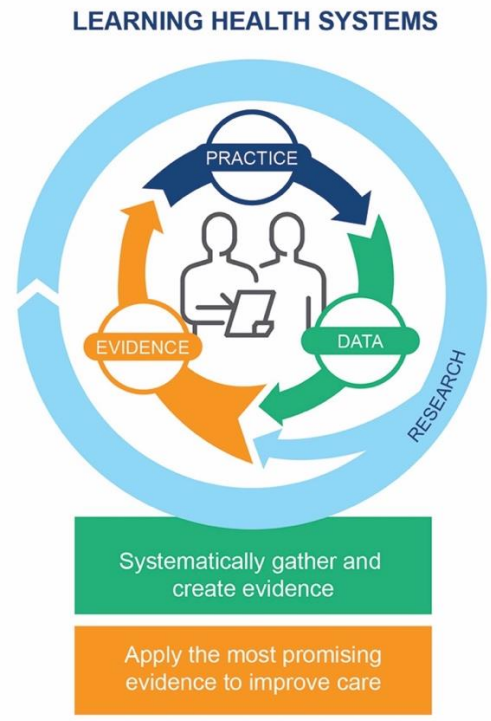

Figure 5. Diagrammatic representation of a learning health system

[19] Agency for healthcare research and Quality. About Learning Health Systems (2019). Available from: https://www.ahrq.gov/learning-health-systems/about.html

8.2 Digital health enablers

To enable the implementation and adoption of digital health to facilitate a learning health care system we need to:

- identify areas of health care where there is a need for improvement and establish what work is already underway to address this, and which stakeholders are involved
- convene stakeholders to form a learning community
- develop an improvement ambition
- make sure there is senior-level support
- identify and map the assets and relevant improvement activity already in place
- identify the assets that do not exist or need further development and set out steps for improving them
- select an initial goal to target within the overarching improvement ambition
- plan the data collection and improvement activities required to achieve the improvement goal.[20]

Several transformative programs of work to achieve a learning health system need to be undertaken. These programs include people, processes, information and technologies.

8.2.1 People

Health care is at a crossroads where rapidly increasing demand is intersecting with new and emerging technologies. This creates a tension for new and transformative ways of working and a pressing set of demands upon the current and future workforce. This forces the need to develop a workforce to facilitate digital transformation of our current and future workforce. As we begin to see new ways of working, new professions and jobs emerging, and new technologies being implemented (e.g. clinical analytics, robotics, artificial intelligence), we do not yet have a clear and consistent method and curriculum for sharing the new knowledge across current and future clinical, operational, and academic teams involved in health care. Currently, almost anyone can claim to be an expert in digital health, a situation which is likely to make health care regulators uneasy, especially as digital health now becomes a clinical, rather than a technical or industry endeavour.

By 2025, the majority of all public hospital services in the nation will be delivered via digital platforms. This changes the way we work and problem-solve. It challenges us to rethink traditional models of health care training, education, delivery, research, and innovation. The recent Topol Review states that in 20 years, 90% of all jobs in the health care sector will have a digital component[21].

Anecdotal experience suggests that a sophisticated digital health care system will have:

- all staff proficient in digital workflows and 20% at ‘super user’ or expert level, with an intent to have a ‘super user’ rostered on every shift

[20] Developing learning health systems in the UK: Priorities for action (2022). Developing learning health systems in the UK: Priorities for action - The Health Foundation

[21] The Topol Review, Health Education England, NHS. Preparing the healthcare workforce to deliver the digital future (2019). Available from: https://topol.hee.nhs.uq/the-topol-review/

- 10% of staff with an industry level qualification (graduate certificate or higher) in clinical informatics
- 1% of staff with a fellowship or higher degree in clinical informatics.

Queensland has several offerings to increase workforce capability including:

- University of Queensland, Clinical Fellowship in Digital Health, see Section 7.1
- University of Queensland, Graduate Certificate in Clinical Informatics and Digital Health, see Section 7.2
- QUT, Graduate Certificate in Digital Health Leadership and Management, see Section 7.3
- Griffith University Graduate Certificate in Digital Health.

8.2.1.1 Recommended actions

Short term (within 2 years)	• Increased digital health literacy of clinical staff • Increased digital health literacy of health leadership and executive • Increased enrolments in postgraduate digital health university study • Promotion of the benefits of using digital health solutions • Develop digital health and clinical informatics senior leadership roles to advocate for the agenda • Foster a culture of continuous learning and improvement among staff at all levels of the organisation
Medium term (within 5 years)	• Increased digital health literacy of legislators and policy makers • Digital health is increasingly topical with consensus of its necessity in combating increase health service demand with limited resources • Digital health leaders commonly consulted on legislation and policy decisions regarding health care • Embedded mechanisms where health staff can access training and coaching from experienced improvement practitioners

8.2.2 Process

New processes are required as information increasingly becomes digital. Clinical workflows need to be digitised as a matter of urgency. New processes such as the use of clinical decision support including artificial intelligence will become part of routine clinical care.

Clinical guidelines will move away from intermittent updates with versioning control, to become living guidelines with timely evidence-based updates which are routinely monitored by clinicians as these documents become injected into the model of care.

First Nations people need to be brought on the journey from the beginning. It is not enough to include them after the processes are developed. The different view of sovereignty of health data needs to be built into the system.

Strong partnerships between the health sector generating the data and global technology companies are established, underpinned with academic partners to enable research credibility. In harnessing large scale health data, opportunities to link with datasets outside health are established, enabling greater insights. Trusted researchers bring academic enquiry to the data to help close the feedback loop.

Consumers and clinicians will have an active role in co-designing digital health technology and actively participate in digital health research. A social licence for dynamic or broad consent regarding the secondary use of de-identified health data is established, supported by strong public awareness campaigns.

8.2.2.1 Recommended actions

Short term (within 2 years)	• Positive dialog with Queensland's First Nations communities to develop culturally sensitive workflows • Continue the implementation of electronic medical records • Standardise digital clinical workflows to ensure data consistency and comparability • Work towards mechanisms where staff are actively supported to experiment with new efficient ways of working leveraging digital health technology • Create 'in house' experience to advise on new health care delivery processes leveraging digital technology • Foster close partnerships between health organisations and academic partners to enhance health care research capabilities
Medium term (within 5 years)	• Streamline research data requests, while ensuring adequate ethics and governance processes, to allow for contemporaneous research • Better understand locally the social licence for the secondary use of anonymised, aggregated health data for research and implement mechanisms for capturing dynamic/broad consent from the public. Create an environment where staff feel able to raise potential problems and have permission to test new ways of working

8.2.3 Information

The hallmark of a learning health care organisation is information. Digitising workflows allows the compute power of information to be realised. Data accessibility and availability needs to be streamlined for clinicians and researchers. Data needs to be truly representative of the whole of society. Data needs to be transformed, structured, and defined in intelligible formats across multiple digital health applications and devices. To achieve a learning health system, we need to greatly mature our access to, and understanding of the overwhelming amount of health data we have created through the digitisation of health care delivery.

8.2.3.1 Recommended actions

Short term (within 2 years)	• Commission efforts to understand the health and population data ecosystem in Queensland • Work towards validated patient matching algorithms and process across digital health applications, creating a standard • Work towards the transformation of digital health and person data into intelligible data models • Develop streamlined data access processes for clinicians and researchers to reduce the evidence to practice translation delay • Develop quality improvement data tools for frontline clinicians promoting targeted quality improvement and new model of care evaluation • Ensure the data capture is implemented widely, with the aforementioned quality mechanisms, to capture the diverse cultural, ethnic, and socioeconomic facets of Queensland population • Develop 'life like' synthetic health data sets allowing for a 'sand pit' type development and research environment removing the need for ethics and governance processes to test new and emerging analytics/technologies

Medium term (within 5 years)	• Increase trained clinician researchers, that is front line clinicians who have the ability and support to conduct rapid quality and efficiency improvement activities and research • Embed safe data access tools for front line clinicians to access to evaluate the care being delivered and actively look for areas of improvement

8.2.4 Technology

Electronic medical records are the base technology for a learning health care system. In addition, Queensland has significant capability in emerging technologies such as:

- virtual and augmented reality
- tele scripts, scripts accessed via QR code from primary carer
- telehealth and virtual care
- remote patient monitoring (blood pressure, temperature, oxygen saturations) from home
- unmanned aerial vehicles to deliver medical supplies to remote or isolated communities (i.e. disaster affected).

Ultimately, health systems will become more permeable with the ability to share data beyond the enterprise structure. This enhanced interoperability will bridge the divide between health sectors and disparate health systems.

8.2.4.1 Recommended actions

Short term (within 2 years)	• Stabilise the rapid expansion of health technology now available to assist with the delivery of health care • Develop and implement data technologies to fully leverage our existing information assets • Work towards ways of using the technology we have more effectively and efficiently • Conduct research in the effectiveness and safety of remote patient monitoring • Focus on technology investment which meet the needs of health care delivery and the community i.e. technology which may allow reduced hospitalisation
Medium term (within 5 years)	• Embed hospital in the home leveraging remote patient monitoring as a business-as-usual tool for hospitals • Safely expand the acuity of 'hospital in the home patients' supported by the use of remote patient monitoring and community health services • Focus on enhanced interoperability of disparate health systems