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ORIGINAL ARTICLE

A co-designed health information system implementation into residential aged care: A mixed-method evaluation

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Abstract

Introduction: Internationally, the adoption of technology into residential aged care settings has been slow and fraught with multiple challenges for residents, staff and service providers. The aim of this study was to evaluate the acceptability, efficiency, and quality of health information system implementation into aged care.

Methods: Three-stage, mixed-methods participatory action research, concurrent with the natural experiment of a co-designed health information system implementation into a 169-bed aged care home in Australia. Data were collected pre-, during, and post implementation between 2019 and 2021. Qualitative data included focus groups, interviews, and observations. Quantitative data included work observations, pedometers, record audits, incident reports and staff and resident surveys. There were 162 participants composed of 65 aged care residents, 90 staff, and 7 managers/consultants.

Results: Improved work efficiency included reduced staff time searching for information (6%); reduced nurse time on documentation (20.4% to 6.4%), and 25% less steps. Documentation improvement included resident assessments (68% to 96%); resident-focused goals (56% to 88%) and evaluations (31% to 88%). The staff reported being better equipped to manage the 'delicacies of dignity'.

Conclusion: Implementation of a health information system into a residential aged care facility was associated with improved resident-focused care and staff efficiency.

Clinical relevance: Technology can support nurses and care staff to spend more time with residents in residential aged care homes, improve the quality of resident care, and assist meeting regulatory reporting requirements. Flexible and tailored co-design strategies can enhance both effectiveness and success of technology implementation into residential aged care.

KEYWORDS
geriatrics, informatics, information systems, mixed methods, nursing homes

Digital documentation using Health Information Systems (HIS) offers residential care staff the opportunity to streamline documentation, contemporaneously capture care delivery, and inform decision-making at the point-of-care to optimize holistic person-centered care (Stanhope & Matthews, 2019).There is evidence that these services experience significant challenges meeting regulatory standards for documentation and personalized interventions (Mariani et al., 2017). Yet globally, despite strong motivations for adopting HIS in nursing homes, uptake has been slow (Davis et al., 2017; Østensen et al., 2019; Yu et al., 2020).

This paper reports a mixed-methods participatory action research study that evaluated the acceptability, efficiency, and quality outcomes of implementing a new HIS in a nursing home setting. Implementation of the system was tailored by the vendor using co-design methods that involved residents and staff in iterative feedback cycles. The purpose of the HIS was to provide a digital documentation system that was resident-focused, sensitive to nurse and carer workflows, and suited to the regulatory, accreditation, and care delivery needs of the service.

INTRODUCTION

Most people entering Australian residential aged care have multiple or complex care needs, often requiring support in one or more of their activities of daily living (ADLs), cognition and behavior, and health and medical care (Gibson, 2020). Individual resident care needs, goals and preferences for care are often complex, and continue to evolve as they age, therefore requiring frequent re-assessment, planning, and evaluation by nurses and care staff. Accurate and up-to-date documentation of care requirements supports effective and timely care by the multidisciplinary team. Documentation for funding and regulatory purposes (Shiells et al., 2020) is among the most time-consuming nursing activities in residential aged care (Ausserhofer et al., 2014; Qian et al., 2016).

Innovation in digital health technologies that release care staff time from administrative work to direct-care, is key for future sustainability of the aged care system (Committee for Economic Development of Australia, 2021). The HIS must simultaneously support requirements for delivering resident care alongside reporting, risk management, accreditation and monitoring (Jiang & Yu, 2015). Contemporaneous capture of care delivery data across all steps in the nursing care process supports suitability, accuracy, transparency and continuity of care delivery, and helps detect and avoid adverse events, duplication, and waste or missed care (Wang et al., 2014). Resident care is improved with ease of access to information and fast retrieval of accurate data providing a comprehensive understanding of residents' preferences, particularly for new staff and those unfamiliar with a resident (Zhang et al., 2012). Timely, accurate, and convenient information exchange between care providers and across healthcare organizations further supports the safety and quality of resident care (Gaskin et al., 2012).

Under-developed, poorly integrated or poorly used HIS compound challenges of care documentation in nursing homes, place unnecessary demands on staff, and increase potential for negative impacts on resident care (Davis et al., 2017). Many challenges for HIS adoption arise from limited engagement with care providers and end-users, during both development and implementation (Henderson et al., 2016). Interventions that successfully improved aged care work environments and quality of care have been developed using participatory approaches that seek to understand, engage and include nurses and care staff (Andre et al., 2020; Dewar et al., 2019; Griffiths et al., 2021).

The research reported here was concurrent with and was independent of the natural experiment of a vendor-led HIS implementation using co-design involving the residents, staff, and managers to tailor and implement a novel point-of-care HIS called aged care ecosystem or 'ACE'. The setting was long term residential aged care with nursing care, equivalent to a nursing home in the United Kingdom or a skilled nursing facility in the United States. Terminology varies globally, and in this paper, the terms residential aged care (sometimes residential aged care facility in Australia) and nursing home are used interchangeably. The aim was to support the staff with accessible and up-to-date documentation in the form of a digital care plan allowing nurses and care staff to access real-time resident information and adapt individual care. Furthermore, ACE was intended to optimize staff workflows and enhance quality of life for residents while supporting data capture for administrative purposes. The study aim was to evaluate the implementation of the new HIS in relation to acceptability to staff, work efficiency, and quality of resident care.

Design

The pragmatic participatory action research design (Coghlan & Brydon-Miller, 2014; Creswell & Clark, 2007; Glasson et al., 2006) suited the natural experiment and allowed flexibility to respond to concurrent external events (e.g., building redevelopment, gastroenteritis outbreak, and response to the COVID-19 pandemic). It also enabled adaptation (e.g., time frames) to the challenges posed to both implementation and data collection by the iterative changes intrinsic to the co-design process. Concurrent mixed-methods data, where equal value was given to each data type, were collected from residents, staff, and facility administrative databases at three time points: pre, during, and post implementation. Multiple levels of inquiry (Carr et al., 2011) provided a rich and informative evaluation of the HIS from multiple perspectives. The multiple data types and collection were informed by the research team, facility staff, and previous research (Blinded).

The study was conducted in a metropolitan for-profit nursing home located in Australia (157-beds at commencement and 169-beds at conclusion). The research team worked alongside the HIS developers and facility managers over 2 years as vendor-led co-design processes (Green et al., 2020) were used to incrementally tailor and implement the HIS. Researchers attended governance and advisory

groups, collected and analyzed data, and provided feedback on iterations of the HIS.

MATERIALS AND METHODS

Prior to commencement of data collection, information packs that included participant information, contact details for researchers, a support letter from management, a consent form, and a survey (resident/visitor or staff) were distributed to all nurses and care staff, residents, visitors, and relatives. Study information was shared via short message service (SMS) (for staff), email (for residents and their relatives), the newsletter, and through posters in prominent positions around the facility (visible to residents, relatives, and visitors).

Researchers approached all nurses and care staff in-person to inform them of the study verbally, invite participation and obtain written consent to participate in all data collection activities. The same process was employed for residents with the addition of a prior discussion with a nurse manager as to who could consent for themselves, those residents for whom consent would be required from a relative and guardian, and those where it would be appropriate to seek agreement from both. The only exclusion criterion was those residents who were unable to communicate due to sensory limitations. At study commencement, there were 22 registered nurses, 4 enrolled nurses, and 121 care workers employed at the nursing home. Health and leisure staff, externally employed or visiting allied health, nurse practitioners and general practitioners were also invited to participate. Convenience samples of staff and residents were invited to participate in specific data collection activities if they had consented to participate and were present at the predetermined data collection times. Consent was re-confirmed verbally at the time of each data collection activity (e.g., observation). The staff were offered a $25 gift voucher on return of a signed consent form as a token of appreciation. As cognition of residents could fluctuate, management advised on resident suitability, or nominated a decision maker to receive study information, provide consent and contribute data.

Data collection

Concurrent mixed-methods data collection was guided by a quality evaluation framework aligned with the research aims and objectives (Table 1). Three two-week time periods (pre-, mid-point, and post-implementation) were pre-selected for the intensive collection of observation, audit, and interview data. This facilitated planning

TABLE 1 Evaluation framework, objectives + data collection methods + tools

Aim	Objectives	Quantitative data	Qualitative data	Action research feedback
Acceptability	1. Reduce staff time spent retrieving information + documenting care 2. Improve staff + residents' satisfaction with care	• Survey: Net Promoter Score Survey (NPS) (Keck, 2020) • Survey: HIS usability (nurse + care staff)	• Anonymous comments box • Field notes of nurse + care staff 'Think-aloud' during work processes • Focus groups • Ad hoc Hallway/bedside interviews	• Steering committee reports • Clinical review committees • Member checking
Efficiency	3. Improve staff use of management-approved clinical treatment protocols 4. Reduce errors by omission + missed documentation 5. Improve data on resident welfare used to allocate resources	• Observation of nurse + care staff work time + motion (adapted from (Qian et al., 2016; Thomson et al., 2009; Westbrook et al., 2011) • Audit of resident care records (adapted QANDAC) (Wang et al., 2014) • Pedometer • Documentation diaries		
Quality	6. Improve resident self-reported quality of life 7. Reduce staff + resident perceptions of missed care 8. Increase staff (nurses + care staff) time with residents.	• Survey: resident self-reported Quality of life (DEMQOL) (Smith et al., 2007) • Survey: Global Estimate Missed care (GEM) (Hamilton et al., 2017) • Observation of nurse + care staff work time + motion (adapted from (Qian et al., 2016; Thomson et al., 2009; Westbrook et al., 2011) • Accident + incident report analysis		

and reduced participant burden and fatigue. Survey data collection was extended up to 4 weeks to facilitate participation and increase response rates.

The eight data sources are outlined below. Figure 1 provides an illustration of the project timeline, data collection, and study processes. An online appendix of all data collection tools is included with the Supplementary Tables.

Time and motion

Non-participant direct observations of nurses and care workers' activities and duration were collected by trained researchers using a pen and paper version of a modified Work Observation Method by Activity Timing (WOMBAT) tool (Qian et al., 2016; Thomson et al., 2009; Westbrook et al., 2011). Activities or actions performed by the staff, interruptions, and multitasking were captured at 1-min intervals for 60-min time blocks between 7 am and 11 am on weekdays. This approach captured peak work activity and provided homogeneity for pre- and post-implementation data comparisons. Activities were grouped into four categories: (1) direct care, (2) indirect care, (3) hunting and gathering, and (4) system care.

Pedometer

Pedometers were worn by staff to collect data on distance walked during the first 4 h of weekday morning shifts (7 am to 11 am) pre- and post- implementation.

Documentation diaries

Self-report diaries were used to capture the type (e.g., reading, writing, or looking for information), activity (e.g., medication round, process notes, and handover) and duration of documentation during each hour of a workday for nursing and care staff. After-hours documentation on weekday shifts was also captured.

Care record audit

A random selection of 21 records were selected from the 49 residents providing consent at baseline. Five were lost to follow-up, leaving 16 resident records that were audited both pre-and post-implementation and data compared. Records captured residents living in six of the eight wings of the facility. All audits were collected by the same researcher, with initial reliability checking (<90%) by a second researcher.

Audit data were collected using a modified Quality of Australian Nursing Documentation in Aged Care (QANDAC) instrument (Wang et al., 2014). To enhance data reliability, the items in the three-part tool (sections a, b, and c) were scored as 'yes' (present and/or complete) or 'no' (not present and/or incomplete), and sum scores of the 'yes' responses were calculated for each section.

Section A (scored out of 14) captured 14 resident nursing history and assessment forms (ADLs, behaviors, bowel continence, urinary continence, communication, dental, oral, depression, falls, pain, psychogeriatric care, skin observation, Braden pressure injury risk, and sleep) required by the facility. A 'yes' score was given if the form was present and fully completed within the previous 6 months as per facility policy.

Section B (scored out of 18) used 18 items to examine documentation of the nursing process (assessment, planning, interventions, and evaluation) for one specific nursing problem experienced by the resident. For consistency, a specific resident problem was selected using a hierarchical approach in the following order: cognition/behavior; falls/mobility; pressure injury/wound; pain; continence; medical. For example, if the resident did not have a cognition/behavior problem, then the audit examined falls/mobility, and so on.

Section C (scored out of 10) used 10 items to examine quality of the five most recent nursing process note entries.

Qualitative data

Qualitative data about subjective perspectives of the HIS in relation to work practices, care experiences, and the local environment were captured from four sources. In 'think-aloud' interviews, researchers

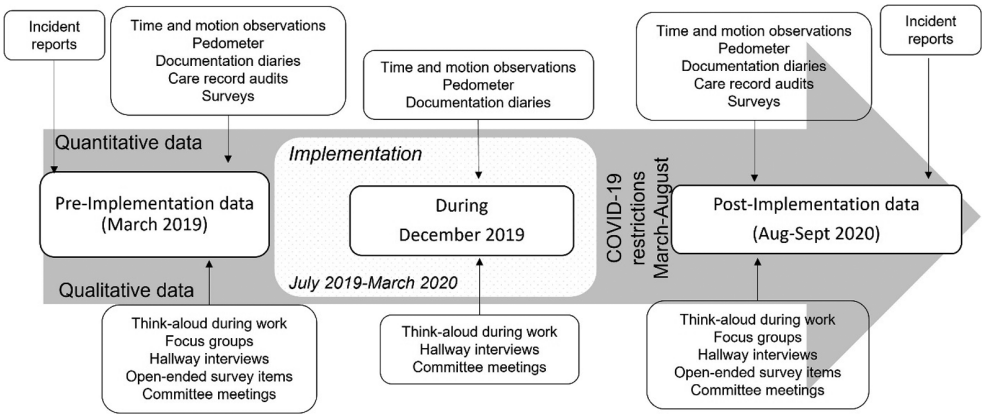


FIGURE 1 Project timeline and data collection

followed nursing and care staff and took ethnographic notes while they performed tasks and discussed different aspects of their activities. Focus groups (pre and post) included semi-structured questions and the staff surveys included open-ended questions. The ad hoc 'hallway' interviews were brief conversations using open-ended questions with the staff, residents, and visitors.

Survey (nurse and care staff)

Surveys could be completed using paper (information pack), or via a link distributed to all nurses and care staff via e-mail, and in a SMS message post-implementation. All survey responses were recorded using *Qualtrics*™. The nurse and care staff survey captured staff characteristics in addition to four tools:

Satisfaction of staff, residents and visitors with the facility was measured using the Net Promoter Score (NPS) (Keck, 2020) with the question "How likely is it you would recommend this facility to family and friends, on a scale from 1 (definitely not recommend) to 10 (would definitely recommend)?"

Missed care was examined using a single-item Global Estimate of Missed (GEM) nursing care measure (Hamilton et al., 2017). The staff, residents, and visitors were invited to respond to the question: "To the best of your knowledge how much nursing care was MISSED in the last 48 h?" using a 0%–100% scale. Previous use of this item has demonstrated acceptable sensitivity and specificity (Hamilton et al., 2017).

System use and usability was captured from staff at post-implementation only, using adapted survey items informed by the unified theory of acceptance and use of technology (UTAUT) (Tamilmani et al., 2021; Venkatesh et al., 2012) (i.e., useability, performance expectancy, effort expectancy, social influence, voluntariness, facilitating conditions, behavioral intention), items specific to functionality of the system (Kramer et al., 2010) and user perceptions of satisfaction and self-reported skill level using the system. Staff participants ranked their agreement with each item using a five-point Likert scale (1 = Strongly agree; 5 = Strongly disagree).

Survey (resident)

Residents (and/or their visitor/s) were invited to complete surveys pre- and post-implementation by a research assistant using in-person interviews. Residents (or their visitor/s) were invited to respond to NPS (Keck, 2020) and GEM care items (Hamilton et al., 2017) as described above, as well as resident quality of life measured using the 'Dementia Quality of Life' (DEMQOL) tool (Smith et al., 2007). This 29-item interviewer-administered instrument assesses quality of life in individuals diagnosed with dementia as well as those without dementia. The integrated instrument measures three factors: feelings, memory, and everyday life. All items are scored on a four-point Likert scale. The DEMQOL has previously demonstrated acceptable internal consistency ($\alpha = 0.94$) with similar populations (Smith et al., 2007).

Accident and incident reports

Accident and incident reports during a four-month period immediately pre-implementation (January–April, 2019) and a similar period post-implementation (April–July, 2020) were examined to compare specific event types (falls, skin tears, pressure injuries, and episodes of aggression) and location within the nursing home.

Ethical considerations

To maximize resident opportunity to participate, staff familiar with the resident provided advice as to whether a resident was unable to provide informed consent, or if their capacity for consent was limited or variable. In these instances, a nominated decision-maker was approached by the research team, informed about the study, and invited to provide written consent on behalf of the resident. Verbal consent was also obtained prior to each data collection event. Ethical approval was received from the (blinded) University Human Research Ethics Committee.

Data analysis

Concurrent mixed-methods analyses involved initial analyses of data from different tools, participants, and sources at each phase of the research (Creswell et al., 2011) before integration. Quantitative data sets were individually analyzed using IBM SPSS Statistics v.26 (IBM Corp, 2021). Qualitative data were managed using Microsoft Word and Excel spreadsheets.

Time and motion observation data for each of the four staff activity categories were initially examined using descriptive statistics. Any data found to be positively skewed used logarithmic transformation to satisfy assumptions of normality. Linear relationships between categories were examined using Pearson's product moment correlations (scale or ordinal data) and Spearman's Rho for continuous data. One-way analysis of variance (repeated measures and mixed model) was used to examine change in pre-post data. Significance was set at $p > 0.05$.

Survey responses were scored using authors' instructions. Step counts were grouped for similar staff roles: (1) nurses (registered and enrolled nurses); (2) care staff; and (3) other staff (health and leisure staff, admissions officers, wounds nurse). Differences between pre- and post- implementation data were analyzed using parametric (student *t*-tests) or non-parametric tests (e.g., Chi square, Mann–Whitney *U* test) suited to data type, distributions, and sample size. Percentage change was calculated for variables with limited data.

After deidentifying all qualitative data by adding codes and changing all names to pseudonyms, six-step thematic analysis (Braun & Clarke, 2006) was used to synthesize the combined transcripts, field notes, and open-ended survey responses. Analyses involved sifting and sorting through verbatim transcripts, field notes, and quotations to detect and interpret thematic categories, identify inconsistencies and contradictions, generate codes and themes to draw conclusions about what was happening and why. Detailed transparency of the qualitative data is reported elsewhere (Blinded). After independent analyses of data from multiple sources, integration of qualitative and quantitative data assisted with interpretation and contextualized findings. Concurrent constant comparative analyses were used to compare and interpret for in-depth understanding of the context and to explain outcomes as they emerged (Boeije, 2002; Creswell & Clark, 2007).

Research rigor

All multi-item survey tools had previously established reliability and validity with similar participant populations, and reliability for the current study population was also examined. Observation and audit tool reliability was examined by two independent auditors rating the same observations or resident records. Inter-observer agreement examined for 20% of observations had agreement between 91.2% and 99.7%. Agreement between independent auditors of the same care records was <80% (pre- and post-implementation).

Data quality was enhanced by using multiple forms of triangulation (Carter et al., 2014). Data source triangulation involved collecting and comparing data collected from different participant groups (residents, their visitors, care staff, nurses, managers, consultants). Methods triangulation involved using multiple data collection methods, and analyst triangulation occurred through independent analyses by multiple members of the research team (Carter et al., 2014) that involved independent coding from at least two members of the research team, group discussion to resolve discrepancies, challenge propositions and assumptions, and consensus on naming themes.

RESULTS

Data were collected from 162 participants: 65 (38%) residents or their visitors, 90 (61%) nurses and care staff, and seven (80%) managers or consultants (Table 2). Sixty percent ($n = 30$) of participating residents and 46% ($n = 69$) of participating staff contributed to two or more data types and more than one data collection phase. A

TABLE 2 Participants and data collected

DATA	Pre-implementation March 2019	During December 2019	Post- implementation August 2020	TOTAL
RESIDENT	(*n* participants)			
Quality of Life (DEMQOL)	31		28	59
Hallway interviews			31	31
Net Promoter Score (NPS; Keck, 2020)	27		38	65
Global Estimate of Missed Care (GEM)	16		19	35
STAFF				
Pedometers	66		64	130
Hallway interviews			47	47
Net Promoter Score (NPS; Keck, 2020)	32		28	60
Global Estimate of Missed Care (GEM)	22		31	53
Think aloud	8			8
Time + motion	56	8	69	134
Documentation diaries	31		34	65
Staff survey			14	14
FOCUS GROUPS				
Manager		3	7	10
Nurses/care staff		1	3	4
Resident/visitors		2	4	6
Consultants		2	5	7
AUDITS				
QANDAC audit	19		19	38
Accident and incident reports	332		407	739

summary of participants and data types is provided in Table 2. The location of consenting residents is provided in online Supplementary Table A. A joint display of mixed methods findings is presented in Figure 3.

Acceptability

Staff surveys of system use and usability (n = 14), hallway interviews (n = 47), and qualitative data were used to examine acceptability of the new HIS to the staff, managers, and residents. In all, 14 staff (15% of all staff participants) responded to the post-implementation survey examining system use and usability included care staff (42.9%, n = 6), nurse managers (21.4%, n = 3), and others (42.8%, n = 5). Most were female (85.7%, n = 12); their median age was 44.8 years (range 22–61 years); they had been employed with their current employer for a median of 8.5 years (range 1–24 years), and they had worked in aged care between 11 months to 30 years. A certificate/diploma (n = 4, 48.6%) or a master's degree (n = 4, 48.6%) were the most common highest qualifications (Supplementary Table B). Participants rated their computer skills as average (50%, n = 7) or above average (50%, n = 7) and used computers or information technology devices (including Smartphones) very often (57.1%, n = 8) or often (42.9%, n = 6).

During hallway interviews (n = 47), most staff 46.8% (n = 22) indicated they either used the HIS 'a lot' or were an 'expert user'; 36.2% (n = 17) reported they used the HIS 'some' or 'a little bit'; only 7.5% (n = 4) reported they had seen but not used the HIS (8.5%, n = 4 missing). Most (71%, n = 10) agreed the new HIS was easy to sign in, easy to learn, and easy to use. All (100%, n = 14) agreed they had the knowledge needed to use the new HIS. All nurses and managers reported care planning, scheduling changes in care, allocating tasks, and identifying if care was given, delayed, or missed was easier with ACE (see Supplementary Table C) and functionality was easy to use (see Supplementary Table D).

Two qualitative themes relevant to the HIS acceptability emerged. Theme 1was about the reduction in time spent retrieving information and documenting care. This finding was supported by comments that the HIS was easy to use, enabled contemporaneous documentation, provided immediate access to information at point-of-care, and reduced searching (walking, reading, flicking). Theme 2 indicated staff and residents satisfaction with the HIS, supported by comments about improved care experiences, resident safety, and person centeredness. Table 3 provides illustrative quotes.

Efficiency

Efficiency of the HIS was examined using work observations, pedometers, and documentation diaries, complemented by findings from the qualitative analysis. Figure 2 illustrates that most of the 92 h (pre-43 h and post-49 h) of direct work observation involved direct care (e.g., showering, toileting, mobilization, hydration/nutrition) and indirect care (e.g., gowning/gloving, preparing equipment, communication with other staff) for both nurses (used here to refer to both registered and enrolled nurses) and care staff. Care staff spent more time than nurses in direct care, and less time in indirect care.

Compared to pre-implementation of the HIS, nurse time on documenting care (including observations, reading, using

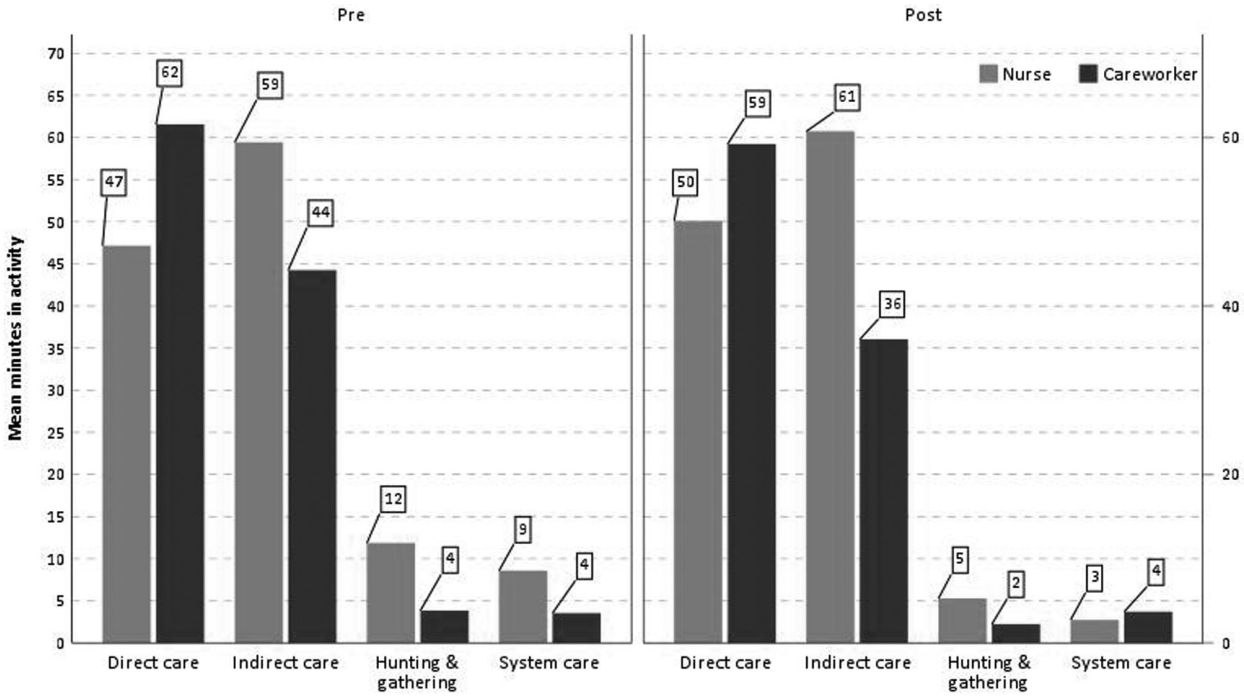


FIGURE 2 Pre- and post-implementation activity data

Acceptability

Reduced time on documentation: 30% for RN/EN

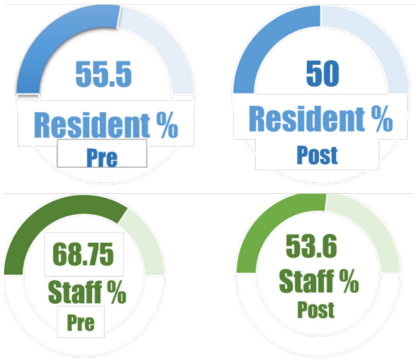
Net Promoter Scores high pre and post:

- Staff promoters* 72% pre and 65% post
- Resident promoters*: 59% pre and 63% post

Staff agreed:

- Easy to sign in (71%)
- Easy to find resident diagnosis (79*%)
- Easier to enter care information (71%)
- Easier to find instructions about care (71%)

*Scored 9-10/ 10 on "would you recommend this facility to family and friends



Could be distracting -some residents thought staff might be using their own phone (rather then the work phones) for Facebook: but I liked that staff *"sit in front of me and fill in the information on the phone …. I think its good"* (resident/ relative)

Transformational- *"Beautiful", "amazing", and "absolutely time saving"* with more time spent on the floor (manager)

Easy-to-use- Staff who did not even use smartphones were now happy to experiment with it as they went, to figure out what they could use (nurse/care worker)

Efficiency

- Documentation of 10 of 14 key assessment forms increased to >90%
- Decreased time staff spent searching (median 7 minutes/ hour)
- Steps on a morning shift by RN/EN reduced by 30% (preM4817, SD 1362 and post M3570, SD1673)

More efficient - Time saved from walking and double-checking paperwork and returning, while time spent seeking, accessing, and returning files for paperwork and audits *"cut in half"* (Manager)

Saves time and improves information quality - "very quick, very convenient, detailed, …. *"it helps, when you've got 30 things to think of, to know what it is you've got to do"*. (nurse/care worker)

Easy access - staff don't have to *"run around"* as much, nor *"shout across the hallway to each other"* (resident/relative)

Immediate – "*They …. Have at their fingertips all the information, like what time Fred needs to go to bed and what type of food Fred prefers…."*(resident/relative)

Quality

- Documentation quality significantly improved: 15 of 17 quality items >80%
- No change in resident incidents or harm, resident QOL unchanged
- Increased reports of missed care indicates greater awareness: reduced mussed care >20%

More time with residents - every few minutes gained improves the residents day: knowing what the resident needs improves care of people with behaviours (nurse/care worker)

Safer- when the plan is updated it's instantly changed everywhere, which is safer for each resident (manager)

Up-to-date - *"it was really reassuring to know that staff knew what things had changed and what Mum needed"* (resident/relative)

Better staff interaction - with reminders and requests built-in, manager-staff conversations are more collegial and less task oriented (manager)

More resident focussed -*"can know the residents properly, about their behaviour and why they are here"* (manager)

We can see what hasn't been done which is really helpful. If they don't do the shower or teeth they also don't document so we know and can **catch up on these missed care**. (nurse/care worker)

FIGURE 3 Joint display of concurrent mixed-methods findings

computers or tablets, incident reporting, or searching, hunting and gathering documentation) decreased after implementation from 23.9 min to 7.5 min per hour ($p = 0.002$) (expressed as a proportion of total nurse time). This represented a decrease from 20.4% to 6.4% of observed nurse time. Similarly, nurse time spent searching for information decreased from 12 min to 5 min per hour ($p = 0.002$) and nurse time spent on communication (a composite of communicating with the residents/visitors, staff, or trying to

TABLE 3 Illustrative qualitative and quantitative data supporting findings

Aims	Themes	Sub-themes	Illustrative quotes[a]	Quantitative findings
Acceptability	1. Time retrieving information and documenting care	1.1 Acceptance of ACE system - easy to use 1.2 Contemporaneous documentation at point of care 1.3 Immediate access to information at point of care 1.4 Reduced searching (walking, reading, flicking)	1.1 Easy to use, easy to explain, information can be found quickly. (SS1) 1.2 So they can just tick it off immediately after doing it. (MFG 2) 1.3 They … have at their fingertips all the information, like what time Fred needs to go to bed and what type of food Fred prefers. (RFG 4) 1.4 Previously we would say to the wound nurse, 'oh, yeah, we're not sure who is due'. She would have to go to every single wound folder, which has nine different folders throughout the facility, whereas now they can sit down and plan their day, where to go, and who is more urgent, and who is not. (SFG 3)	Reduced time spent on documentation • 30% Registered and enrolled nurses Staff agreed the system was easy: to sign in (71%), to find resident diagnosis (79%), to enter care information 71%, to find instructions about care (71%)
	2. Satisfaction with care	2.1 Satisfaction with increased resident safety 2.3 Satisfaction with increased person centeredness	2.1 As an AIN [care worker] I think it is very good for us, especially for the safety of the residents, safety of residents, especially a long time back we used to do lots of residents. (SFG 3) 2.3 Nurses use the system to record everything they do as they do it. Think that the technology has impacted her care for good. I've noticed a distinct bettering of the care. (RHI 18)	Net promotor scores high pre- and post-implementation
Efficiency	3. Working with management-approved clinical care protocols	3.1 Easy access to most recent specialist review improves staff responsiveness to care changes 3.2 New immediacy of translating care planning update into care interventions for residents 3.3 Easy visibility improves person centered care	3.1 It does not have to wait for the resident nurse to think, 'oh, the dietitian came this morning, I better do something about that'. And then do the triplicate, and then it goes here, and then the receptionist fills it up, or the kitchen does something. It is immediate, it is right there. (SFG 3) 3.2 If you wanted to find out whether Mary needs her food pureed or not, first of all you have to look through that folder, but secondly you might find the wrong form. You might find the form from 3 weeks ago or it might be on the food preference part but that is not the chart I've got up there yesterday … [Now] if you go to the food preferences in the care plan you get the latest consistency of the food. (HFG 1) 3.3 I can document if the resident is cranky or needed extra pads or what she is upset about. The normal things. But itis so important. (SHI 36)	Documentation of 10 of 14 key assessment forms increased to >90% Decreased time spent searching (median 7 min/h) Steps on morning shift reduced by 30% (RNs/ENs)
	4. Care errors + omission, + missed documentation	4.1 Improved information capture 4.2 Easy to see information 4.3 Preventing inaccuracies in documentation	4.1 For me, it is more complete, the system, how you say, compared to manually, before. It is much more complete. Everything is mentioned that we are going to do. Everyone hour we check, to see location, especially when I go to other wings, helps me know more. (SHI 36) 4.2 Yeah, it is very clear and neat. Everybody will understand the same thing. (SFG 2) 4.3 Before we used to write notes in reports and incidents and I honestly feel like I did not write it correctly, because we come from non-English backgrounds. (SFG 3)	
	5. Care decisions supported by resident data	5.1 Flagging enables resource prioritization 5.2 Operational efficiency potential	5.1 After days off I can see how Peter was over the weekend. Keeping record, the behavioral management, whether we need new strategies, can use in combination with talking to staff. (SHI14) 5.2 It is taken away the beginning of shift [issues when the team is] under the pump to shower these three residents before breakfast because that is what the resident wants. In the old allocation system, they would do it on paper. This [ACE system] has taken away that planning that would slow it down, they had to wait for the RN to do allocation and maybe they were late, or they were with someone with a fall. And the AINs [care staff] are sitting twiddling thumbs. Now they can move faster first off. They have got to go so fast. To get it done before breakfast you have got to go clappers. What they had to do at the nursing station they can now do on the run. (SHI 29)	Documentation of 10 of 14 key assessment forms increased to >90%

TABLE 3 I(Continued)

Aims	Themes	Sub-themes	Illustrative quotes[a]	Quantitative findings
Quality	6. Resident quality of care	6.1 Benefits of care scheduling 6.2 Quality of documentation/ information supports quality of care	6.1 Improved level of care given to patients as we are more guided. For example, toileting, I need to do this at this time, and repositioning etc. (SHI 19) 6.2 Has made me more aware of looking at what I'm doing, comparing to things. Before you would just tick the one form. (SH10)	Documentation quality improved, 15 of 17 quality items >70%
	7.Perceptions of missed care	7.1 Missed or delayed care is now more visible + easier to address 7.2 Missed care is sometimes related to prioritization 7.3 The prompts reduce cognitive load for nurses/care staff, which reduces missed care	7.1 But we can see what has not been done which is really helpful. If they do not do the shower or teeth, they also do not document so then we know and can catch up on these missed care. (SHI 45) 7.2 One out of 15 people get forgotten. You might have planned to take someone for a walk, but then have to do eyedrops for someone instead. (SHI 47) 7.3 Less things to remember at the end of the day because you have been doing it throughout the day. Otherwise at 3pm it is like "oh crap, what happened at 07:00?" (SH17)	Increased reports of missed care indicates greater awareness Reduced incidence of missed care greater than 20%
	8. Nurses + care staff time with residents	8.1 Time released to spend time with residents 8.2 The system enables more companionable multi-tasking	8.1 I can spend my time with other residents. (SFG 3) 8.2 It is not like paperwork where we would have to go to nurses' desk, find the folder. Now we can do it anywhere, anytime, it is very convenient. We can do it sitting with someone. We can stay with the residents and make sure the ones that do not get along do not have an altercation, it is much better. (SHI 28)	
Implementation Process	9. HIS implementation successes	9.1 Co-design 9.2 Feedback specific to study site	9.1 ACE is developed to meet needs of our residents and staff. It is being built to suit our needs and we do not have to change the work culture to fit the need of software. (SS 2) 9.2 I'm really impressed with how they have treated me, they are really friendly and taken the time. They are caring. There is not a lot missed here…a lot of places are under the pump, 'Go, go, go', but here is more relaxed. The staffing to resident ratio is really good. ….I actually really like working here. (SHI 16)	
	10. Teething problems	10.1 Refining the scheduling issues 10.2 Access to on-the-job training 10.3 Frustration at learning, slow speed or glitches	10.1 It's time consuming when we are doing it twice, it is already there. If it is already attended, 3 or 4 times it comes, even though it is recording. The unnecessary thing happens on A wing and C wing. (SHI 18) I use it every day since they started F wing. Formal training has not happened, Jane is very busy, I have learned from CNC and my colleagues, it is easy, I know most things. (SHI 28) It used to be slow, now it is fine. (SHI 28)	
	11. Improvement opportunities	11.1 Limited access (by casuals/ professionals) can increase missed care 11.2 Interoperability with other information technology 11.3 Other suggestions	11.1 Sometimes because new staff or agency, cannot make them aware, they do not know the ACE system. We use agency a lot. Only 2 of us know ACE so we do all the documentation [today]. [There are] 4 agency staff today. (SHI 6) I have been using the system since I started. I like it but my main gripe is that as an outsider I cannot email myself my notes. That would mean I do not have to write it twice. I have to do notes [again when I return to office]. (SHI 8) 11.3 The only [thing] I want to know, I want to be able to do the drawing in the notes, so they can see the instructions for the dressing. And for the government to see that too. It is very important, if they have a sinus or whatever. In [other systems] you can draw, with the mouse, you can make a circle on the photo. This will be fantastic. You can point out where on the body. The front, and the back, the head. Should be the whole body with clear anatomy. Can expand. Photos of wound is good but need to know which leg it is. (SHI 4)	

[a]Codes: MFG, manager and consultant focus group; RFG, resident focus group; RHI, resident hallway interview; SFG, staff focus group (mixed: Nurses, Care staff, CNC, manager); SHI, staff hallway interview; SS, staff survey (qualitative component).

contact the staff or relative) increased from 42.7 to 52.6 min per hour ($p = 0.049$).

Consistent with the reduction of 'hunting and gathering' activities, analysis of pedometer data indicated a significant reduction in the mean number of steps per shift (7 am–11 am) for both nurses and care staff, with a modest non-significant reduction for managers (Table 4).

Analyses of self-report documentation diaries (65 diaries, 31 matched pairs) indicated no statistically significant change in the proportion of time spent on documentation pre- (M = 48.7%, SD 21.7%) and post-implementation (M = 50.9%, SD 21.97%) ($t[27] = 0–0.454$, $p = 0.653$). However, nurses ($n = 8$) reported a 30% decrease in self-reported documentation time post-implementation, complemented by qualitative data supporting staff perceptions that documentation time reduced and was spread evenly across the shift after the HIS implementation. Conversely, care staff ($n = 14$) reported a 21% increase in documentation time.

Three themes relevant to HIS efficiency were identified in analysis of the qualitative data. Theme 3 indicated staff perceived improvements when working with management-approved clinical-care protocols, supported by comments about improved staff responsiveness, access to specialist review, translation of care planning into interventions, and person-centered care (Table 3). Theme 4 related to staff perceptions that using the HIS reduced errors of omission and missed documentation. This finding was supported by comments about improved information capture, easy access to information, and visualization of documentation (Table 3). Theme 5 related to improved management decisions, allocation of resources and resident welfare. This theme was supported by comments about enabling resource prioritization and potential for increased operational efficiency (Table 3).

Quality of care

Change in quality of care related to the HIS implementation was examined using audits of document quality, reported incidents, surveys of satisfaction, resident QOL, and perceptions of missed care. Qualitative data findings complemented these data.

Resident and staff satisfaction scores were high both before and after the HIS implementation, suggesting implementing the HIS had no negative impacts on resident or staff satisfaction (see Supplementary Table E). This finding was supported by qualitative comments (Table 3) indicating stability in staff and resident satisfaction at the facility over the duration of the project that also included the COVID-19 pandemic response. Similar to satisfaction, comparison of resident self-reported QOL using mean scores on DEMQOL at pre- ($n = 33$, M = 116, SD 15.3) and post- ($n = 28$, $M = 111.5$, SD 13.4) the HIS implementation showed no significant change ($t[59] = 1.338$, $p = 0.186$).

The proportion of residents (or their visitors) who reported missed care in the previous 48 h rose from 33.3% ($n = 8$) (pre-implementation) to 100% ($n = 33$) (post-implementation) ($p < 0.001$). However, the proportion of residents (or their visitors) who reported more than 25% of care was missed reduced significantly from 25% pre implementation to 3% ($p < 0.001$) post-implementation. These findings indicate the visibility of perceived missed care for residents increased, but the volume of care that was missed decreased. In contrast, there was no significant change in the proportion of staff who reported no missed care (0%) in the previous 48 h at pre-implementation (17.2%, $n = 5$) compared with post-implementation (31.6%, $n = 6$) ($p = 0.276$).

Of the 21 resident records randomly selected for audit, five were 'lost to follow up' at post-implementation, leaving 16 matched resident records audited (Supplementary Table F). Just over half (57.1%) were for female residents, the average age was 84 (SD 9.1) years and they had lived at the facility between 1 and 6 years.

The number of completed nursing history and assessment forms for each resident (out of a possible 14) increased from an average of 61% pre-implementation to 86% post-implementation. Assessment of the residents' ability to perform ADLs was most improved (pre-75% and post-100%) (Supplementary Table G). Conversely, fewer falls and depression assessment forms were completed post HIS implementation. Qualitative data revealed nurses perceived completing the falls and depression assessments in the HIS were a low service priority for maintaining resident safety as these activities were conducted by other staff (e.g., physiotherapist). Similar to assessment, there was a significant change in documentation of the nursing process for a specific resident problem (Supplementary Table H) (out of a possible score of 18) from a median score of 10 pre-implementation to a median score of 17 post-implementation ($p < 0.0001$) (Supplementary Table I). The quality of nursing process note entries improved in all criteria except for the identification of the health care professional completing the documentation (Supplementary Table J).

TABLE 4 Characteristics of pedometer step data

Steps	*N*	Pre-implementation, M (SD)	Post-implementation, M (SD)	Statistic, % change from pre- to post-
Overall	65 pre 57 post	4133.0 (1596.7)	3058.1 (1471.9)	$t(120) = 3.847$, $p = 0.000$ (−26%)
Management	7 pre 11 post	3069.7 (1711.9)	2293.4 (1291.4)	$t(16) = 1.097$, $p = 0.289$ (−25%)
Care worker	40 pre 32 post	4011 (1577.9)	3096.9 (1368.7)	$t(70) = 2.589$, $p = 0.012$ (−23%)
Nurse (RN/EN/EEN)	18 pre 14 post	4817.7 (1362.2)	3570.6 (1673.9)	$t(30) = 2.325$, $p = 0.027$ (−26%)

Three themes relevant to HIS related quality of care were identified in analysis of the qualitative data. Theme 6 related to perceptions of improved resident health and quality of life. This finding was supported by participant comments about benefits of care scheduling, the quality of documentation and information supporting quality of care. Theme 7 related to perceptions of reduced missed care, supported by participant comments about missed care becoming more visible with the HIS, prioritization, and reduced cognitive load for staff. Theme 8 captured participant perceptions of increased time for nurses and care staff to spend with residents. Supporting comments included time released from low-value care and companionable multi-tasking (Table 3).

Implementation

Three themes related to the HIS implementation were identified in the qualitative data. Theme 9 captured perceptions of implementation successes, supported by comments about the co-design process used for implementation, and feedback participants wanted to provide to the site team (Table 3). Theme 10 captured minor 'teething problems' associated with the implementation and related to refining scheduling issues, access to on-the-job training and frustration expressed about learning processes, slow speed or glitches with the technology (Table 3). Theme 11 related to improvement opportunities. This theme was illustrated by comments about limited access to casuals/professionals which can increase missed care, interoperability with other information technology and general suggestions (Table 3).

DISCUSSION

The implementation of a novel HIS called aged care ecosystem (ACE) into a single nursing home was associated with high acceptability to the staff and residents, and multiple benefits for efficiency of work and the quality of resident care. The two-year pragmatic participatory action research design aligned closely with the experienced based co-design processes (Green et al., 2020) used to incrementally implement and tailor the HIS in response to user feedback. Concurrent collection of mixed-methods data facilitated participation of a wide range of staff, residents, and visitors; integration and triangulation of data captured from multiple sources provided comprehensive and in-depth contextual understandings that enhanced rigor and supported interpretation of findings.

Overall, the staff with a range of qualifications and self-reported computer literacy found the HIS easy to use; they could easily sign in to access the system, find and enter resident information, and use this information at the bedside when needed. In particular, the perceived ease of use by the staff with minimal computer skills is an important finding that may help to address concerns about investment required for training when implementing a new information system (Ko et al., 2018). Such costs have been cited as barriers to the uptake of digital systems in residential aged care (Kruse et al., 2017; Rantz et al., 2010). This was overcome in the current project by staff involvement in testing and informing iterations, thereby building their skill over time, but also ensuring fit with local care processes and preferences.

A key goal for the ACE system was to decrease worker time spent on documentation while simultaneously increasing documentation and care quality. This goal addresses common problems of documentation burden (Moy et al., 2021), and specific concerns about data quality (Ausserhofer et al., 2014; Gaskin et al., 2012; Qian et al., 2016) and personalization of care (Mariani et al., 2017). The findings suggest these goals were realized with time and motion data indicating documentation times for nurses decreased, complemented by increases in staff time spent in direct communication with residents. In addition, qualitative findings suggest the time released from documentation was redirected towards resident-focused care. These findings are consistent with previous research about how nurses in aged care prioritize their time (Ausserhofer et al., 2014). The 25% reduction in walking distance for nurses, and 23% reduction for care staff, was complemented by a decrease in time spent searching for information and documenting care, and a reduction in multitasking. Walking distances have been frequently examined to identify efficiency opportunities as well as staff satisfaction and wellbeing (Sedgwick et al., 2019; Welton et al., 2006; Yi & Seo, 2012). In addition, time savings were achieved by reducing searching for information (6.0%), reflecting removal of 'waste' activities which impacts nurse work satisfaction, and assists to maximize nursing resources (Hendrich et al., 2008; Zadeh et al., 2012). However, caution is needed to ensure resident care quality is not compromised by a focus on efficient use of resources (Harvey et al., 2018; Willis et al., 2016).

This study benefited from a strong commitment to the co-design process for implementation of the HIS by facility management and highly engaged staff. Co-design was particularly useful for differentiating the different workflows and information needs of nurses and care staff. Qualitative data highlighted the desire to balance the focus of HIS implementation on efficiency and acceptability, with a shared common goal to deliver high quality care to residents. This was consistent with literature highlighting system efficiency and acceptability is pointless if the system is not effective in improving quality outcomes for the target population (Kieft et al., 2014; Krick et al., 2019).

This study demonstrates how a technology system can be successfully used to increase availability, access, and quality of resident-focused information, and assist nurses and care staff with quality resident care. The findings revealed a simultaneous increase in visibility and decrease in the proportion of missed care, as perceived by residents and their visitors. This finding has not yet been reported in the literature. Such a HIS aligns with value statements for the aged care sector in terms of principles of choice and control for older peoples' quality of life, personalization, co-design, and co-evaluation (Aged Care Industry IT Council, 2017).

Quality of care in nursing homes is complex. High documentation burden is a major challenge for meeting regulatory and clinical goals

(Yu et al., 2013). This study demonstrated improvements in legibility, completeness, and accessibility of care documentation, concurrent with a reduced documentation burden; resident assessments, individualized goal setting and evaluation of care reached 90% after the HIS implementation. The system shows promise for increasing the visibility of the nursing process and clinical decision making (Bail et al., 2021; Wisner et al., 2019) linked to improved resident care (Sworn & Booth, 2020). In addition, time release from documentation and 'waste' activities was redirected into direct-resident care. Staff reported improved information access helped them to be better equipped to personalize care, better respond to individual needs, and manage the 'delicacies of dignity'.

Limitations

This real-world pragmatic study encountered several constraints and methodological limitations. The study was undertaken in a single nursing home with comparatively high staffing levels (e.g., registered nurses provided >44 min care per resident per day; total care staff provided 242 min per resident per day) meeting the requirements for a '4-star level' (Royal Commission on Aged Care Quality and Safety, 2020) hence generalizability to other nursing homes is limited. Changes occurred during the study limiting pre-post comparisons including:

- building redevelopment from accommodating 157 residents at pre-implementation (March 2019) to 169 at post-implementation (Aug 2020);
- staff and resident turnover (50% overall, with 95% of resident turnover due to death);
- a proportion of transient staff (e.g., consultant and allied health) not employed by the facility;
- a gastroenteritis outbreak;
- the COVID-19 pandemic and responses to the pandemic.

These factors contributed to challenges to project progress, participant recruitment and retention, data collection and the potential for sampling and response bias.

Relatively high response rates (61% of staff and 38% of residents), and transparency in reporting methods and participant characteristics enhance credibility. Attrition bias was ameliorated by using brief validated data collection tools to minimize participation burden (Smith et al., 2007; Wang et al., 2014; Westbrook et al., 2011). Triangulation of data from different participants and sources, and consistency in findings across multiple data methods and types lend credibility to the findings. Assurances of anonymity and ad hoc hallway interviews enhanced staff survey responses.

The prevalence of cognitive impairment limiting provision of informed consent is a well-documented issue for aged care research (Simmons, 2011). To respect individual choice and maximize resident opportunity for participation, where possible, prior consent was obtained from clinicians or relatives/trustees for those with conditions causing moderate to severe, or fluctuating cognitive impairments, as well as those with severe illness or nearing the end of life. Work observation data were collected between 7 am and 11 am, which may limit generalizability across the 24-h care cycle. However, this time captures the busiest time of the day for residents and staff, hence provided a strong basis for detecting changes in staff work patterns. This approach also provided homogeneity to strengthen data for analysis of pre-post comparisons. Self-report documentation diaries complemented observations by capturing data specific to staff documentation over the entire shift; while less reliable than observation (Ampt et al., 2007), consistent methods were used pre and post HIS implementation.

CONCLUSION

Implementation of the new ACE system was associated with improved quality of resident care and increased staff efficiency. Benefits of co-design used for implementation were high levels of sustained engagement throughout the implementation, and to ensure the system suited the values and needs of all the end-users (residents and their visitors, nurses, care staff and visiting health professionals). These findings contribute to the evidence about how technology systems can promote both quality and efficiency in residential aged care.

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CLINICAL RESOURCES

https://www.canberra.edu.au/about-uc/faculties/health/research/ageing/Evaluation-of-ACE-in-Aged-Care_Cover_2F52.pdf.

CONFLICT OF INTEREST

The author(s) declare(s) that there is no conflict of interest. Under the funding agreement, the funder reviewed manuscript content before submission but were unable demand any changes or withhold publication, thus managing potential competing interests.

STTI CHAPTER

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table A

Table B

Table C

Table D

Table E

Table F

Table G

Table H

Table I

Table J

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