

REMEDI – Tactics of Expanding a Science Gateway Community

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Abstract—The Regenstrief Center for Healthcare Engineering (RCHE), an interdisciplinary research center located at Purdue University, facilitated the development of a scientific gateway for medical device informatics, known as Regenstrief National Center for Medical Device Informatics (REMEDI). Initially formed in 2009, REMEDI is an evidence-based community of practice, focused on smart pump technology and infusion therapy safety. REMEDI is a virtual community of pharmacists, nurses, other clinicians, infusion pump vendors, researchers, and national organizations such as the American Association of Medical Instrumentation (AAMI) and the American Society of Health-System Pharmacists (ASHP). In 2017, in response to a need identified by AAMI, REMEDI expanded its scope to include new applications, databases, and community engagement spaces for respiratory therapists, nurses, and ventilator vendors.

Keywords—Science Gateways, patient safety, hospital self-analysis, evidence-based community, applications

I. INTRODUCTION

Regenstrief National Center for Medical Device Informatics (REMEDI) was created to address patient safety issues associated with the administration of medications using infusion pumps. According to the US Food & Drug Administration (FDA), in a 5-year period 2005 – 2009, there were 56,000 adverse events and numerous deaths associated with infusion devices [1]. Smart infusion pumps, those infusion pumps containing a library of medications with dosing guidelines are intended to ensure safe intravenous medication use by preventing over and under dosing, were in use by 72.9% of hospitals in 2013 [2].

Since many hospital patients receive infusions, the REMEDI project was initiated in response to the national priority to improve patient safety for infusion pumps and to a request from the Indianapolis Coalition for Patient Safety. The mission and primary activity of the collaborative are to conduct activities that improve patient safety and the quality of healthcare delivery.

Organizing 34.8 million alerts and compliance data representing nearly 136 million infusions in a database, the REMEDI science gateway is used for benchmarking and provides pharmacists, and

other clinicians, evidence to make more informed decisions related to infusion pump medication administration therapy. Community members drive REMEDI operations. Through regular meetings, representatives of the member hospitals share their knowledge in a collaborative environment, fostering knowledge development to advance medication administration practice and improve patient safety

Membership in REMEDI includes hospitals of many types (e.g., critical access hospitals, university teaching/research hospitals, safety net hospitals, etc.) and is provided at no cost to members that are willing to share their data and knowledge. Current membership includes approximately 50 systems, representing 300 facilities in 24 states, plus 1 hospital in Costa Rica. More than 120 clinicians have used REMEDI analytics tools to generate over 60,000 reports since 2009.

During this gateway expansion, REMEDI and the teams

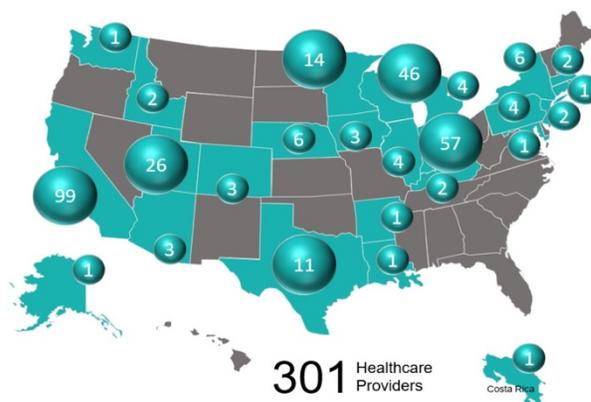


Figure 1: REMEDI membership growth and representation in the United States.

supporting the platform have developed best practices for onboarding new community members, designed a new system for accepting hospital contracts, introduced new applications for new community members, and initiated outreach plans targeting future members. Through all of this work, REMEDI has developed a few

tactics for handling growth and has set future goals for continual growth.

II. BACKGROUND

In 2009, medication errors topped the list of adverse events occurring in hospitals [3]. Realizing that alarm safety was an emerging concern among hospital administrators and national regulatory organizations, Regenstrief Center for Healthcare Engineering (RCHE) focused attention on this escalating patient safety challenge in 2010 before it reached the level of high national awareness [3]. RCHE is exponentially expanding to enable an even greater impact on the safety and quality of healthcare delivery nationwide. We are actively working on projects to 1) significantly increase the capability of the current system to allow more users and move users away from using a local system that does not encourage data sharing to a collaborative platform; 2) capture all infusion pump alarms, not just those generated against the drug limit libraries; 3) dramatically increase the capabilities to include physiological sensing monitor data; and most important 4) linking smart pump and physiological sensing monitor data to anonymized patient data to better measure impact. Forming new communities around these additional medical devices will provide fertile ground for Purdue researchers and our partners to examine not only the use of these devices but how these communities advance patient safety and quality.

Currently, REMEDI communicates with their active community through their online collaborative platform offering forums, applications to interact with data records, and ability to publish findings with the community through publications and research results. Users of the REMEDI platform can perform thousands of unique analyses by selecting different combinations of hospital, date range, profile or care area, facility, type of limit (hard/soft), infusion duration, drug or fluid, action taken by clinician, alert type, and field limit type. Once we have enough information, the goal is to provide a standard shared alert level based on patient type and other values in order to provide hospitals with enough information to make informed decisions. REMEDI also sends direct email announcements and shares marketing information through the Purdue University Research social media accounts on Facebook, Twitter, YouTube, and Google+. No patient or sensitive data is shared outside the REMEDI platform. REMEDI also hosts regular community webinar meetings and an annual community conference. During the webinars and conference, the REMEDI team interacts with community members to analyze the scope for new features or improvement plans for existing applications.

REMEDIE is funded by the Regenstrief Foundation, which is why membership is currently free for the REMEDI community. The Regenstrief Foundation was created as part of a \$17 million endowment left by Sam Regenstrief with the intention to improve healthcare delivery.

A. Competitors

REMEDIE has one direct competitor to their infusion pump community, Bainbridge Health [4]. This company was formed in 2017 and is also vendor-neutral, meaning they provide applications that compare data between hospitals despite what medical device company they buy their machines. REMEDI is unique in the fact that they are a free resource, also vendor-

neutral, identify hospitals by name, and provide a community space on their online platform. Infusion pump vendors and respiratory machine vendors are indirectly REMEDI's competitors because they also offer applications to view data. These vendors may see REMEDI as a threat for they sell consulting while REMEDI offers free community-driven consulting. To our best knowledge, REMEDI is the only project offering such services and is prepared to offer them also at the international level.

B. Publics

REMEDIE's current audiences are pharmacists, nurses, infusion pump vendors, national organization representatives, and Purdue University researchers. These audiences are primarily medical professionals actively working in hospitals. All current members actively work with the infusion pump applications. After the April 2017 conference, a survey was sent to all attendees. Feedback from this survey has helped pinpoint what the infusion pump community thinks about the REMEDI platform, community interactions, and applications.

The infusion pump community views REMEDI and their support with a high satisfaction with room for improvement in training (2.2/5.0) and documentation (2.0/5.0), see Figure 2, on a five-point scale where 1 = Excellent and 5 = Terrible. Conference participants also gave feedback on the benefits of using REMEDI. One attendee stated that, "REMEDIE has greatly helped us identify areas for performance improvement with our Plum360 infusion pump drug library alerts [4]." They also found benchmarking data against other hospitals and collaborating with hospitals to be a major benefit. Another benefit that community members found was that REMEDI, "simplified the reporting and investigative process for our site. It takes away many of the challenges one is faced with in an

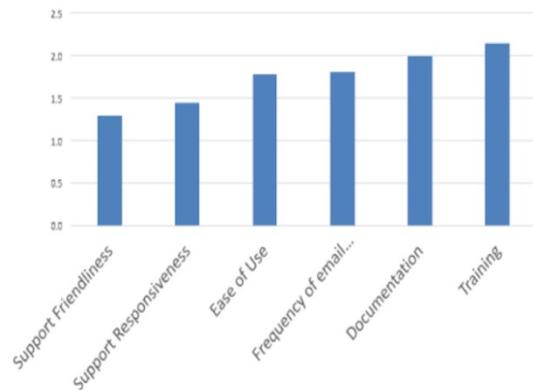


Figure 2: 2017 Infusion Pump Community Survey, community satisfaction rating per unit

attempt to interpret data from the vendor's standard reporting system [5]."

Participants also gave input on where they would like to see improvements with the platform. "I would like to be able to pull more data when basic infusion mode is used - what care profile, time of day, possibly what meds were programmed before and after, etc. This would help me better understand why basic infusion is being used so I can target my compliance

education where it is needed [5].” Others suggested more documentation on using the different applications available on the platform and more information on using the platform overall.

This feedback is in line with what participants said in the overall satisfaction with REMEDI. From this feedback, REMEDI has developed a plan to build out the documentation for their infusion pump community. This information also has helped us predict the needs of future communities.

C. Platform

Around 2011, the cyberinfrastructure team supporting nanoHUB.org, a science gateway run by the Network for Computational Nanotechnology (NCN) at Purdue University with a mission to create, deploy, and operate a national resource for theory, modeling, and simulation in nanotechnology, realized that the web based solution that build nanoHUB is needed by scientific disciplines [6-7]. The project HUBzero was developed out of the Rosen Center for Advanced Computing (RCAC) the computing research division of Information Technology at Purdue (ITaP). The HUBzero team produced an open source software platform that allows researchers from any field or study to build a dynamic web site, called a Hub. On a Hub, researchers can host analytical tools, publish data, share resources, collaborate, and build communities [8].

Every Hub is a self contained eco-system that supports any user through their research process with the ability to host analytical tools, publish data, share resources, collaborate, and build communities in a single web-based ecosystem. The HUBzero infrastructure includes a tool execution and delivery mechanism based on Virtual Network Computing (VNC). Any tool with a graphical user interface can be installed on a Hub and deployed within a few hours. The jobs themselves can be dispatched to the high performance computing resources. A Hub can be enhanced by installing Jupyter notebooks, RStudio, and other Web applications for easier tool development. Anyone with a registered account can develop a tool through these services and publish a finalized version on their Hub so their peers can access the simulation or model they have developed. Each Hub is built to be flexible. The creation of tools and access to published tools can be controlled with configurable permissions. Each tool is containerized and can easily be deployed when a user requests to run the tool simulation.

Each Hub also comes with a guided system to help registered users publish research products or data. Platform managers can provide experts on the Hub with access to review submitted materials before they are published. Every publication can receive a digital object identifier (DOI) which can be included in a white paper about the research or in a journal publication so readers can access the data after the completion of a study.

Finally, every Hub comes with collaborative spaces for research teams and peers to share ideas, track project progress, and connect file services such as Google Drive, GitHub, or Dropbox. Communities come with a system to manage new memberships, share ideas through collections, discuss

important topics through forums, and brand their collaborative space.

REMEDI is hosted by HUBzero locally at Purdue University in the United States. United States hospital patients give their consent that anonymized data can be collected and used. Any patient data must remain on a secure system meeting the Health Insurance Portability and Accountability Act of 1996 (HIPAA) compliance level. REMEDI is HIPAA compliant. HUBzero has administrative safeguards including risk management plans, risk analysis checks, sanction policy, information system activity reviews, contingency plans, security responsibility, information access management, security awareness measures, security training, access control, audit control, and other technical safeguards. All of these policies and procedures come United States legislation to provide data privacy and security provisions for medical information.

III. GROWING A GATEWAY COMMUNITY

Existing REMEDI members, national healthcare priorities, and national organizations have driven RCHE to explore REMEDI’s expansion, capturing data from smart pumps, increase data collection from monitors, and linking data. Forming new communities around these additional medical devices will provide fertile ground for Purdue researchers and partners to examine not only the use of these devices but how these communities advance patient safety and quality. Through these relationships, REMEDI is in a unique position to continue growing the entire REMEDI community to include many more U.S. hospital members and additional international members. REMEDI also can continue meeting the needs of current and future community members through developing a space for collaboration and build applications unique to their medical devices and needs.

A. Best practices for onboarding a new community member

AAMI introduced two new communities as opportunities for REMEDI’s growth. The ventilator application audience would be made up of respiratory technicians, national organization representatives, vendors, and community administrators. The physiological monitor audience consists of nurses, hospital leads, national organization representatives, vendors, and community administrators. For both of these communities, they required similar set-up as how the infusion pump community was created on REMEDI. The REMEDI team created applications that analyzed data provided by each hospital and provided a community space for each new group.

B. Introducing new applications

In October 2017, REMEDI soft-released a new set of applications for respiratory therapy and physiology monitoring. The Physiological Monitor Defaults application was designed to address the answer of “where does one start when monitoring patients?” The Physiological Monitor Defaults application, see Figure 3, helps clinicians answer this question by providing benchmarking tools to see where other hospitals initially set their alarm thresholds for heart rate (HR), peripheral capillary oxygen saturation (SpO₂), systolic and

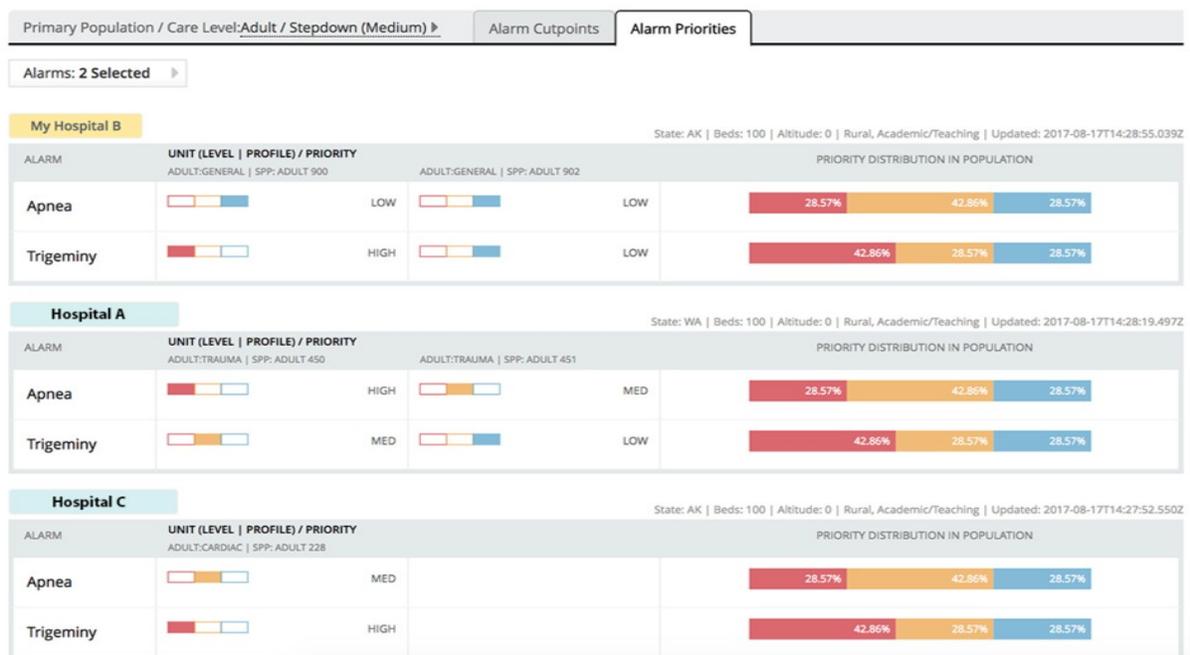
Monitor Defaults in **My Hospital B** compared with **4 of 46 hospitals** ▶

Figure 3: Physiological Monitor Defaults application

diastolic blood pressures (BP), end-tidal carbon dioxide (EtCO₂), and other alarm conditions. Additionally, clinicians can use the application to compare detection priorities for numerous alarm options for apnea, asystole, brady, vfib/vtach, PVC, trigeminy, and more. The Ventilator Settings application, allows respiratory technicians and other clinicians the ability to examine the variation in the default settings hospitals use for key ventilator alarms including positive end-expiratory pressure (PEEP), peak inspiratory pressure (PIP), tidal volume (VT), minute volume (MV), respiratory rate (RR), apnea and disconnect priority. Users can benchmark other hospitals by filtering on several hospital characteristics (e.g., urban/rural, size, teaching/non-teaching, primary population, care level, etc.).

These two applications will be formally launched with marketing campaigns from AAMI and the American Association for Respiratory Care (AARC) in Spring 2018.

C. Gathering feedback from potential Ventilator Device users

Prior to the official launch of the Ventilator Settings application, we contacted 18 medical professionals from AAMI's respiratory clinicians mailing list to gather early feedback on their interest in community activities around this application and the two new AAMI databases the REMEDI team was developing. To understand this new audience, a short five-minute survey was developed and sent out to members of the AAMI mailing list. Through the survey we will be able to understand who would make up the REMEDI ventilator community and determine this group's needs and customize the platform to fit these needs. The survey is designed to meet the following results

1. 35% of targeted participants will respond to the survey and submit their feedback by November 17th.
2. 50% of respondents will express concern the number of false alarms and increase in alarm fatigue.
3. 85% of respondents will be interested in participating in the ventilator community.

We expect these results since these 18 medical professionals expressed interest of acting as founding users for the community when AAMI sent out information about the possibility of this new community. The survey is an anonymous online poll that allows text and radio button answers. Some questions allow multiple choices to be selected, while others enable participants only to choose one response. Most questions allow participants to fill in an "Other" text box if the options provided do not match their answer. Concepts will be measured by how participants structured their responses and key driving terms, such as "alarm fatigue."

After the survey has closed, we reviewed the qualitative and quantitative results through text answers and bar graphs. Since the sample size is small, we have not use any additional analysis tools to assist with analysis.

D. Results and analysis

The survey was sent out November 10th, 2017 and data was collected on November 17th, 2017. There was a 39% response rate. Participants answered what state they work in and what primary work area or unit of the hospital they work in, see Figure 4. From the survey, we were able to gather that the new community would be made up of

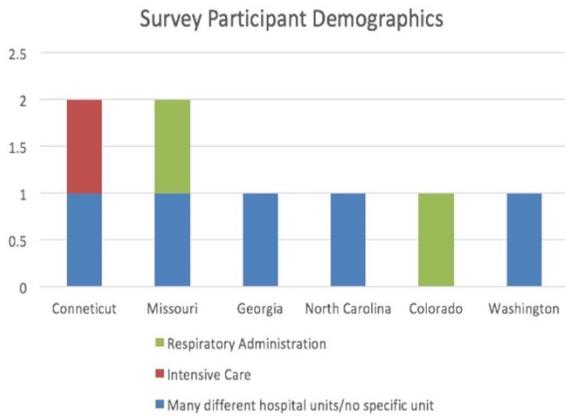


Figure 4: 2017 Potential Ventilator Community Survey, survey participant demographics

respiratory technicians, nursing staff, patient safety officers, hospital administrators, respiratory therapists, and respiratory managers. These medical professionals expressed in the survey that they are facing problems with productivity requirements that are pushing therapists to cut corners such as, “1) limited time to spend assessing and treating ventilated patients, 2) limited time to spend orienting new employees, 3) limited time to monitor quality.” Participants also stated that there are issues with alarm fatigue/priority signals and volume of the signals. Excessive alarms cause alarm fatigue for the medical professionals monitoring the patients. The inconsistency with alarms and what triggers an alarm is a need for almost all community members from therapists to nurses. Thus, all of these points should be discussion threads in the new community.

Survey participants stated that they are interested in participating in the following areas in order to improve patient safety in the respiratory field:

- A. Sharing ventilator default settings
- B. Sharing ventilator alarm data
- C. Leveraging a database to analyze their alarms against other hospitals
- D. Sharing standards
- E. Participating in online forums/discussion threads
- F. Sharing tribal knowledge
- G. Attending a virtual or in-person conference
- H. Speaking at a virtual or in-person conference

Participants were able to select all that applied to them and most showed interest in each area, see Figure 5.

Sharing data, settings, and standards is important to this new community. This enthusiasm to share information is promising. Members will have access to applications to share hospital data and machine settings once they have signed a contract with REMEDI and officially registered as a member of REMEDI. Members will be able to share standards and best practices through an online forum connected to the community platform. The platform is flexible enough for members to sign-up for to

receive alerts when new discussions occur at a daily, weekly, or monthly digest rate. Members will be able to share documents through a group shared file system, publish materials on the site for public consumption related to patient safety best practices, create wiki pages, blog posts, dynamic HTML pages for community branding, and other activities to encourage members

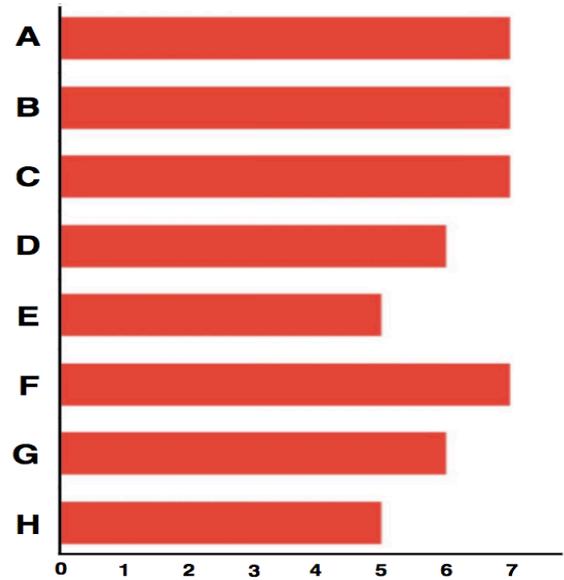


Figure 5: Potential Ventilator Community Survey, tasks and activities of interest to participants

to create a unique online space that fits their community’s needs.

E. Accepting new hospital contracts

As of December 2017, there are 301 facilities (hospitals and infusion centers) connected with REMEDI.³ With a rate of one hospital joining per week, onboarding new hospitals used to take a lot of time. The REMEDI team would spend around three hours per interested hospital answering questions via email and providing a one-on-one webinar demonstrating the community applications. If a hospital decided to sign-up to be a member of REMEDI, they would have to sign a general contract with REMEDI to agree with sharing data that will be viewed by cohorts. No patient data is shared. Due to the sensitivity of the shared data, REMEDI administers the data with security and privacy requirements needed for HIPAA data.

To automate this process and expedite on-boarding membership, REMEDI and HUBzero worked together to add in a custom PDF with an electronic signature into the REMEDI platform. This allows hospitals to sign-up to be a member without going through an administrator of the website first. We have also published online platform tutorials to help with on-boarding and provide training documents to new users. Streamlining this process has allowed a major roadblock to be overcome and improved the onboarding experience that will help REMEDI reach one of its goals to continue expanding and include all 5,534 U.S. registered hospitals and potentially international hospitals [3].

IV. PLANNING FOR THE FUTURE

A. *Gathering feedback*

The REMEDI team has realized the importance of community feedback as the project has matured. The major success of this gateway is the opportunity to tap into these resources and gather feedback from both the larger group and focused feedback from the steering committee, which is made up of industry professionals who are aware of problems hospitals and medical staff are facing with new devices. Use-cases and design documents for new applications and databases are developed in collaboration with the REMEDI steering committee and the community during monthly meetings. The community also provides feedback during the annual in-person conference hosted by REMEDI.

B. *Outreach and marketing plans*

REMEMI needed to rebrand their current marketing materials and the REMEDI gateway before the release to make the portal more inclusive of new communities.

The REMEDI and HUBzero team ran an analysis of the platform's audience and marketing materials to gauge where to adjust the message, so it was more inclusive. Through this analysis, the REMEDI team was able to discover several broken communication paths and include new communities that have recently joined in the marketing. This work helped the engagement with AAMI since the materials and outlook for the outreach campaigns AAMI was leading were already prepared by us before meeting with the AAMI communication team.

While there has been no formal communication launch, AAMI and AARC reached out to community members to see if they would be early adopters and help pre-populate data into REMEDI's new applications. AAMI and AARC are also working on launching marketing materials for how to join REMEDI, how to use both applications and capture data, and finally how to access the new applications and databases.

C. *Addressing the international community*

REMEMI works exclusively with the US community and US hospitals yet, analyses are underway in collaboration with researchers working with hospitals in Australia and New Zealand. While hospitals also on those continents may use the same vendors for smart pumps, for example, there might be diverse and additional vendors with different characteristics of the instruments and available data.

The main challenge is to address the health regulations in the different countries and the sharing data policies by hospitals [9]. The benefit for the users of sharing data via REMEDI seems obvious. However, the procedure for hospitals participating in REMEDI in the US might be not sufficient for further countries or the sharing of data on an international level might need various procedures. If the policies and regulations on an international level will hamper applying the existing science gateway in diverse countries, we anticipate to establish multiple HUBzero instances with REMEDI services dedicated to diverse countries. The long-term goal is to interchange data between such instances as open as possible regarding regulations and policies for each country. The more data can be exchanged, the more the user communities can benefit from the services.

The analyses for Australia and New Zealand are underway and the next target for an international outreach are The Netherlands since the HUBzero team closely collaborates with researchers at the Amsterdam Medical Center.

Setting up a European instance in The Netherlands might open possibilities for further European countries. We are aware of that each European country has its own health data regulations but sharing inside of Europe is probably easier to achieve than sharing on intercontinental level with the US, Australia or New Zealand.

V. CONCLUSIONS

Through the expansion of the REMEDI platform to include new communities, REMEDI was able to improve onboarding new hospitals, work with national organizations to provide relevant applications for their members and develop new outreach campaigns with the help of AAMI and AARC. REMEDI's impact on patient safety in the United States has been noted in several journal articles, and the collaborative was recognized as impacting a significant clinical care problem when it received the AAMI Foundation & Institute of Technology in Health Care's Clinical Solution Award and the Institute for Safe Medication Practices (ISMP) Cheers Award.

We plan to continue expanding the alert applications for the infusion pump community, discuss other medical device technologies including bar code medication administration in the next upcoming conference, and continue to onboard new hospitals. We also plan to continue collaborating with medical professionals internationally and share our lessons learned with new science gateways. The most prominent takeaway from this gateway expansion was to prioritize requirements based on the community's needs. Moving forward, our vision is to continue improving the platform and adding in more machines and continue working towards patient safety in hospitals. In the future, we would like to integrate more medical professionals into this community and open doors for the public to also become involved. While there is always more work, one can do, understanding the priority from a community will keep work relevant and keep the gateway thriving.

ACKNOWLEDGMENT

This work was supported by the REMEDI Project and by HUBzero, both Purdue University affiliated projects.

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