2023

Evaluation of a Hospital PDMP EHR-Integration Implementation: A Mixed

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EVALUATION OF A HOSPITAL PDMP EHR-INTEGRATION IMPLEMENTATION: A MIXED METHODS STUDY

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A DISSERTATION

Submitted to the graduate faculty of The University of Alabama at Birmingham,
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

BIRMINGHAM, ALABAMA

2023

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ABSTRACT

Background: Many providers continue to over prescribe opioids for pain, and Prescription Drug Monitoring Programs (PDMP) can be used as a tool to assist with appropriate opioid prescribing decisions. Despite mandates requiring opioid prescribers to review patients' prescribing history in their state's PDMP, barriers to PDMP success still exist such as a difficult PDMP logon process and having to log on to a separate PDMP system, which can cause access, workflow, time commitment, and ease of use issues and deter providers from using the PDMP. Some health care organizations have implemented PDMP electronic health record (EHR) integration (PDMP EHR-integration) to help overcome these barriers. One type of integration is access integration, where a link to the state PDMP is provided in the EHR as opposed to logging onto a separate PDMP state website. The Task-Fit Technology (TTF) Theory provides insight that the closer a technology fits a user's tasks, the greater is that individual's performance. Objective: Using this framework as a guide and given that PDMP EHR-integration is often implemented to reduce the gap between a PDMP user's tasks and the PDMP technology's characteristics, this project set out to determine if, and why or why not, PDMP EHR-integration via access integration led to an average reduction in opioid ordering after implementation. Methods: A mixed methods sequential Quant → Qual study design was used. An adapted TTF conceptual model guided both quantitative and qualitative strands of the study. Twelve months of daily, clinical opioid ordering data

were collected and analyzed for control and treatment groups in the quantitative strand using an interrupted time series approach with an ordinary least squares (OLS) model. These results were used to inform part of the semi-structured, one-on-one provider interview questions in the subsequent qualitative strand. Fourteen providers were interviewed, with 7 in the control group and 7 in the treatment group, and their responses were thematically coded using the TTF theory as an initial guide. A joint display was used to help integrate the results of the two strands and identify meta-inferences. Results: The quantitative results revealed that the intervention had an immediate clinically significant, trending toward statistical significance, increase of 15.933 MMEs per patient per day (p-value: 0.0667) for the treatment group. No over time statistically significant impact was found for the treatment group (p-value: 0.5124), and no immediate or over time statistically significant impact was found for the control group (p-value:0.31, p-value: 0.927). Six themes and 20 subthemes emerged around the conceptual framework's dimensions of access, use, workflow, and data completeness. The themes identified were Registration/Access Process, Ease of Use, Patient Data, Time Commitment, Validation, and Ordering/Prescribing. Mixing the two study strands led to 24 meta-inferences. Conclusions: Providers chose to use the PDMP to either validate patients' existing medications or when they intended to order opioids for patients. Most providers in the treatment group felt the integration improved the TTF due to improved access, ease of use, and workflow but not due to a change in data completeness, and they increased their frequency of PDMP use because of these improvements. Many providers in the control group felt that the access, ease of use, and workflow components of using the state PDMP website without the integration link were not issues and did not see a benefit of

trying to use the intervention. Most providers in both groups experienced or speculated that opioid ordering increased immediately after the intervention due to providers being more comfortable, confident, or feeling more appropriate to order opioids due to using the PDMP more frequently or for the first time after the link was implemented.

Keywords: Prescription Drug Monitoring Program, PDMP EHR-Integration, Integrated PDMP, Opioid Ordering

DEDICATION

This dissertation is dedicated to my family, especially my mother, Dr. Sue H. Duran, my husband, Matthew A. Martin, and my daughters, Evelyn, Lillian, and Rosalyn. Thank you for your support and sacrifices that helped make my dream a reality.

ACKNOWLEDGEMENTS

I could not have accomplished this work alone. I would like to acknowledge the University of Alabama at Birmingham (UAB) Department of Health Services Administration for providing a comprehensive, high quality education that gave me confidence to complete this study. Thank you to my advisors, Dr. Sue S. Feldman (committee chair) and Dr. Allyson G. Hall for their support and guidance. Thank you to my dissertation committee for their time and expertise that helped to strengthen this study. I would like to thank Dr. David T. Redden for his help with the stastical elements of this study and Nancy Bishop who answered many questions about the Alabama PDMP; both of their efforts contributed to this manuscript's accuracy. I would like to recognize the UAB Pain and Addiction Special Interest Group (PASIG) for including me to learn about substance use disorder and pain management in our community. I am also grateful to the UAB Opioid Stewardship Committee for providing information about this implementation. I am grateful to UAB Medicine, the UAB Center for Outcomes and Effectiveness Research (COERE), the UAB Center for Clinical and Translational Science (CCTS), and the UAB Learning Health System for supporting students who want their research to be connected to practice. Finally, I express my gratitude to God, who never left my side during this journey; may I always remember to use my gifts to help others.

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CHAPTER 1

INTRODUCTION

Background

The opioid epidemic is one of the most severe public health situations the United States (U.S.) is facing (May, Baumgartner, Garrety, & McLaughlin, 2020). The U.S. has one of the highest opioid use disorder (OUD) death rates in the world (International Narcotics Control Board, 2018). Overprescribing opioids for pain management along with opioids being consumed by people who were not prescribed opioids, also known as opioid diversion, contribute to this high OUD mortality rate. Alabama (AL) prescribed the most controlled substances per capita in the U.S. in 2020, and almost half of the AL 2020 drug overdose deaths involved opioids (Centers for Disease Control and Prevention, 2021). OUD death rates have surged since the global pandemic began (American Medical Association, 2021a; Yurkanin, 2021). AL has not been spared from this surge: AL experienced a 25% increase in OUD death rates in 2020 (Yurkanin, 2021). Much of this increase is due to illicitly manufactured fentanyl, which is often a powerful synthetic opioid, being mixed with other illicit drugs like methamphetamine and cocaine (American Medical Association, 2021a). Inappropriate opioid prescribing can lead to OUD, using illicitly manufactured fentanyl when prescriptions are no longer available, opioid overdose, and death (American Medical Association, 2021b; National Institute on Drug Abuse, 2019).

The World Health Organization (WHO) recommends monitoring opioid

prescribing and dispensing as a specific measure to prevent opioid overdose. A Prescription Drug Monitoring Program (PDMP) is an electronic database that tracks controlled substance prescriptions and is housed and maintained at the state level in the U.S. (Center for Disease Control and Prevention, 2020).

PDMPs can be used to help monitor opioid prescribing and/or dispensing, a physicians licensed to prescribe controlled substances, including opioids, are often required by their state professional regulatory boards to check the PDMP prior to prescribing controlled substances with the goal of having a more complete patient picture prior to making treatment decisions including prescribing decisions. Prescribing occurs in an outpatient setting while ordering occurs in a hospital setting.

The class of drug being prescribed that requires the prescriber to check the PDMP varies by state, but most states include drugs identified under the Control Substances Act, such as Schedule II drugs that have high abuse potential (Alabama Department of Public Health, 2022). AL requires anyone who dispenses Class II, III, IV, or V controlled substances to report daily the dispensing of these drugs to the AL PDMP (Alabama Department of Public Health, 2022). The Center for Disease Control (CDC) provides specific guidelines on when opioid therapy should be given, which drug to use, and the duration of therapy to promote appropriate opioid prescribing for pain management. These guidelines have been used to inform some state-level policies on how frequently prescribers must check the PDMP when making controlled substances prescribing decisions (Center for Disease Control and Prevention, 2019). These policies normally do not apply to providers ordering controlled substances for inpatients in a hospital setting except upon patient discharge, although they are often recommended in the hospital

setting to help determine appropriate opioid ordering ("Ala. Code § 20-2-214: Limited access to database permitted for certain persons or entities," 2023).

PDMP administrators and law enforcement in some states but not in AL, also monitor electronically transmitting prescribing and/or dispensing data submitted to the PDMP to help identify prescription drug abuse and diversion (PDMP TTAC, 2018b). Prescribing and/or dispensing data availability in the PDMP varies between states. Only dispensing data are submitted to and available in the AL PDMP.

Despite these benefits and mandates around the PDMP, many barriers to reviewing the PDMP exist. Such barriers include a lack of timely data, lack of timely reporting, a complicated logon process, difficulty accessing the PDMP outside the electronic health record (EHR), forgetting one's PDMP password, and lack of time to check the PDMP due to work related pressures (Martin, Modi, & Feldman, 2020). Many of these barriers are due to providers having to check the PDMP outside of a hospital's EHR which can interrupt provider and employee workflow, causing inefficiencies and time burdens to practitioners who are already under a heavy patient load and tight time constraints (Finley et al., 2017). Although the CDC recommends prescribers to always check the PDMP when prescribing greater than 90 MME morphine milligram equivalents (MME), how frequently a provider should check the PDMP when prescribing less than 90 MMEs is often left up to the provider's discretion, especially in an in-patient setting where providers are often not required to check the PDMP and are even less familiar, on average, with the patient's prescribing history compared to an outpatient setting. Therefore, such PDMP inefficiencies can deter providers' PDMP use and take away their time with patients, which can impact opioid prescribing decisions.

Purpose Statement and Research Questions

Although checking the PDMP has been shown to promote appropriate opioid prescribing, the impact of PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting is not known. The purpose of this study is to evaluate the impact of PDMP-EHR Integration via access integration on inpatient opioid ordering at UAB hospital using a mixed methods sequential explanatory design.

PDMP EHR-integration is having automatic access, versus manual entry, in the EHR to clinical information from PDMPs within a state and across state lines and using that information when treating a patient (PDMP TTAC, 2021).When a user uses this functionality in AL, the user logs into the organization's EHR and accesses the PDMP link from within the patient's chart. The advantage of this process is that the user does not need to log into the PDMP separately and outside of the EHR.

PDMP EHR-Integration is often implemented to reduce PDMP barriers, such as issues with access and workflow, by closing the gap between a users' tasks and the PDMP technology's characteristics. The Task-Technology Framework (TTF) framework indicates that the better a technology fits a user's tasks, the better that user performs. Individual performance, in the case of a PDMP, user can be measured by appropriate opioid prescribing. Appropriate opioid prescribing means that patients receive the appropriate pain treatment with careful consideration of the benefits and risks of treatment options (Dowell, Haegerich, & Chou, 2016). Checking the PDMP is one tool to make those benefit and risk assessments. Providers in AL over-prescribe opioids on average compared with the rest of the U.S.; thus, one could assume a reduction in individual opioid prescribing would improve appropriate opioid prescribing (individual

performance) for the average AL provider (Centers for Disease Control and Prevention, 2021). There is some evidence in the literature that supports this assumption. One study found that PDMP EHR-Integration via access integration decreased the number of opioids dispensed, the number of patients receiving an opioid prescription, and the mean morphine equivalents (MME) per prescriber (Weiner et al., 2021).

While numerous studies have examined PDMP use, no study has undertaken an information systems perspective to evaluate the integrations' impact on appropriate opioid ordering (Benson-Tilsen, 2019; Herndon & Springfield; Holmgren & Apathy, 2020; Martin et al., 2020; May et al., 2020; Underwood et al., 2021; Weiner et al., 2021; Weiner et al., 2019). Therefore, this study seeks to use a mixed methods to attempt to answer the following research questions:

Quantitative Research Question

1. What is the impact of implementing PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting?

Quantitative Hypothesis

Hypothesis: Implementing PDMP EHR-Integration via access integration decreased the average number of total opioids ordered per inpatient.

To test the quantitative hypothesis, EHR prescribing data 6 months before and 6 months after the intervention's implementation at UAB hospital were examined. After the intervention's impact on opioid ordering was evaluated quantitatively, these results were connected to inform the qualitative strand with the goal of having a better understanding of why the intervention did or did not have an impact on opioid ordering due to a change in TTF or other factors.

Qualitative Research Questions

1. What are providers' attitudes toward using the PDMP before and after the PDMP EHR-Integration implementation?
2. To what degree do providers believe the PDMP EHR-integration implementation improved the TTF between the PDMP and checking patients' controlled substances prescribing history?
3. To what degree did other factors besides TTF affect the intervention's impact on opioid ordering?

These results were *connected* to inform 3 interview questions which provided an understanding of the direction of impact PDMP EHR-Integration implementation had on opioid ordering.

Mixed Methods (Integration) Research Question

How can the understandings that emerge from the qualitative interviews provide a deeper understanding of the quantitative findings of the impact of PDMP EHR-Integration implementation on opioid ordering in an inpatient setting?

Theoretical Framework

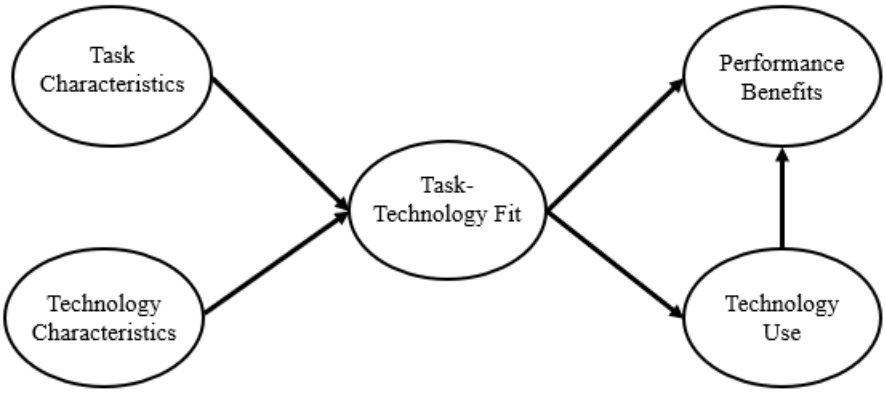
TTF theory claims that an information technology (IT) is more likely to have a positive impact on individual performance and be used if the capabilities of the IT match the tasks that the user must perform (Goodhue & Thompson, 1995). TTF theory is defined here in the context of information systems (IS). TTF theory views technology as a tool that a goal-oriented individual (user) utilizes to perform specific tasks. TTF theory can be used to determine the degree to which systems' characteristics match users' tasks needs (Goodhue, 1995). This theory was developed from IS designers' and evaluators'

need to have a theoretical foundation to guide objective measurement of system success, because user evaluations, which are normally subjective by nature, alone were insufficient to understand if the IS system improved user performance (Goodhue, 1995). This theoretical perspective was needed for a more objective IS outcome evaluation. Moreover, there are numerous ways to categorize users' beliefs about an IS such as usefulness, ease of use, attitude, etc. TTF theory provides a single theoretical perspective that links IT systems to their impacts. These evaluations of user performance or IS use can be used to measure the value an IT investment adds to an organization and/or help target TTF problem areas for improvement (Goodhue, 1995; Goodhue & Thompson, 1995).

As shown in Figure 1, TTF theory contains five main constructs: task characteristics, technology characteristics, task-technology fit, performance impacts, and utilization (Goodhue & Thompson, 1995). Task characteristics and technology characteristics are independent constructs; performance benefits and technology use are dependent constructs. Utilization can also be an indirect construct with performance as its dependent construct; the impact of TTF on performance is posited as occurring either directly or indirectly through its impact on technology use. TTF serves as a dependent construct to the task characteristics and technology constructs and an independent construct to performance impacts and utilization (Furneaux, 2012; Goodhue & Thompson, 1995)

Figure 1

Task-Technology Framework (Furneaux, 2012; Goodhue & Thompson, 1995)



TTF theory defines tasks as actions carried out by individuals (users) to turn inputs into outputs (Goodhue & Thompson, 1995). Technologies are defined as IT tools users operate to carry out specific tasks (Goodhue & Thompson, 1995). Users are defined as those who use technologies in the performance of their tasks and individual characteristics, e.g. training, experience, attitude, can affect their ability and agility to use the technology (Goodhue & Thompson, 1995). TTF is the degree to which the IT system assists the user in performing his or her portfolio of tasks (Goodhue & Thompson, 1995). Utilization is defined as the behavior of employing technology to complete tasks. Utilization can be measured in different ways such as by frequency of use over a specified period or continuous length of time used (Goodhue & Thompson, 1995).

TTF theory implies that a higher TTF increases utilization, because the TTF is one determinant of the user's belief of IT usefulness (Goodhue & Thompson, 1995). The utilization dependent construct can also be affected by organizational or policy use mandates. Performance impacts are defined by the accomplishment of the users' portfolio of tasks. TTF theory implies that a higher TTF increases impact performance, and at any

given level of utilization, an increase in TTF leads to increased performance. TTF and the gap between the IT's functionality and a user's tasks have an inverse relationship. As the distance between the tasks' requirements and IT functionality widens, the fit of the technology to the task becomes smaller or worsens. The closer the IT system's functionality is to the user's tasks, the stronger the TTF (Goodhue & Thompson, 1995).

TTF is deterministic in that it allows for only the fit between tasks and technologies to impact performance and utilization. However, the TTF theory is seen as being embedded in a larger context that is impacted by other components such as human, organizational, and policy factors (Zigurs & Buckland, 1998). Therefore, the context of the IS and its users must be considered when using TTF theory to guide IS evaluation. TTF theory helped to guide this study's methodology and analysis by providing a structure and sub-constructs by which to understand and evaluate the intervention, PDMP use via the link, and opioid ordering. Mixed methods research (MMR) was used to understand the degree of those relationships and why they occurred.

Significance of the Study

This study is unique in that it is the first of its kind to use TTF theory to study not only the impact of PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting, but also the reasons behind that impact.

Furthermore, this MMR study allows those who have already or plan to invest in PDMP EHR-Integration via access integration to gain some insight as to the potential impact that investment may have on inpatient opioid ordering and why. Knowing if and why or why not PDMP EHR-Integration via access integration promotes appropriate opioid ordering may help health care organizations make a more informed decision when

deciding to invest in PDMP EHR-Integration and/or will help them identify target areas to improve their investment. This information can be used to improve the PDMP EHR-Integration process and the ultimate success of this intervention.

Policy Impact

This study has the potential to impact PDMP policy. Some U.S. policy makers recognize that over prescribing opioids contributes to the opioid epidemic (CDC, 2020c; NGA, 2016). Forty-three governors signed a pact in 2016 to fight opioid addiction which included integrating PDMPs into EHRs (National Governors Association 2016). CMS currently offers optional bonus reimbursements to providers that allow querying of the PDMP within the EHR (Cohen, 2019). Moreover, CMS has proposed making this integration mandatory in the past but have faced provider backlash about this potential policy change due to providers wanting more time to evaluate the changing PDMP landscape. Cerner Corporation, a leader in the EHR industry, also indicated CMS should not require PDMP EHR-Integration until state PDMPs develop a standard for this type of integration. The results of this study contribute evidence to CMS for making a more informed decision relative to its PDMP EHR-Integration requirement for reimbursement.

This study also has potential to impact PDMP delegate access and expansion policy. Prescribers often delegate PDMP use to other clinical employees due to time constraints and the cumbersome process of logging in to the state PDMP. If the qualitative results show an improved TTF with integration, there may be less need for policy that increases delegate PDMP access (Bao et al., 2018).

The qualitative results highlight target areas for intervention improvement. These results may be used by state PDMP administrators who mandate PDMP use to also

consider an integration mandate. This study may contribute evidence on various factors that may be critical to successful PDMP EHR-integration.

Study Organization

This study sought to explore how a PDMP EHR-integration implementation impacted opioid inpatient ordering by (a) calculating the impact of the intervention on providers' inpatient opioid ordering and providers' attitudes of the integration link and why those results occurred by (b) thematically coding and analyzing semi-structured, one-on-one, open-ended interviews. The results of these two findings were then combined to form meta-inferences. The report of the research in this study is organized as follows:

- Chapter 1 discusses the rationale for the study, its purpose, the quantitative and qualitative research questions, key terms, the theoretical framework that guides the study, delimitations, limitations, and study's significance.
- Chapter 2 provides a review of the literature of the history of the PDMP and PDMP EHR-integration, of different types of PDMP EHR-integration, of costs associated with integration, and of its impact.
- Chapter 3 gives an overview of the study's research design and methodology including the MMR rationale, process, philosophical assumptions, conceptual framework, MMR design, research setting, sampling strategy, interview protocol development, recruitment, data collection, data analysis, and integration,
- Chapter 4 discusses the results of the study first by the quantitative strand and then by the qualitative strand. Each strand revisits the appropriate research

questions and hypotheses, followed by the results, and then a summary of the strand.

- Chapter 5, the discussion, revisits the TTF and summarizes the major findings. This chapter also presents the theoretical and practical contributions as well as implications for future research. Study limitations are also discussed.

Summary

Using a mixed methods sequential explanatory design, this study will evaluate the impact of implementing a link in the EHR to PDMP data in an AL hospital. This study will contribute to an increased understanding of if and how this type of intervention can help providers order or prescribe opioids for patients more appropriately when they bypass the traditional method of accessing and using a PDMP state website. Recommendations will benefit PDMP users, administrators, and policy makers who seek additional tools or process improvements to promote appropriate opioid ordering and prescribing as one effort to help battle the U.S. opioid crisis.

CHAPTER 2

REVIEW OF THE LITERATURE

History of the PDMP

The history of the PDMP spans just over a century. The earliest PDMPs were primarily established as enforcement and regulatory tools that provided data to officials responsible for enforcing drug laws and oversight of prescribing and dispensing controlled substances (PDMP TTAC, 2018a). These PDMPs faced legal and political challenges against establishment from the pharmaceutical industry, practitioners' organizations, and various advocacy groups (PDMP TTAC, 2018a). The Drug Enforcement Agency (DEA) was the only federal agency that supported PDMPs followed by the Department of Justice (DOJ).

The first PDMP originated in the U.S. in New York State in 1918 and was a manual process that required prescriptions above a certain amount for cocaine, codeine, heroine, morphine, and opium, that were legal to prescribe and dispense at the time, to be reported to the state (Bulloch, 2018). This need for a PDMP in New York originated from its concerns of its growing drug problem which led to widespread drug legislation to address the crisis. Physicians had to start using serial numbered official prescription blanks issued by their health department. Pharmacies were then required to provide copies of prescriptions to the health department. The requirements only lasted 3 years but laid the path for the PDMP.

California was the next state to initiate a PDMP, a paper process also, in 1939. California has the oldest continuously operated PDMP program in the U.S. California put the PDMP under the newly created Bureau of Narcotic Enforcement (PDMP TTAC, 2018a). Hawaii was the next state to follow in 1943; the Hawaii PDMP was housed in the state's Narcotic Enforcement Agency. The next PDMP was not developed until 18 years later in Illinois in 1961 and was housed in the Department of Health for the first time. Idaho became the first to house the PDMP in the Board of Pharmacy in 1967. Pennsylvania, New York, and Rhode Island then established PDMPs in the 1970s; the Pennsylvania PDMP was housed in their Attorney General's Office. Texas and Michigan established programs in the 1980s. All of the above mentioned state PDMPs were considered a tool for enforcing drug laws, only collected Schedule II controlled substances prescription information, required one or two copies of state issued prescription forms to prescribe and dispense Schedule II medications, and required sending information to the state within 30 days or less from the drug dispensed date (PDMP TTAC, 2018a).

Oklahoma developed the first electronic PDMP in 1990 with its landmark legislation that required electronic transmission of prescription data from a pharmacy directly to the state PDMP. This was the beginning of the electronic era of the PDMP. This legislation opened the door for other states to consider establishing a PDMP as the electronic process reduced the start-up and maintenance costs of administering a PDMP due to no longer having printing, distribution, and manual data entry costs (PDMP TTAC, 2018a).

The number of states with PDMPs continued to grow throughout the 1990s and

early 2000s, which was mainly the result of the Harold Rogers PDMP Grant providing funds to states for starting their own PDMPs. This decade also saw a major development in the PDMP that was the development of requirements to collect data for Schedules II - V controlled substances (PDMP TTAC, 2018a). Oklahoma, Massachusetts, Utah, Indiana, and Kentucky laid the groundwork for these legislative changes.

By the beginning of the 2000's, PDMPs began to take root around the country along with research on their effectiveness that showed they were valuable instruments for promoting patient safety and preventing drug diversion (PDMP TTAC, 2018a). They were gaining support from multiple entities, even drug manufacturers began to support them. Twenty-seven PDMPs were established during this decade including Virginia, Maine, Tennessee, New Mexico, Wyoming, Colorado, North Dakota, Ohio, Mississippi, North Carolina, Connecticut, Vermont, Iowa, Louisiana, South Carolina, Arizona, Washington, Minnesota, New Jersey, Alaska, Kansas, and the AL PDMP in 2006. This decade saw the development of more PDMPs than any other decade in the past 100 years. From 2011 to 2016, seven additional PDMPs were established including Arkansas, Georgia, Montana, Maryland, Nebraska, New Hampshire, the District of Columbia. By 2021, 49 states in the U.S. had a state PDMP (Bulloch, 2018; Yurkanin, 2015). Missouri is the only state that currently has no state governed PDMP but has recently made plans to develop a statewide PDMP (Rodriguez, 2023).

Unlike in the early 20th century, many federal agencies such as the Substance Abuse and Mental Health Services Administration (SAMSHA), The Office for the National Coordinator for Health Information Technology (ONC), The U.S. Department of Veteran's Affairs (VA), and the U.S. Department of Health and Human Services

(HHS) currently support and recognize the value of PDMPs. They established policies, laws, and regulations that allow different interested parties to participate in PDMPs along with providing funding for PDMP enhancements. PDMPs continue to evolve into more efficient and effective tools to reduce prescription drug abuse and diversion.

PDMP Governance

The state agency that houses and governs the PDMP can vary from state to state and includes four major categories: public health, law enforcement, licensing or regulatory boards, and substance abuse facility licensing authorities. Currently, 18 PDMPs are governed by their state's Board of Pharmacy, by the Department of Public Health or Public Health and Human Services, 1 by Department of Public Health and Environmental Control, 3 by Prescription Drug Monitoring or Registration, 2 by their Bureau of Narcotics or their Narcotics Enforcement Division, 2 by the Director of Occupational and Professional Licensing or their Bureau of Professional Licensing Agency, 1 by their Department of Justice, 1 by their Department of Consumer Protection, 1 by the Division of Professional Regulation, 1 by the Pharmaceutical Control Division, 1 by the Department of Human Services, 1 by Health and Family Services, 1 by the Department of Safety and Professional Services, 1 by the Department of Law and Public Safety, and 1 by Health Authority, Injury, and Violence Prevention (Prescription Drug Monitoring Program Training and Technical Assistance Center, 2023b). Regardless of the governing body for each state PDMP, they share common goals, such as enhancing patient care, providing education and information, mitigating the abuse and diversion of controlled substances, and enhancing drug misuse prevention and treatment programs. Some states and territories, like Missouri and Puerto Rico, started operating PDMPs on a

more local jurisdiction in 2016.

PDMP Authorization, Access, and Data

Prescribers and dispensers in all states can access the PDMP, and delegates, law enforcement, regulatory boards, emergency departments, wholesale medication distributors, licensed hospital pharmacists, physicians, veterinarians, dentists, behavioral health service providers, and research organizations have authorization and access that varies by state (PDMP TTAC, 2018a; Substance Abuse and Mental Health Services Administration, 2017). Each state has its own set of regulations that require who, when, and how frequently providers must enroll and query the (Prescription Drug Monitoring Program Training and Technical Assistance Center, 2023a). Some non-traditional stakeholders such as drug courts, medical examiners, and drug abuse counselors are starting to gain access to PDMPs to help identify providers inappropriately prescribing controlled medications, to control diversion of medication by prescribers, pharmacies, and organized criminals, or to be notified when a prescriber's or prescription recipient's activity exceeds established thresholds). Some PDMP administrators are working to expand PDMP data to include distribution of naloxone to law enforcement agencies also.

Health care professionals, regulatory boards, and the law enforcement community depend on PDMPs to have timely and accurate data (PDMP TTAC, 2018a; Substance Abuse and Mental Health Services Administration, 2017). Data housed in the PDMP can vary by state. It can include dispensing data only, prescribing and dispensing data, or data on Schedules II-IV or Schedules II-V controlled substances. Some states allow data sharing with other states, especially neighboring states, to mitigate "doctor shopping" across state lines (Substance Abuse and Mental Health Services Administration, 2017).

Over half of PDMPs are expanding their data across systems, agencies, and states to gain benefits. For example, many providers can now obtain patient prescription history within the EHR system instead of logging into two separate systems, state Medicaid agencies can share data with federal health care providers, and state agencies can share information across state lines to prevent cross-state diversion or provide better coordination of care for patients receiving care in multiple states (Substance Abuse and Mental Health Services Administration, 2017). These data interoperability arrangements often take two parts where a state offers to share their data and/or receive data from another state (Prescription Drug Monitoring Program Training and Technical Assistance Center, 2021; Substance Abuse and Mental Health Services Administration, 2017).

Many state PDMPs receive frequent electronic feeds of PDMP dispensing data and many of them produce periodic reports with frequency intervals that vary by state such as by week or day (Substance Abuse and Mental Health Services Administration, 2017). Starting with Oklahoma in 1990, 44 states have shortened PDMP data collection intervals to one business day or less. The information provided typically includes date dispensed, patient, prescriber, pharmacy, medication, and quantity. In 2010, five (5) states (CO, DE, LA, NV, and OK) had mandatory query laws, and today 40 states have such requirements. States are continually improving their programs to be more responsive to stakeholders' needs and provide faster and more complete and accurate information in their PDMPs.

AL PDMP

The AL Department of Public Health governs the AL PDMP (Alabama Department of Public Health, 2022). Controlled substances, classes II = V, which are

dispensed are required to be reported to the PDMP. All AL practitioners that have a DEA license and currently prescribe these controlled substances have access and are required to check the PDMP by their state board codes, and the frequency that they are required to check the AL PDMP varies by health profession. These providers may assign a delegate to check the PDMP for them. Veterinarians currently do not report or have access to the AL PDMP.

PDMP Barriers and Facilitators

Although PDMPs help prevent prescription drug misuse and diversion and many states require checking a patient's controlled substances dispensing history in the PDMP prior to prescribing opioids, PDMPs still face many barriers to success from an IS standpoint and facilitators can be employed to help overcome those barriers (Martin et al., 2020). For example, lack of interstate data sharing between PDMPs, difficulty registering for and accessing the PDMP, lack of time to check the PDMP, lack of awareness of knowledge of the PDMP, and lack of EHR integration are barriers to PDMP IS success. Expanding interstate data sharing capabilities, incorporating real-time data updates to improve data quality, integration with the EHR to reduce the amount of time to check the PDMP have been reported as facilitators to these barriers.

PDMP EHR-integration

A hospital can make its state's PDMP data available within its EHR to help overcome these barriers, and this functionality is called PDMP EHR-Integration (Martin et al., 2020). PDMP EHR-Integration is offered to health care organizations in at least 33 states while the total adoption rate is currently unavailable (APPRIS HEALTH; Benson-Tilsen, 2019; Holmgren & Apathy, 2020). PDMP EHR-Integration has the potential to be

important in hospitals, as they offer ambulatory and post-operative care and substantial potential opioid prescribing for pain management (Holmgren & Apathy, 2020).

There are multiple types of PDMP EHR-Integration including access integration, information integration, and data integration (PDMP ASSIST, 2019). Access integration solely provides access to a separate PDMP system within the EHR such as providing a single sign-on link to the state PDMP within the EHR (PDMP ASSIST, 2019). Information integration is when information is structured or presented to make data more meaningful to the user, and data integration is when data from the PDMP and EHR are combined, such as passing PDMP data through to the EHR to be combined or merged with existing EHR data (PDMP ASSIST, 2019).

PDMP EHR-Integration cost can vary depending on the type of integration. Technical and policy hurdles that are unique to each state's PDMP and each health care organization's technical environment may exist also. Some technical hurdles exist such as smaller pharmacies having to manually upload data due to technical infrastructure limitations, and users that do not prescribe controlled substances daily having to report no prescriptions filled to meet PDMP requirements (AWARxE, 2022). Various data matching issues between EHR and PDMP patient data frequently occur also due to issues such as similar given names in both systems. Cost has found to be one of the most significant barrier to PDMP EHR-Integration (May et al., 2020). Some states, including AL, offer technical and/or financial assistance to health care organizations to assist with integration implementation and/or ongoing support. PDMP EHR-Integration has also been shown to lower opportunity costs of lost wages by allowing prescribers to see more patients due to time efficiencies from this intervention (Benson-Tilsen, 2019).

Some states use PMP InterConnect, a highly secure communications exchange platform that facilitates the transmission of PDMP data across state lines to authorized requestors. PMP InterConnect if used to facilitate transfer of PDMP data across state lines, while other organizations use this data when the PDMP is integrated with their organization's EHR (Pharmacy, 2020). . Interstate data sharing between a state's PDMP site and the data available in PMP InterConnect with PDMP EHR-integration can vary due to states agreeing to different data sharing terms between another state's PDMP and another state's PMP InterConnect data sharing agreement. This means that data for out of state patients may only be available in the state PDMP database, not the PMP InterConnect data that is used in the PDMP EHR-integration, which forces users to have to use the state PDMP database to check the prescribing history for some out of state patients.

Despite the possible benefits PDMP EHR-Integration can bring, including improved clinical workflow, access, and use, PDMPs still face challenges from an information systems standpoint (Martin et al., 2020). Integrating the PDMP data with the EHR is one reported facilitator to these challenges. Research on PDMP EHR-Integration's impact on opioid prescribing or ordering is not prevalent yet, mostly due to this integration technology being relatively new for state PDMPs and due to some state's inability to share sensitive prescribing data with other states at the patient and provider levels. This is further complicated by some states not sharing the information within their own state (Barker, 2023).

There have been several studies that discuss how PDMP-EHR Integration occurred and improved user access and workflow, but there have been very few studies

that directly evaluate or measure the impact of PDMP EHR-Integration on PDMP use or appropriate prescribing or ordering (Benson-Tilsen, 2019; Herndon & Springfield; May et al., 2020; Weiner et al., 2021; Weiner et al., 2019). Most studies about PDMP EHR-integration reported that EHR-integration increased PDMP use (Benson-Tilsen, 2019; Hutchison, Carhart, & Whalen; May et al., 2020; Weiner et al., 2021). One study found, however, that use decreased because out of state patient data was not integrated with the PDMP (Underwood et al., 2021). Another study used PDMP data to determine PDMP EHR-Integration via access integration's impact on prescribing and found that it decreased the number of opioids dispensed by 4.8%, decreased the number of patients receiving a prescription by 5.1%, and decreased the mean morphine equivalents (MME) per prescriber decreased by 5.4% (Weiner et al., 2021). A similar analysis of PDMP data to determine this intervention's impact on prescribing is not currently possible in AL due to legislation around PDMP data access restrictions (Alabama State Legislature, 2016). Another study measured cost implications of integration, measured through the change in provider's time with the patient due to integration, and found PDMP EHR-Integration to save time, specifically more time for prescribers in large healthcare organizations compared to those in smaller healthcare organizations (Benson-Tilsen, 2019). A final study examined the barriers to PDMP EHR-Integration and found that cost was a significant barrier, along with difficulty accessing the PDMP, and EHR vendor unavailability (May et al., 2020).

Although most of the studies did not clearly state the type of PDMP EHR-Integration, such as access versus data integration, most of the integrations mentioned provided enough information to assume they were access integration implementations

(Benson-Tilsen, 2019; May et al., 2020; Weiner et al., 2021; Weiner et al., 2019). One study did appear to assess the impact of a data integration, while another appeared to investigate a message-oriented integration through the state's health information exchange's (HIE) messaging system (Benson-Tilsen, 2019; May et al., 2020). Because the type of integration could impact use, utility, and data volume, future studies around this topic should make the type of integration more transparent.

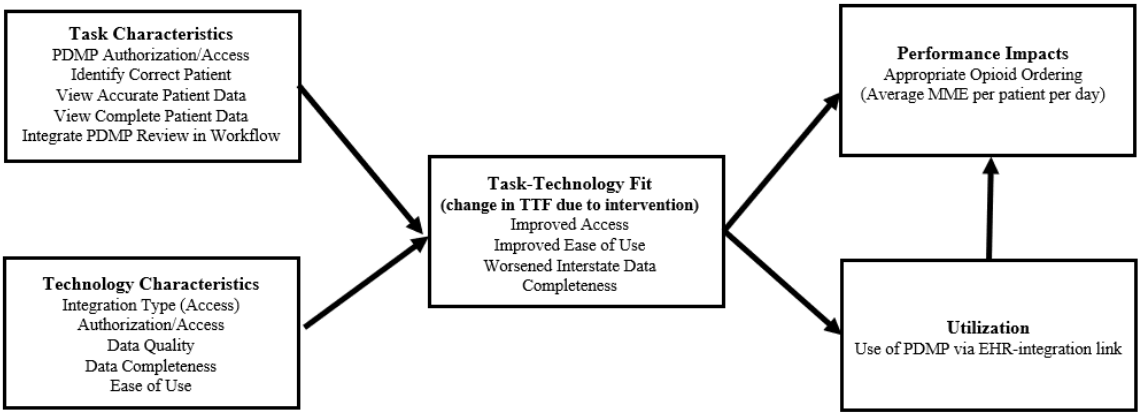
Conceptual Framework

TTF theory indicates that improved technology use and performance benefits occur when the characteristics of a technology are well-suited to the tasks that must be performed (Goodhue & Thompson, 1995; Zigurs & Buckland, 1998). TTF theory is appropriate for this study because it allows for the examination of the impact PDMP and its integration into the EHR has on PDMP use. No study has undertaken an information systems perspective to evaluate the integrations' impact on appropriate opioid prescribing. Using TTF theory allows exploration of this topic from an IS perspective including changes in system access, data accuracy, data completeness and user workflow.

A conceptual framework was adapted from TTF theory to help assess the impact the PDMP EHR-Integration had on opioid prescribing at UAB hospital (see Figure 2).

Figure 2

Adapted TTF Framework (Goodhue & Thompson, 1995)



TTF theory contains five main constructs including task characteristics, technology characteristics, task-technology fit, performance impacts, and utilization; a detailed explanation of these constructs as defined in the literature can be found in Chapter 2 (Goodhue & Thompson, 1995). The following sub-constructs were created based on PDMP literature mentioned in this chapter, knowledge the PI gained from taking AL PDMP online training, and corresponding with a representative from the AL Board of Pharmacy (Alabama Department of Public Health, 2021). The Task Characteristics construct was adapted to this study and defined as tasks characteristics users carry out to review patient history in the PDMP to inform their opioid ordering decisions. The Task Characteristics construct contains 5 sub-constructs including PDMP Authorization/Access, Identify the correct patient, View accurate patient data, View complete patient data, and Integrate PDMP review in workflow. To check a patient's controlled substances prescribing history in the PDMP a user must login or access the PDMP, which led to the creation of the sub-constructs PDMP Authorization/Access, identify the correct patient, which led to the creation of the sub-construct. They then must identify the correct patient, and then view that patient's data, which led to the creation of these sub-constructs, View accurate patient data and View complete patient data. This

process of checking the PDMP must be integrated into the provider's existing clinical workflow which led to the creation of the sub-constructs Integrate PDMP review into workflow. In an inpatient setting, the PDMP is often used more for a reconciliation of prescriptions that the patient states he or she is taking upon admission compared to an initial prescription history review that often occurs in the outpatient setting.

The Technology Characteristics construct of TTF was adapted to this study and was defined as PDMP technology characteristics that the providers utilize to review patient history to inform their opioid ordering decisions. The technology characteristics constructs contain sub-constructs including Integration type, Authorization/Access, Data Quality, Data Completeness, Ease of Use. As discussed, in this chapter, the PDMP can be integrated with an EHR using different integration methods. These different types of integration methods create different ways of accessing the PDMP which led to the creation of the sub-construct Integration type (Access). A user must register for and gain access to the PDMP which led to the creation of the sub-construct Authorization/Access, and the way a user accesses the PDMP varies based on if they are using the PDMP state website or the integrated link. The patient's data quality and completeness can vary depending on if the data is obtained from the PDMP state website or using the integrated link which led to the creation of the sub-constructs Data quality and Data completeness. Finally, the ability to use the PDMP with ease can vary depending on if the provider uses the PDMP link within the EHR versus going to the state website, because using the link eliminates workflow process steps, which led to the creation of the sub-constructs Ease of use.

The TTF construct was defined as the fit between the users' tasks characteristics

of using the PDMP to check a patient's opioid prescribing history and the PDMP's technology characteristics, due to the PDMP EHR-integration. Comparing the sub-constructs of Tasks Characteristics and Technology Characteristics indicated how the PDMP EHR-Integration improved TTF. TTF is displayed in Figure 2 as the change in TTF due to the intervention. Based on the literature mentioned in Chapter 2, the PDMP EHR-integration link was expected to improve user's access to and ease of use of the PDMP which led to the development of the sub-constructs Improved access and Improved ease of use. The sub-construct Worsened interstate data completeness was created due to data limitations for out of state patients when using the integrated link compared to using the PDMP state website and also based on one study's results mentioned in Chapter 2 (Underwood et al., 2021).

A provider used the PDMP to help inform their treatment decisions including opioid prescribing decisions for some patients. The Performance impacts construct was adapted to this study and the sub-construct Appropriate Opioid Prescribing was created due to the belief, based on the literature in Chapter 2, that an improved TTF from using the intervention led to more appropriate opioid ordering. Therefore, this sub-construct was defined as the change in opioid ordering that occurred due to the PDMP EHR-Integration implementation. The TTF construct's impact on the Performance impacts construct was used to guide the quantitative analysis of assessing PDMP EHR-integration's impact on opioid ordering. It was expected that the intervention reduced the TTF gap through improved access and ease of use, but it was unclear if this change led to a significant decrease in opioid ordering. Providers not being able to access neighboring states of FL and TN patients' prescribing history via the link had the potential to impact

the results and is noted in Figure 2 in the TTF construct. The qualitative interview questions were focused on the Task Characteristics' and Technology Characteristics' sub-constructs to understand the intervention's impact on TTF, based on the quantitative results, and TTF's impact on opioid ordering. Specifically, the TTF sub-constructs helped to confirm if the PDMP EHR-Integration improved PDMP access, ease of use through workflow, and data completeness, and if there were any barriers and facilitators to improving TTF hindered or helped PDMP EHR-Integration success from an IS standpoint.

The Utilization construct was adapted to this study and defined as the act of providers using the PDMP to review patient history to inform opioid ordering decisions. Although PDMP EHR-Integration's impact on PDMP utilization was not included in the quantitative strand of this study due to utilization data constraints, the construct is included in Figure 2 to indicate the potential impact of a change in TTF on PDMP use via the integration link, and that use's impact on appropriate opioid ordering data. PDMP utilization data constraints included state PDMP use data not being available for analysis due to legal restrictions, and PDMP use data not currently being captured at this hospital. The Utilization construct was captured in the qualitative strand of the study in the interview questions and results. Since the Utilization construct simply indicates the use of the PDMP via the integration link, no sub-constructs were developed.

Summary

The development of PDMPs began in the early 20th century with a paper-based, manual system that was developed for enforcing drug laws; similar state-based programs expanded to many other states over the next 70 years. The electronic era of the PDMP

began in the 1990s and laid the groundwork for technological advances to better facilitate the spread of similar state-based systems. Most of the states developed their PDMPs in the early 2000s, with all states except Missouri having PDMPs by 2015, along with gaining support from various types of organizations that had opposed PDMPs many decades prior to this. PDMP governance varies by state with state health departments and boards of pharmacy governing the most PDMPs. PDMP access and data varies by state also, but prescribers and dispensers in all states can access their state's PDMP. PDMP EHR-integration has been implemented in over 30 states to reduce access, time commitment, and workflow barriers to checking the PDMP, and there has been some reported success with these initiatives. Overall, the PDMP has a rich history that will continue to evolve as states find new opportunities to maximize their PDMPs potential.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

Introduction

The purpose of this study is to understand the impact of a PDMP EHR-integration link on inpatient opioids ordering, why that impact occurred, and providers' attitude of the integration link. This is in hope of gaining insight on how to improve the intervention's use and improve the implementation of similar initiatives. To try to achieve this goal, the study addressed the quantitative research question: what is the impact of implementing PDMP EHR-integration via access integration on opioid ordering in an inpatient setting? And the study addressed the qualitative research questions: 1. What are providers' attitudes toward using the PDMP before and after the PDMP EHR-Integration implementation? 2. To what degree do providers believe the PDMP HER-integration implementation improved the TTF between the PDMP and checking patients' controlled substances history? 3. To what degree did other factors besides TTF affect the intervention's impact on opioid ordering?

This chapter describes the research design and methodology, including the rationale for a mixed methods explanatory sequential design, the research sample, description of the study design, methods of data collection and analysis, ethical and quality considerations, and philosophical assumptions.

Mixed Methods Research Rationale

The mixed methods research (MMR) process is an undertaking where quantitative and qualitative methods of data collection and analysis are integrated to best understand a purpose or phenomena (Ivankova & Wingo, 2018)More specifically, MMR is where the investigator collects and analyzes data, integrates the findings, and draws inferences using both quantitative and qualitative approaches in a single study (Tashakkori & Creswell, 2007). MMR was the appropriate approach for this study to allow for more valid conclusions about PDMP EHR-integration implementation by obtaining, connecting, and integrating results from quantitative methods to those obtained from qualitative methods for convergence and divergence (Ivankova & Wingo, 2018). Furthermore, MMR allowed for complementarity and triangulation to increase the validity of results by converging two research methods (Greene, Caracelli, & Graham, 1989; Ivankova & Wingo, 2018).While there are multiple MMR approaches, a sequential design was appropriate for this study to increase the validity of results by using the results of one method to inform the sampling and data collection methods (Greene et al., 1989; Ivankova & Wingo, 2018). Ultimately, MMR allowed for an evaluation of not only the impact of PDMP-EHR Integration via access integration on inpatient opioid ordering, but also the reasons behind that impact.

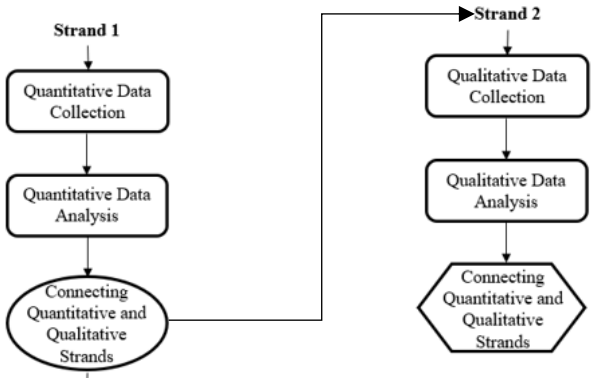
Mixed Methods Research Design

A sequential MMR design (quant → qual) was used for this study and the detailed corresponding study design logic can be found in Appendix A. As shown in Figure 3, a sequential design was used for the initial set of quantitative results to inform, or connect to, the follow-up qualitative data collection including sample selection and interview question development. An inter-method mixing of using two different types of

quantitative and qualitative data collection methods was used due to the sequential nature of the study (Ivankova, 2014).

Figure 3

Sequential Mixed Methods Design Flow



A sequential design was chosen to first assess the intervention's impact on opioid ordering, and then to use those results to further explore the situation from the providers' perspectives. This process of using one research method to inform the other is called *connecting* which is a type of mixing of two research method designs (V. L. Plano Clark, Ivankova, Nataliya V, 2015). The quantitative strand increases the understanding of *what* impact the intervention had on opioid ordering while the qualitative strand provided a deeper understanding of *why* the impact did or did not occur (V. L. Plano Clark, Ivankova, Nataliya V, 2015). The research questions were revisited throughout the study to guide each method's execution, connection of the two methods, and the final integration process. The procedural diagram in Appendix A portrays the research design of the study and its sequence of procedures.

The qualitative strand included interviewing providers who ordered opioids for inpatients to gain insight into how PDMP EHR-integration impacted the TTF between the

tasks required to check a patient's controlled substance prescribing history and the PDMP's technology characteristics, along with the intervention's impact on PDMP utilization and inpatient opioid ordering.

This type of design was used because it was more straightforward and easier to interpret by one researcher (V. L. Plano Clark, Ivankova, Nataliya V, 2015). This research design was also chosen, because a purely quantitative approach would have only collected data on the change in opioid ordering after the intervention was implemented due to data not being available on the intervention's impact on access, ease of use, data completeness, and use. Adding a qualitative element to the study through one-on-one, semi-structured interviews with physicians that did and did not use the intervention allowed data to be gathered around these sub-constructs in the conceptual framework along with revealing additional themes and sub-themes not related to these sub-constructs. This design type also was fitting for this study because the quantitative results were not expected, as shown in the study's hypothesis. The qualitative strand allowed the PI to investigate the unexpected quantitative results. This design type was chosen to provide that level of flexibility to tailor a portion of the interview questions to explore those quantitative results. MMR often uses theories or frameworks to help thoroughly investigate research questions. But due to data limitations, the quantitative strand only answered the research question around the conceptual framework's TTF and Performance impact constructs while the qualitative strand was able to collect more information around the other constructs in the conceptual framework. Integrating the two strands to create meta-inferences is another benefit of MMR that allows the combined results of the two strands of the study to often be greater than the sum of their parts, which further

strengthens the study's results (V. L. Plano Clark, Ivankova, Nataliya V, 2015). Many meta-inferences emerged at the end of the study that may provide direction for PDMP administrators and users who want to maximize PDMP EHR-integration from an IS success standpoint.

This study gave equal weights to the quantitative and qualitative strands, because each strand contributed equally to understanding the study's overarching research question about the intervention's impact (V. L. Plano Clark, Ivankova, Nataliya V, 2015). The quantitative strand provided vital results around the change in opioid ordering while the qualitative strand sought to understand the reason behind that change and providers' attitudes toward the intervention.

Research Setting

The research was conducted in AL where the PDMP EHR-integration was implemented. The quantitative study strand used hospital clinical data to gain insight of the impact on opioid ordering, 6 months before and after implementation, and of the PDMP EHR-integration intervention's impact. This clinical data were stratified to help purposely select providers to be recruited and interviewed for the qualitative strand of the study.

UAB hospital, an 1100 bed, tertiary hospital and academic health science center underwent a PDMP EHR-Integration implementation (access integration) on August 1, 2019, as part of a hospital wide initiative to promote appropriate opioid ordering. This integration provided a single sign-on link in the EHR, meaning the user did not have to login to the state PDMP, a separate website, with separate log in credentials. In other words, once the user logged into the EHR, their credentials were passed to the state

PDMP site for seamless access. Some states' PDMP data were not available using this link that uses data from PMP InterConnect, but that data was available using the PDMP state website. This implementation was one step of many by the hospital's Opioid Stewardship Committee (OSC) to promote appropriate opioid ordering. Opioid ordering tracking in MMEs became available for the inpatient setting beginning February 1, 2019, and was also originated by the OSC.

The PDMP-EHR Integration link at this health system does have some limitations compared to the state PDMP. PMP Gateway is the platform that integrates the AL PDMP into EHRs. Some organizations that do share their PDMP data with other state PDMPs have chosen not to share their PDMP data with PMP Gateway. Tennessee and Florida, neighboring states, have chosen to share their PDMP data with the AL PDMP but not to this hospital via the PMP Gateway. This means that prescribers who want to review prescribing history in the PDMP for patients who were prescribed controlled substances in FL or TN, such as out of state patients, will not be able to see these patients' data with the link but instead must log into the AL PDMP website using separate credentials. The PDMP EHR-Integration link, just like the PDMP state website, also requires the PDMP user to have a non-expired password with the AL PDMP. If that is not the case, the user must go to the AL PDMP website and update the password prior to using the PDMP EHR-Integration link.

Research Sampling

The quantitative sample consisted of all providers who ordered opioids at least once in the UAB inpatient health system over a 12-month period from February 1, 2019, to January 31, 2020. The raw data were at the patient encounter level and was itemized

by opioid administration time, which meant that a patient could receive multiple MME doses per day. Therefore, the total MME ordered per patient was summed up daily. Encounters where the total amount of daily opioids ordered per patient was greater than 4000 MME were removed from the sample as outliers (Newhook et al., 2019). The sample included all prescribers, regardless of whether or not they used the PDMP EHR-Integration link, and this differentiation was used to group the providers in a control and treatment group.

The qualitative strand followed with purposeful sampling using a maximum variation sampling strategy. Maximal variation sampling is a type of purposeful sampling strategy used in qualitative research to maximize heterogeneity and representation in the study participants. This sampling approach aims at identifying key dimensions of variations and selecting participants that vary in at least one characteristic (Palinkas et al., 2015). . This strategy was chosen to identify a wide range of providers' perspectives and experiences (Tashakkori & Creswell, 2007). Patient encounters with providers who changed positions between the study time period to when the clinical data were collected in January 2022 were removed from the qualitative sample to avoid contamination (Yu & Ohlund, 2010). Nurse practitioners were removed from the qualitative sample to help control for different opioid training received; the TTF conceptual framework recognizes that a user's performance can vary depending on components such as training (Goodhue & Thompson, 1995; Lozada, Raji, Goodwin, & Kuo, 2020). The providers in the quantitative strand were stratified by their demographics and the demographics of the patients for whom they ordered opioids. One-hundred twenty-seven providers were emailed to participate in one-on-one, semi-structured

interviews, and 7 interviewees in the control group and 7 interviewees in the treatment group were interviewed, after which saturation was reached.

Literature Review

A thorough literature review was conducted to inform this research study, and the results can be found in Chapter 2. The purpose of the literature review was to understand the history and the current state of the PDMP and its integration with the EHR and the reported impact of PDMP EHR-integration. TTF theory was also explored to determine its relevance to the study and, to some degree, to inform the sub-constructs. This literature review was necessary to understand the potential impact the intervention had on the interventions impact on the change in TTF fit between the tasks needed to use the PDMP and the PDMP technology and the intervention's impact on performance, measured in this study as appropriate opioid ordering.

Quantitative Strand

Data Collection

Opioid ordering data

Structured clinical data were requested from UAB's Research and Informatics Service Center (RISC) and UAB's Health Services Information Services (HSIS) for the quantitative strand to evaluate if the PDMP EHR-integration had an impact on opioid ordering. The PI requested and received approval from the Internal Review Board prior to data collection and analysis. Twelve months of longitudinal opioid ordering data, including 6 months of pre-intervention and 6 months of post-intervention data, for patients who were admitted to the UAB inpatient health system from February 1, 2019, to January 31, 2020. Other inclusion criteria included those for whom an opioid was ordered

at least one time during their hospital stay. The data were at the patient encounter level and were deidentified by the RISC before being handed over to the researcher. The data set resulted in 2,005,907 unique observations.

The quantitative strand's data variables and their definitions are provided in Table 1.

Table 1

Summary of variables and variable descriptions

Variable Name	Description
Order_Date	The day the opioid was ordered in the hospital
Day	Variable which equals one at the first time point and is incremented by one for each subsequent time point (1 – 365)
Treat	Dummy variable that equals 0 for the control group (did not use integration link) and 1 for the treatment group (used integration link)
Post	Dummy variable which equals 1 at the time immediately following the introduction of the intervention of interest and for every time point thereafter
Post_Day	Variable which equals 0 until time 181 + 1 and then is incremented by one for each subsequent time point
Day*treat	Variable that indicates the change in the slope of days or time for the control group in the post period
Treat*post	Variable that indicates the immediate shift in the mean on the first day of the post period
Treat*post_day	Variable that indicates a change in the slope of the treatment group over time in the post-period compared to the pre-period
Avg_MME_Ppatient_Pday	Outcome variable that indicates the average of the total MMEs ordered per patient per day
Admit_Count	Covariate that equals the count of all hospital admissions per day
Avg_LOS	Covariate that equals the average length of stay for all hospital admissions per day
MME_Patient_Visits_Per_Day	The number of patients per day that received an opioid order; used in the calculation of Avg_MME_PPateint_PDay

PDMP EHR-integration Data

Data that indicated which prescriber used the PDMP EHR-integration link from when the link was implemented on August 1, 2019, to January 31, 2020, 6 months post-implementation, were collected from UAB's HSIS and included the name of the provider

who logged into the EHR and used the PDMP EHR-integration link (Prescriber_Name) and the date the provider accessed the link (Date_Accessed). This data set resulted in 15,743 unique observations. This data set was loaded to SAS Enterprise Guide 8.1 for data preparation.

Covariate Data

Two covariates were also collected from UAB's RISC to consider possible external factors that occurred during the study period. De-identified patient numbers (DE_ID) were provided by admission date (ADMIT_DATE) for patients admitted to the UAB inpatient health system from February 1, 2019, to January 31, 2020. This data set resulted in 55,464 unique observations. Length of patient stay (LENTH_OF_STAY) was provided for patients discharged from the UAB inpatient health system from February 1, 2019, to January 31, 2020, because length of stay can be related to hospital efficiency, quality of patient care, and operational efficiency (Wen et al., 2022). And these elements may have impacted the amounts of opioids ordered over the study period. This data set resulted in 152,186 unique observations. Both data sets were loaded into SAS Enterprise Guide 8.1 for data preparation.

Data Preparation and Transformation

Opioid Ordering Data

The opioid ordering data were transformed in SAS Enterprise Guide 8.1 for data preparation. The first step was to add up the total amount of opioids ordered (SUM_CHARTED_MME) per patient per day and summing the number of patients that received an opioid order per day (MME_Patient_Visits_Per_Day). Outliers of the outcome variable (SUM_CHARTED_MME) greater than or equal to 4000 MMEs per

patient per day were removed based on evidence that the majority of patients receive less than 4000 MMEs per day (Newhook et al., 2019).Then the total amount of opioids ordered per patient per day were divided by the total number of visits per day to yield the outcome variable of average MME ordered per patient per day; this calculation is also shown in this equation:

$$\frac{SUM\_CHARTED\_ME}{MME\_Patient\_Visits\_Per\_Day} = Avg\_MME\_PPateint\_Pday$$

The MME of the opioid ordered per dose per patient was summed per patient per day to coincide with CDC opioid prescribing guidelines that provide total daily MME prescribing recommendations per patient (Dowell, Ragan, Jones, Baldwin, & Chou, 2022). Although these guidelines are not enforced across the UAB inpatient Health System, they still serve as a guide to some providers ordering opioids for inpatients. The median of the MMEs ordered per patient per day (Median_MME) and standard deviation of the MMEs ordered per patient per day (SD_MME) were both calculated daily to later help test the robustness of the data sample. Time was removed from variable that held the date and time the opioid was ordered in the hospital (ORDER_DATE_TIME) to create the variable (Order_Date).

PDMP EHR-integration Data

Data that indicated which provider used the PDMP EHR-integration link were matched to the transformed opioid ordering data in SAS Enterprise Guide 8.1. The two data sets were matched on a hierarchy by first matching on provider and then matching on co-signer. This matching hierarchy was based on anecdotal information that the provider normally checks the PDMP compared to the cosigner. These data were also matched by when the provider normally checks the PDMP relative to the time during the

patient encounter which was admission date first, discharge date second, and order date third. Therefore, the data sets were matched where the provider who used the PDMP EHR-integration link equaled the ordering provider first then cosigning provider second. They were also matched first where integration link access date equaled patient admission date, then where integration access data equaled patient discharge date, then where integration access date equaled the order date. This matching strategy yielded 2,034,172 observations.

The merged opioid ordering and PDMP EHR-integration ordering data were separated into control and treatment groups where the control group consisted of providers who did not use the PDMP EHR-integration link during the 6-month post-implementation period while the treatment group consisted of providers who did use the integration link at least once during the 6-month post-implementation period. A binary treatment field (Treat) was created where Treat = 0 for the control group and Treat = 1 for the treatment group to indicate this separation. This step in the data transformation process resulted in 200,411 observations in the control group and 49,230 observations in the treatment group for 12 months of daily data during the study period from February 1, 2019, to January 31, 2020. The data were grouped by order date to yield 365 observations (N=365) of opioid ordering data, each in the control and treatment groups. Data were collected 6 months prior to the PDMP EHR-integration's implementation, because the MME outcome variable was created exactly 6 months prior to this implementation and to provide a sufficient sample size for the study. Six months of data were collected after the implementation to provide a sufficient sample size for the study and to avoid any external influence that may have occurred due to the COVID-19 pandemic that began in the U.S.

in the spring of 2020.

Covariate Data

Two covariate data sets were transformed in SAS Enterprise Guide 8.1. The total number of patients admitted to the hospital were summed per visit as shown below:

$$\frac{LENGTH\_OF\_STAY}{SUM(DE\_ID\_VISIT)} = AVG\_LOS$$

AVG_LOS was then grouped by admission day and discharge day, respectively, to yield the covariates of total admissions per day (Admit_Count) (N = 365) and average length of stay per day (Avg_LOS) (N = 365). These two covariate data sets were merged with the transformed opioid ordering data by matching on the month, day, and year in the study period. These covariates were collected to consider any external factors that may have occurred at the hospital during the study period.

Final Data Sample

The three data sets mentioned above were exported to MS Excel. The final data sample (N=730) that consisted of the 3 transformed and merged data sets and resulted in a control group (N=365) and treatment group (N=365). This data set included the variables Order_Date, Day, Avg_MME_PPatient_PDay.as shown above.

MME_Patient_Visits_Per_Day was previously calculated, as shown in the equation in this chapter, as the number of patient visits per day where an opioid was ordered. Admit_Count was calculated as described above and indicated the total number of admissions for the entire hospital per day regardless of if an opioid was ordered or not. Avg_LOS was calculated as described above and indicated the average length of stay for a patient regardless of if an opioid was ordered or not. Finally, a Treatment variable was

created that indicated if the observation was in the treatment or control group. In order to make this final data set in MS Excel, each variable was created in an individual data table and grouped by Order_Date, creating 4 data sets for the control group and 4 data sets for the treatment group, each with 365 observations. The variables were merged into two data sets, one for control (N = 365) and one for treatment (N = 365). A day variable (Day) was created that ranged from 1 to 365 to indicate each observation's day in the study. Then the data were stacked to be loaded into SAS Enterprise Guide 8.1 for data preparation.

In SAS Enterprise Guide 8.1., a treatment variable (Treat) was created where Treat = 0 where the observations were in the control group, and Treat = 1 where the observations were in the treatment group. A post variable (Post) was created where post = 0 for the first 181 days of the study and post = 1 for the second 181 days of the study to indicate the pre or post implementation period. A continuous variable, Post_Day, was created to measure the change in the slope of the control group where post_day = 0 for days 1-181 of the study and post_day = 1-181 for days 182 – 365 of the study. A weighted variable was created (Weight_MME) where:

$$\frac{1}{(std\_err)^2} = weight$$

and

$$\frac{sd\_mme}{sqt(MME\_Patient\_Visits\_Per\_Day)} = std\_err$$

to check the robustness of the results by absorbing some of the MME variance with the weight. (The variable sd_mme was previously calculated in MS Excel for this calculation.) The $variable\ Day \times treat$ was created to indicate the effect of time on the

treatment group in the pre-implementation period. The variable Treat*post was created to indicate the immediate shift in the mean for the treatment group in the post-implementation period while the variable $treat \times post\_day$ was created to indicate if there was a change in the slope, or over time effect, of the treatment group in the post-implementation period. This weighted outcome variable was not used in the final analysis, because it did not change the results. A variable (Median_MME) that indicated the median MME ordered per patient per day was created to test for robustness in the results. This median outcome variable was not used in the final analysis, because it did not change the results.

The final data sample (N=730) that was analyzed included the variables Order_Date, Day, Post, Post_Day, Treat, Avg_MME_PPatient_PDay, MME_Patient_Visits_Per_Day, Admit_Count, Avg_LOS, and Treatment. These variables and their descriptions are listed in Table 1 along with their descriptive statistics.

Reliability and Validity

A power analysis was conducted with the aid of a statistician to confirm the sample size (N=365), or 365 days over a year, was sufficient. Moreover, there is evidence that N=365 is more than a reasonable sample size for this type of quantitative analysis (Zhang, Wagner, & Ross-Degnan, 2011).

The validity of a statistical measure is the degree to which the statistical measure in question captures the underlying concept that it is intended to measure (Organisation de coopération et de développement économiques, 2013). There is a validity risk with single interrupted time series analysis, because it assesses only individuals that were impacted by the intervention, thus, not capturing any outside events that may have

occurred during the study period that could have impacted the immediate and sustained effect of the intervention (Baicker & Svoronos, 2019). To help account for this risk, this current study used a multiple interrupted time series approach which included a control provider group that ordered opioids but did not use the PDMP EHR-integration link during the study period to eliminate this validity risk. Coefficients found in the interrupted time series approach also separately represent the immediate and subsequent effects of the intervention, respectively, which is often seen as a strength of this design approach (Baicker & Svoronos, 2019).

The multiple interrupted time series design's validity rested on the following assumptions: linearity, a normal distribution, homoskedasticity, and the absence of autocorrelation (UCLA Statistical Methods and Data Analytics, 2021). And the predicted residuals of the model should be normally distributed and have a constant variance around the mean or be homoscedastic. The predicted residuals of the final model were visually inspected and showed a normal distribution around their mean. The relationship between the predictors and outcome variable was linear, indicating that the parametric OLS final model produced valid results. And the model's residuals, or errors, varied constantly around the mean.

Autocorrelation is defined as the degree of correlation between the errors of a model over time (Science, 2018). While autocorrelation does not bias the coefficient estimates of the model, it does tend to underestimate the model's standard errors which can violate the assumptions needed to use an OLS model (Baicker & Svoronos, 2019). A Durbin-Watson test was performed to test for autocorrelation for 1 through 7-day lag in the longitudinal quantitative data sample. The Durbin-Watson statistic for a 1-day lag

correlation was 1.8819 with a positive auto-correlation p-value of 0.0309 and a negative auto-correlation p-value of 0.9691. There was no autocorrelation found in the final model beyond a 1-day lag correlation. The results in the final model were adjusted to account for this 1-day lag of autocorrelation.

Additional steps were taken to ensure the model's validity. The interrupted time series statistical model was run with a weighted outcome variable (Weight_MME) to help evaluate the robustness of results. These preliminary numbers were similar with respect to the coefficients and statistical significance comparing the final model to this adjusted model, which supported the validity of the final model. Similarly, another adjusted model was run with a median outcome variable (Median_MME) and yielded similar results with respect to the coefficients and statistical significance as the final model, supporting the final model's validity as well.

Furthermore, reliability of a statistical measure is defined as the model producing similar results under consistent conditions (Organisation de coopération et de développement économiques, 2013). The strength of the interrupted time series approach is its ability to produce reliable estimates of program impacts and is commonly used with longitudinal data as a robust design when randomization is not possible (Baicker & Svoronos, 2019; Hategeka, Ruton, Karamouzian, Lynd, & Law, 2020; Kontopantelis, Doran, Springate, Buchan, & Reeves, 2015); which is the case of one time interventions such as the PDMP-EHR integration here investigated.

Data Analytics

Interrupted Time Series

An interrupted time series analysis with an OLS model was used with a Durbin-

Watson statistic autocorrelation test, adjusting the number of lags according to the results of the Durbin-Watson statistic test for autocorrelation. The final model generated 4 trend lines based on actual, daily clinical data points. The two trend lines in the pre-implementation period represent the average change in MMEs ordered per patient per day for the control and the treatment groups while the two trend lines in the post-implementation period represent the average change in MMEs ordered per patient per day for the control and treatment groups. This analysis produces 2 tests: (1) the immediate effect, and (2) the over time effect. The immediate effect is the change in the level of the trend line on the day after the introduction of the intervention. The over time effect measures a change in the slope of the trend line after the intervention implementation. Both tests are calculated for the control and treatment groups separately and then the difference between the two groups is calculated (Colicchio et al., 2018).

Qualitative Strand

Data Collection

A purposeful sample from the quantitative data sample's control and treatment provider groups was chosen for the qualitative strand using a maximum variation sampling strategy. This strategy was chosen to identify a wide range of providers with different combinations of department and patient demographics including patients' residential state, gender, and race, to increase variability among providers' perspectives and experiences (Tashakkori & Creswell, 2007). These providers' demographics, along with the demographics of the patients for whom they ordered opioids, are shown in Table 2. Nurse practitioners were excluded from the qualitative sample to collect a consistent position perspective by only interviewing physicians who ordered opioids for inpatients,

because physicians and nurse practitioners undergo different academic training and have different opioid prescribing patterns (Lozada et al., 2020). This exclusion resulted in 4,210 providers in the control group and 216 providers in the treatment group. Patient encounters where the provider changed roles during the study time period, February 2019 – January 2020, and when the clinical data were collected in January of 2022, were excluded from the qualitative sample to avoid contamination (Yu & Ohlund, 2010). This exclusion resulted in 1,944 and 111 providers for possible recruitment in the control and treatment groups, respectively.

The qualitative treatment and control groups were each divided into groups, first based on provider department, and then by the residential state, gender, and race of the patients they prescribed opioids to during the study. Participants with the greatest diversity of patient residential state, gender, and race were chosen from each physician department group to better represent the provider population, with at least one attempt, including a follow-up email, to recruit a provider from each department to be represented in the sample. The primary selection of recruits was those who worked in different departments and ordered opioids to the highest variety of patients based on patient race, gender, and residential state, where possible, to collect the widest range of providers' perspectives. Specifically, the list of providers found in the quantitative sample was grouped by provider department, then by the demographics of the patients each provider treated with an opioid order. At least one provider from each department with the maximum variety of patient demographics was recruited first followed by additional providers in each department, each with less of a variety of patient demographics than the previous recruitment group, due to limited sample variety. This small group (N = 14) of

information rich interviewees were chosen to provide insight on if the intervention impacted their opioid ordering or prescribing, particularly focusing on understanding the integration's impact on the TTF gap (Ivankova & Wingo, 2018). Having participants that prescribed opioids to a variety of non-AL patients was particularly important to explore their view about if the intervention had impacted data completeness, due to the data limitations of out of state patients when using the PDMP EHR-integration link.

Table 2

Qualitative strand participant descriptives

P	G*	Department	State**	Gender***	Race****
1	C	Psychiatry Service	AL	M, F	W, B
2	C	Medical Emergency Team	AL, FL, GA, KY, MS, TN	M, F	W, B
3	C	Obstetrics & Gynecology Services	AL, GA	F	W, B, H, A, P
4	C	Emergency Medicine Service	AL, CA, FL, MS, TX	M, F	W, B, H, A
5	C	Obstetrics & Gynecology Services	AL, FL, MS	F	W, B, H
6	C	Medicine Service	AL, FL, GA, MS, TN, TX	M, F	W, B, H, A
7	C	Neurology Service	AL	M	W
8	T	Emergency Medicine Service	AL	M, F	W, B, A
9	T	General Internal Medicine, Pediatrics	AL	M, F	W
10	T	Medicine Service	AL, MS	M, F	W, B, A
11	T	Medicine Service	AL	M, F	W, B, H, A
12	T	Renal Transplant	AL	M	W, A
13	T	Emergency Medicine Service	AL	M, F	W, B, A
14	T	Anesthesiology	AL, GA, MS	M, F	W

*Interview Group: C = Control, T = Treatment
**Patient State: AL = Alabama, CA = California, FL = Florida, GA = Georgia, KY = Kentucky, MS = Mississippi, TN = Tennessee, TX = Texas
***Patient Gender: M = Male, F = Female
****Patient Race: W = White, B = Black or African American, H = Hispanic or Latino, A = Asian, P = Native Hawaiian/Other Pacific Islander

Recruitment

Through purposive sampling, 127 providers (93 control, 34 treatment), identified using a purposeful, maximum variation strategy. To accomplish this, first the quantitative data sample mentioned above was used to identify providers for recruitment. They were individually emailed to invite participation in one-on-one, semi-structured interviews. Recruitment emails were designed by the PI and approved by the dissertation chair, OSC, and the IRB. Recruitment emails were sent to both control and treatment groups in batches over an 8-week period. A $50 e-gift card was offered to participants who completed the interview. Reminder emails were sent if needed. Of the 127 providers that

were initially emailed, 14 providers responded and agreed to be a participant, 6 responded and declined to participate without reason, 1 offered only 1 time to meet which was a time the PI was not available, and 106 did not respond. Seven interviewees suggested another provider to contact for an interview; however, none of those responded to the email. The final response rate was 11%. The recruitment email can be found in Appendix B.

Interview Protocol Development

The quantitative results were used to inform a portion of the interview protocols with corresponding probing questions to promote response richness. A copy of the interview protocols can be found in Appendix C. The interview protocols' questions varied for the treatment and groups to allow for understanding of why the prescribers did or did not use the PDMP EHR-integration intervention and to reveal both groups' unique perspectives of the TTF gap with and without the intervention.

The treatment group's protocol was developed with the intent to explore providers' attitudes toward using the PDMP before and after the PDMP EHR-integration implementation, if prescribers believed the intervention impacted their opioid prescribing and/or improved the TTF gap, along with the goal of further understanding the quantitative findings around the intervention's impact on opioid prescribing. The control group's protocol was developed with the intent to explore prescribers' attitudes toward using the PDMP in the inpatient environment why they did not to use the intervention during the 6-month period after implementation, and what their attitude of the TTF was without the intervention. This was accomplished by creating the TTF interview questions around the sub-constructs listed in Figure 2.

Several providers in the control group provided additional valuable information about using the link after the post-implementation period. These responses were included in the qualitative data analysis and results to strengthen the richness of the qualitative results.

The detailed interview questions were strategically formed to capture the most meaningful information from the users, with each question having its own purpose and rationale. The interview protocols were reviewed by two faculty members with health information technology and/or mixed methods knowledge. Two interview protocols were developed to capture the reasons behind and experiences of providers using and not using the intervention. Questions about the feasibility of some of the questions from a clinical standpoint were cross-checked with one physician who orders opioids and uses the PDMP EHR-Integration link in the inpatient environment. This was an iterative process where modifications were made until the questions were sequenced, flowed properly, and were transparent to the interviewees. The final protocols were submitted to the university's IRB and UAB Hospital's OSC for approval prior to recruitment emails being sent to physicians.

Both protocols (control and treatment) listed the open-ended questions to be asked as well as an introduction section explaining the purpose and time period of the study, how the interview would be conducted, and the security of the data collected (Creswell, 2012). The control and treatment groups' protocols had a total of 18 and 16 questions, respectively, as shown in Table 3.

Table 3

Summary protocol questions for control and treatment groups

Question Category	Control (number of questions)	Treatment (number of questions)
Participants identify verification, job role, patient type seen during study period	2	2
Reasons using the PDMP	2	1
PDMP access, data completeness, and workflow	3	3
When and why PDMP was checked	4-5	2-3
Association of PDMP EHR-integration and medication orders	3	3-4
Anything else not covered about PDMP EHR-integration	1	1
Permission to follow-up if needed	1	1
Snowball interview suggestion	1	1

Sample Size

Qualitative interview data were used to help explore the intervention's usefulness and inform modifications to PDMP EHR-Integration, if needed (V. L. Plano Clark, Ivankova, Nataliya V, 2015). Purposeful maximal variation sampling was used to select providers to be recruited for interviews. Purposeful sampling is a form of non-

probabilistic sampling (Guest, Bunce, & Johnson, 2006). No standard guidelines currently exist to determine sample size for non-probabilistic sampling methods and calculating the adequacy of a probabilistic sample in practice is extremely difficult. Purposeful sampling most commonly relies on the concept of saturation, where no new themes are found in the qualitative data analysis (Guest et al., 2006). Maximum variation sampling typically requires the largest minimum sample size of any purposeful sampling method; the more variability within in the sample, the more numbers of sampling units are needed to reach saturation (Sandelowski, 1995). But having a goal of saturation does not provide guidance on specific sample size. Some literature make recommendations for sample size for maximum variation sampling. For example, Kuzel (1992: 41) recommended 12 to 20 data sources when trying to achieve maximum variation, although no evidence was included with this recommendation, while other works note that even sample sizes as small as 4 interviewees can provide valuable information (Guest et al., 2006). With that said, appropriate sample size is often a function of each study's goals and how one intends to perform data analysis. A smaller size is often more appropriate for a study on a homogeneous group (Guest et al., 2006). This study had two homogeneous groups, a control and treatment group, with a goal of continuing data collection until saturation was reached, with each main theme in each homogenous group. A sample size of 7 interviewees per group met this goal.

Data collection yielded an interviewee sample of 14 providers (N = 14) that agreed to participate in the study including 7 in the control group (n=7) and 7 in the treatment group (n=7). Interviews ceased when saturation was reached, which was defined as no new main themes being identified with additional interviews.

Interviews were scheduled and conducted using the Zoom video conferencing platform from August 16 to October 12, 2022. Participants received a copy of the interview questions prior to each call to give the provider time to reflect and provide more complete responses. Participants were not blinded to which interview group they were assigned. Each interview lasted approximately 30 - 45 minutes with no interview exceeding 45 minutes. Probing questions were used to promote response richness (Ivankova & Wingo, 2018). Prescribers' responses were retrospective; since, the study period ended in January 2020. The PI took handwritten notes during every interview in addition to the audio recording.

Recorded interviews were saved to a secure Box folder after the interview concluded. These audio recordings were transcribed using Zoom's closed captioning feature, and the resulting text file was validated at a later time by the PI against the raw audio recording.

Data Analytics

Thematic Analysis

After the qualitative data were collected with the one-on-one interviews, a thematic analysis using the TTF constructs as *a priori* codes was conducted, first for each control and treatment group separately, then recording cross themes between the groups. Additional themes were added as appropriate. The unit of analysis was at the prescriber level due to data being collected during individual prescriber interviews.

Coding Structure Organization

The TTF adapted conceptual framework was used to help inform and organize the interview protocols, and it was also used as a starting point of the coding structured for

the interview responses. The sub-constructs of PDMP access, ease of use through workflow, and data completeness were carried through to the coding structure, then new codes were created as themes emerged during the qualitative coding and analysis. This was an iterative process where themes were continually compared, first within each participant group and then across participant groups, organized and named until no new themes emerged. Each main category was in ALL CAPS, each sub-category was mixed cases, and each lowest level code was lower case; this coding organization provided easy visualization of the sub-categories withing the main categories. See Appendix D for the coding structure.

Data Coding

Thematic analysis is a qualitative approach that allows the researcher to identify common themes within the data (Barnett, Vasileiou, Djemil, Brooks, & Young, 2011{Vaismoradi, 2013 #85; Braun & Clarke, 2006). The thematic analysis included becoming familiar with the data, developing themes and sub-themes from common code categories, and refining the themes and subthemes (Barnett et al., 2011). NVivo 12, a qualitative analysis software, was used for thematic coding and analysis.

Procedures. Data analysis followed the method discussed by Creswell and Ivankova (Creswell, 2012; Ivankova, 2014). The transcribed interview recordings from the validated Zoom closed captioned text files were textual evidence for analysis. The PI read each transcript while listening to the interview's audio recording to clean and validate the transcription and to listen for common themes found in the responses. The PI noted in writing any common, interesting, or unusual responses. The validated text files were batch loaded into NVivo 12 and put into appropriate control and treatment file

groupings. Through an iterative, constant comparative process, segments of texts were organized into predetermined (deductive) codes from literature around the PDMP and TTF and emergent (inductive) codes (Glaser & Strauss, 2017; Ivankova, 2014). Some of the codes naturally aligned with the TTF framework mentioned in Chapter 3 and were later categorized into this framework's constructs, as the interview protocol questions were written to align with this framework. Other codes were allowed to emerge by identifying commonalities between text segments and/or relying on the researcher's knowledge and experience of the PDMP from a technological sense. Once all text segments were coded, a cross-coding analysis was performed, first within the control and treatment groups, then across them, to consolidate codes with similar meaning or naming, where applicable. Although the interview protocols contained some different questions, the responses still were reported consistently across groups or within each group to identify themes and subthemes. These codes later became sub-themes that were categorized into higher level, common main themes. The final themes and subthemes were grouped by theoretical construct, following the adapted TTF framework {DuBay, 2014 #110}. These sub-themes and main themes were refined into a comprehensive list of themes and sub-themes found in Table 4.

Quality Assurance

Many steps were taken to assure quality in the qualitative strand of the study. A purposeful, maximum variation sampling method was used to identify participants to allow for a wide range of interview perspectives and responses. This step allowed the qualitative data to be completer and more diverse. Interview questions were reviewed by faculty with expertise in health information technology and mixed methods research

which improved the intent and clarity of the questions. Participants who did not change positions and had similar prescribing patterns by profession were only recruited in the qualitative interviews to help prevent contamination of the results, which was another quality step taken in this strand. The interviewees were informed multiple times about how their data would be kept confidential and secure, which helped promote participant trustworthiness and authentic interview responses. Protocols were emailed to interviewees ahead of the interview, giving them ample time to read and reflect on their possible responses. This was necessary as the study period occurred 3 years prior to the interviews; so, extra time for recollection was needed for better recall of the events around the study period. An open-ended question asking for anything else the interviewees would like to discuss around the PDMP EHR-integration was included that increased qualitative data completeness. The qualitative data transcripts were validated against their corresponding audio files to ensure data accuracy in conceptual meaning and context. The qualitative data were thematically analyzed with a tested technological framework, the TTF framework, initially guided by thematic coding, then creating additional codes for a more in-depth analysis and understanding. Using the TTF framework to guide the thematic analysis also led to external validity and inference transferability, because the results may be used to inform PDMP EHR-Integration efforts at other health systems where the TTF framework and PDMP are applicable (Ivankova & Wingo, 2018).

The MMR sequential design increased the study's quality of results by allowing the quantitative strand to inform the qualitative strand (Greene et al., 1989; Ivankova & Wingo, 2018). Specifically, the quantitative strand measured the relationship between the

change in TTF and appropriate opioid ordering due to data limitations, while the qualitative strand examined the change in TTF, PDMP utilization, and appropriate opioid ordering. Therefore, the quantitative results could only inform a portion of the qualitative interview questions. The qualitative results helped to explain the quantitative results, as the qualitative interview questions captured prescribers' attitudes toward the intervention that could not have been captured solely with the quantitative data. Meta-inferences were conducted around the study's research question, reporting converging, and diverging results, to promote transparency and meta-inference credibility and mitigate researcher bias. Using a mixed methods study also strengthened the validity of the entire study's results by integrating two research methods (Ivankova & Wingo, 2018)Greene, 1989 #64}.

Data Interpretation

The interpretation of the results found in Chapter 5 used the PDMP literature and conceptual TTF framework literature. This literature and framework were essential in understanding the meaning and value of the quantitative and qualitative findings.

Integration and Meta-Inferences

The results of the two strands were integrated, or mixed, to provide a richer understanding of the study's research questions and strengthen the results; integration in mixed methods research is where the quantitative and qualitative components interact with each other in meaningful ways leading to a more comprehensive understanding of the of the results together than if analyzed separately (V. L. Plano Clark & Sanders, 2015). The results from both strands were compared using a joint display found in Table 7to identify areas of convergence and divergence. A joint display is a tool researchers can

use to help integrate the results of the qualitative and quantitative strands of a mixed methods study, among other ways to use a joint display, to develop meta-inferences after individually analyzing the two separate strands of the study (Guetterman, Fetters, & Creswell, 2015; R. E. Johnson, Grove, & Clarke, 2019). The display was used to interrelate the TTF's construct of performance, or the specific quantitative results, with the related qualitative themes and subthemes identified in the qualitative analysis. Meta-inferences made from combining these specific quantitative results with these themes and subthemes are also listed in the joint display also shown in Table 7.

Ethical Considerations and Data Management

This study was conducted ethically to minimize the risk of harmful effects to study participants. A detailed quantitative research design and high-level qualitative research design was initially given to the IRB committee and OSC due to this being a sequential, two-part MMR study. Two qualitative interview protocols and recruiting email were submitted as an amendment to the IRB committee. See Appendix E for the IRB submission, approval, and accompanying documents.

All data were stored in a secure UAB Box account. These data did not include patient encounter level protected health information (PHI) as the medical record number (MRN) was deidentified using industry standard protocols prior to the PI receiving data from the EDW team (Portability & Act, 2012). Identified provider data were de-identified to protect participants from any hospital employer repercussions. A waiver for participant consent was obtained for interviews. The study's purpose was communicated to physician participants to promote transparency.

Philosophical Assumptions

MMR has a pragmatic approach to ontology, epistemology, axiology, transferability, causation, and logical thinking (abduction) (Teddlie & Tashakkori, 2010). MMR allows us to examine multiple paradigms or world views for enhanced understanding (Christensen, Johnson, Turner, & Christensen, 2011; Greene, 2007). One object or phenomenon is examined in MMR through objective statistical analysis of structured data along with multiple subjective outcomes through open-ended interviews or focus groups. A more pragmatic approach to ontology was taken for this study. Multiple realties, or perspectives, were revealed from the different providers who were interviewed. However, only one true reality can exist around the amount of opioids ordered in an inpatient health system, assuming the clinical data were accurate, which was indicated with the quantitative results. Two epistemology approaches were taken in MMR; the knower and the known were distinguishable in quantitative research but inseparable in qualitative research. This study took a more pragmatic approach around epistemology; the quantitative data had one meta-known while the qualitative results contained multiple perspectives and knowns.

MMR is a combination of value-free and value-bound research (R. B. Johnson & Onwuegbuzie, 2004). Quantitative statistical analysis is objective and value-free, to a certain extent as all data have some degree of bias, while qualitative research includes researchers' values in interview responses and analysis (R. B. Johnson & Onwuegbuzie, 2004). However, quantitative data manipulation, confounders, and dependent variable choices can be somewhat subjective, such as when outlier MME thresholds in this study were determined, leading to different results when taking different statistical routes. A

more pragmatic approach was taken in the study, because researcher bias was recognized and minimized as much as possible in the research design. MMR is generalizable, but care must be taken to apply it in similar contexts. A more pragmatic approach, again, was taken for this study; other PDMP users and administrators can use findings if their contexts are similar to the context of this study. The intersubjectivity nature of MMR makes distinguishing cause and effect moderately distinguishable. Here, a constructivism approach was taken; relationships between the target intervention and opioid ordering were identified as opposed to pure cause and effect. MMR research has both deductive and inductive approaches (abduction). A pragmatic approach was initially taken here; research was performed in a deductive manner to confirm the TTF theoretical framework. Then, the study took an idealistic approach with qualitative interviews to try to understand what was occurring at the practice level and why.

This sequential (quant → qual) mixed methods study started with a deductive, quantitative approach, using TTF theory to test the relationship between an intervention (PDMP EHR-Integration implementation) closing the TTF gap and that intervention's impact on individual performance (opioid ordering). The study then took an inductive approach with prescribers' interviews that helped to further clarify the quantitative results.

Summary

An overview of this study's methodology was provided in this chapter. MMR was defined along with justification of its use in this study including benefits of the quantitative and qualitative strands, integration, and the sequential nature of the study's design. A Sequential Quan → Qual Mixed Methods Design Logic was presented to give

an illustration of the procedures, products, and sequencing of the study. An explanation of the research setting, sampling strategy, interview protocols, data collection, and data analysis was also discussed. The quality control measures and ethical considerations for the study were also listed. An explanation of the philosophical assumptions made to perform this MMR study was also discussed.

CHAPTER 4

RESULTS

Following the sequential MMR approach, this chapter first presents the quantitative data strand's results followed by the qualitative data strand's results. The results are presented relative to the TTF theory and then expanded upon with additional details from the qualitative interviews. A joint display is used to help integrate the two strands of the study to form meta-inferences.

Quantitative Strand

The quantitative strand of the study sought to understand the immediate and over time impact of the PDMP EHR-integration implementation on opioid ordering using clinical data. This chapter presents the quantitative results.

Research Question and Hypothesis

The quantitative research question answered was: What is the impact of implementing PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting? The hypothesis was: Implementing PDMP EHR-Integration via access integration will decrease the average number of total opioids, measured by MMEs, ordered per inpatient.

Results

Table 4 provides descriptive statistics for the variables included in the qualitative strand. Both groups had 179 observations, or days, in the pre-period and 185 days in the post-period. The mean MME ordered per patient per day in the pre period for the control group was 121.18 with a standard deviation of 17.45 and 101.65 with a standard

deviation of 35.95 for the treatment group; the mean MME ordered per patient per day in the post period for the control group was 121.06 with a standard deviation of 17.35 and 121.84 with a standard deviation of 40.47 for the treatment group. The mean total admissions per day for the hospital was 152.07 with a standard deviation of 36.15 in the pre period and 151.80 with a standard deviation of 34.93 in the post period. The mean length of stay per day for the hospital was 6.63 with a standard deviation of 1.23 in the pre period and 6.72 with a standard deviation of 2.27 in the post period.

Table 4

Descriptive statistics for quantitative strand

Treat*	Post**	N	Item***	Mean	Median	Std. Dev.	Min	Max
No	0	179	Avg_MME_PPatient_PDay	121.18	118.51	17.45	86.18	174.77
			Admit_count	152.07	166.00	36.15	77.00	209.00
			Avg_LOS	6.63	6.38	1.23	4.63	14.23
	1	185	Avg_MME_PPatient_PDay	121.06	119.90	17.35	83.93	201.58
			Admit_count	151.80	166.00	34.93	78.00	206.00
			Avg_LOS	6.72	6.47	2.27	4.26	33.66
Yes	0	179	Avg_MME_PPatient_PDay	101.65	94.64	35.95	28.00	208.83
			Admit_count	152.07	166.00	36.15	77.00	209.00
			Avg_LOS	6.63	6.38	1.23	4.63	14.23
	1	185	Avg_MME_PPatient_PDay	121.84	115.84	40.47	39.27	304.22
			Admit_count	151.80	166.00	34.93	78.00	206.00
			Avg_LOS	6.72	6.47	2.27	4.26	33.66

*No = Control study group, Yes = Treatment study group

**0 = Pre-implementation period, 1 = Post-implementation period
***Avg_MME_PPatient_PDay = Outcome variable that indicates the average of the total MMEs ordered per patient per day, Admit_Count = Covariate that equals the count of all hospital admissions per day, Avg_LOS = Covariate that equals the average length of hospital admissions per day

The OLS interrupted time series analysis revealed a statistically significant intercept at the beginning of the study period of 134.88 (p-value<.0001) which indicated the average MME ordered per patient per day at the beginning of the study period for the control group was 134.88 MME per patient per day. The Day variable of 0.0358 indicated the effect of day, or time, on the average MMEs ordered per patient per day for the control group in the pre-period was zero and not statistically significant (p-value: 0.3986). The Treat variable indicated the difference between the control and treatment groups' means at the beginning of the study period, or day 0; therefore, the treatment group was ordering 19.197 fewer MMEs per patient per day than the control group at the beginning of the study period (p-value: 0.0023). The Post variable showed the immediate impact of the intervention on the control group's opioid ordering, but this immediate decrease of 6.2345 MMEs ordered per patient per day after the intervention was implemented was not statistically significant (p-value:0.31). The Post_day variable indicated the change in the slope in the post period for the control group, or the over time effect on the control group due to the implementation; there was no evidence that the intervention had an impact on the control group's opioid ordering over time due to the coefficient of -0.0054, which was not statistically significant (p-value: 0.927). The $variable\ Day \times treat$ revealed no statistically significant difference in slopes between the control and treatment groups in the pre-period (p-value: 0.9519); so, there was no evidence that time had an impact on the control group versus the treatment group comparison in the pre-period. The $variable\ Treat \times post$ showed that the treatment group had a different intercept at the time the intervention was implemented as it moved into the post period with an immediate increase of 15.933 MMEs per patient per day (p-

value: 0.0667).That is, there was an immediate increase in MMEs ordered per patient per day for providers who used the integration link in the post period. Although p values greater than 0.05 may not be considered statistically significant at traditionally rigorous levels, this immediate MME increase that occurred post intervention implementation for the treatment group (p value = 0.0667) could be considered to be clinically significant, because it was trending toward statistical significance (Thiese, Ronna, & Ott, 2016). In any case, it is illustrative of a change that occurred as a result of the intervention. The $variable\ Treat \times post\_day$ indicated that the slope of the treatment group did not change significantly in the post-implementation period as compared to the pre-implementation period (p-value: 0.5124). The control variable Admit_count showed that after controlling for covariates in the model, the average MME per patient per day decreased 0.1412 for every additional person admitted to the hospital on a given day (p<.0001). The Avg_LOS coefficient indicated that the average length of stay for all patients in the hospital did not have a statistically significant impact on opioid ordering during the study period (p-value:0.255). These results are summarized in Table 5, and a graphical display of these results is included in Figure 3.

Table 5

Summary of interrupted time series analysis

Variable*	Estimate	SE	t-Value	p-value
Intercept	134.88	7.877	17.12	<.0001
Day	0.0358	0.0423	0.84	0.3986
Treat	-19.197	6.2648	-3.06	0.0023
Post	-6.2345	6.1368	-1.02	0.31
Post_day	-0.0054	0.0585	-0.09	0.927
Day*treat	-0.0036	0.0599	-0.06	0.9519
Treat*post	15.933	8.6772	1.84	0.0667
Treat*post_day	0.0542	0.0826	0.66	0.5124

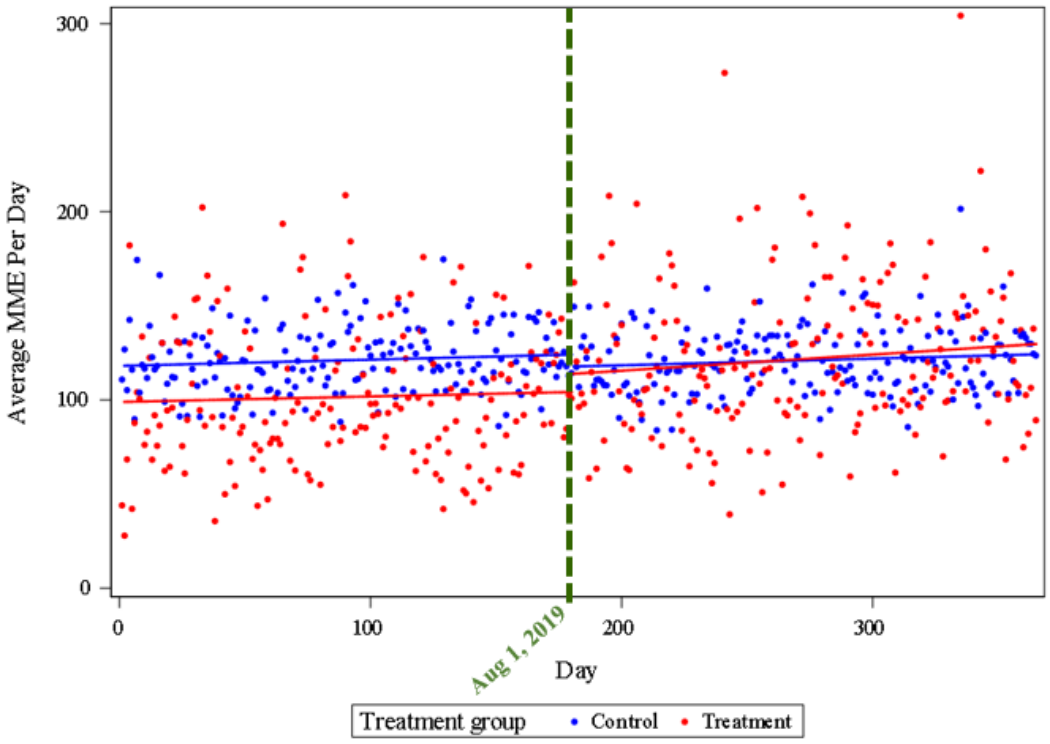
Admit_count	-0.1412	0.0309	-4.57	<.0001
Avg_LOS	0.6806	0.5975	1.14	0.255

*Variable Descriptions:

Order_Date	The day the opioid was ordered in the hospital
Day	Variable which equals one at the first time point t and is incremented by one for each subsequent time point (1 – 365)
Treat	Dummy variable that equals 0 for the control group (did not use integration link) and 1 for the treatment group (used integration link)
Post	Dummy variable which equals 1 at the time immediately following the introduction of the intervention of interest and for every time point thereafter
Post_Day	Variable which equals 0 until time 181 + 1 and then is incremented by one for each subsequent time point
Day*treat	Variable that indicates the change in the slope of days or time for the control group in the post period
Treat*post	Variable that indicates the immediate shift in the mean on the first day of the post period
Treat*post_day	Variable that indicates a change in the slope of the treatment group over time in the post-period compared to the pre-period
Admit_Count	Covariate that equals the count of all hospital admissions per day
Avg_LOS	Covariate that equals the average length of stay for all hospital admissions per day

Figure 3

Interrupted Time Series Analysis: Average MME Ordered Per Patient Per Day



Summary

The quantitative strand of this MMR study was conducted to help understand the impact of implementing PDMP EHR-integration via access integration on opioid ordering in an inpatient setting with the hypothesis that this intervention's implementation decreased the average MMEs ordered per patient per day. Three clinical data sets were collected, transformed, and merged. Additional variables were then created, and this final data set was analyzed using an interrupted time series analysis using OLS while controlling for autocorrelation of a 1-day lag. The quantitative results revealed that the over time effect of the intervention on opioid ordering was not statistically significant for either control or treatment group. But there was an immediate increase in opioid ordering for the treatment group (providers who used the PDMP EHR-

integration link). These results contradicted the hypothesis made at the beginning of the MMR study, and the qualitative results presented in Chapter 5 helped explain this finding.

Qualitative Strand

Research Questions

The second strand of this mixed methods study was performed to understand the providers' attitudes toward the PDMP EHR-integration. This strand primarily investigated if they believed that the integration improved the TTF between the PDMP as a technology and the task of reviewing patients' controlled substances prescribing history in the PDMP along with if they believed any other factors besides TTF affected the intervention's impact on opioid ordering. This chapter outlines the methods used to attain this goal including data collection, analysis, and the results of that analysis.

Connecting Quantitative and Qualitative Data in Mixed Methods Design

The quantitative phase of this study set out to answer the following research question:

1. What is the impact of implementing PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting?

A sequential mixed methods study design requires the first strand to inform the design of the second strand of the study (Teddlie and Tashakkori, 2009). As the quantitative results did not confirm the quantitative study hypothesis, the interviews gave an opportunity to understand the underlining reasons behind this finding. Thus, the quantitative strand's statistical results were used to inform one of the qualitative strand's interview questions to better understand why there was an average increase of nearly 16

MMEs per patient per day ordered immediately after the PDMP EHR-integration link was implemented.

Results

Six themes and 20 subthemes emerged from the qualitative data analysis; Table 6 summarizes these findings including themes, sub-themes, theoretical construct, and supporting quotations which are organized around the elements found in the adapted TTF conceptual framework shown in Figure 3. Providers are referred to as “they” in the quotations, and assigned participant and department numbers are used in Table 7, when needed to provide confidentiality due to the sensitive nature of prescribing and ordering opioids.

Table 6

Themes, Sub-themes, Theoretical Construct, and Illustrative Quotes

Theme	SubTheme	Theoretical Construct	Illustrative Quote
Registration/ Access Process	Easier to Access with Link	TTF - Access Improvements	“But it’s like way easier to have it in the PDMP tab and have it pulled up for me.” (Interviewee 5)
	Registration/Access Issues with Website	TTF - Access Issues	"The biggest frustration was how frequently you had to update your password." (Interviewee 1)
Ease of Use	Difficulty Locating and Navigating Website	TTF - Access Issues & Ease of Use/Workflow Issues	"So, it's definitely you know quite a few steps to get the information you need." (Interviewee 12)
	More User Friendly with Link	TTF - Ease of Use/Workflow Improvements	"I think the EMR one is like super user friendly." (Interviewee 5)
	Workaround to Locate Website	TTF - Access Elements (Neutral)	"You know they email you so often to change your password that I would just see what the PDMP link was there [in the email]. And that's how I would get it." (Interviewee 5)
	No Ease of Use/Workflow Issues with Website	TTF - Ease of Use/Workflow Elements (Neutral)	"…you need first name, last name, and a date of birth …; that's something you could get pretty easily from the chart, and then just open up a separate window with the PDMP." (Interviewee 1)
	Less User Friendly with Website	TTF - Ease of Use/Workflow Issues	"So, it's not user friendly because you have to go back and forth between the patient record and the PDMP, or like the actual state, website." (Interviewee 5)
	Easier to Locate with Link	TTF - Access Improvements	"It's much easier to find." (Interviewee 12)

Patient Data	Additional Steps for Out of State Patients with Website	TTF - Data Completeness Issues	You had to make sure you picked, especially if someone lives near the border you had to pick the neighboring state. So, if you forgot to do that … then those might be missed." (Interviewee 12)
	Inaccurate/Missing Patient Data with Website & Link	TTF - Data Completeness Issues	"Usually, it's inaccuracies and the name given on the PDMP website or date of birth as it relates to the name and date of birth they are registered with [in the EHR]." (Interviewee 13)
	No Patient Data Entry/Lookup with Link	TTF - Ease of Use/Workflow Improvements	"When you click on it [, the link,] if you already have the patient selected, … it'll take you to that patient. It's going directly from the patient's medical record." (Interviewee 10)
	Patient Matching Issues with Website	TTF - Data Completeness Issues	"Usually, it's inaccuracies and the name given on the PDMP website or date of birth as it relates to the name and date of birth they are registered with [the EHR]. So, finding a patient basically." (Interviewee 11)
Time Commitment	Delay in Displaying Data with Link	TTF - Ease of Use/Workflow Issues	"Every now and then there would be a patient where they would say I got my prescription filled 2 weeks ago, and it wouldn't be listed where I think there was probably some more delay, as pharmacies were, kind of rolling that out, or it was becoming more part of their process." (Interviewee 10)
	Time Consuming Process with Website	TTF - Access Issues & Ease of Use/Workflow Issues	"And then when you click on it, it doesn't it's not as instantaneous loading as the stuff that's all built in within you know, within the software itself, the primary software." (Interviewee 7)
	Faster Access with Link	Task-Technology Fit - Access Improvements	"So, with that, it just takes almost no time at all …" (Interviewee 10)
	Faster Patient Lookup with Link	Task-Technology Fit - Ease of Use/Workflow Improvements	"So, it's so fast; it makes it so easy." (Interviewee 10)
Validation	Possible Drug Misuse	Utilization - Reasons Used PDMP	"…trying to get a sense of whether or not a patient is accessing narcotic medications or opioids from several different sources." (Interviewee 3)
	Validate Medications	Utilization - Reasons Used PDMP	"… mostly seeing if they had a filled prescription drug, controlled substance, prior to coming into the hospital." (Interviewee 9)
Ordering/Prescribing	Help with Opioid Ordering/Prescribing Decision	Utilization - Reasons Used PDMP	"… to ensure that we were prescribing the appropriate medications." (Interviewee 1)
	Patient Indicates They Have Pain	Utilization - Reasons Used PDMP	"… if someone comes in for a painful complaint…" (Interviewee 4)

The remainder of this chapter describes the themes and subthemes in detail found in Table 6.

Theme 1: Registration/Access Process

Providers reported that they had multiple types of issues with the process of registering and accessing the PDMP through the state's website and using the embedded link.

Subtheme 1: Easier to Access with PDMP EHR-integration Link. Providers in the control group who used the link after the study period found the link made accessing the PDMP easier. One interviewee pointed out the increase ease of use found by several providers after the link was implemented by saying, "People look at the PDMP just because it's easier to do so and less cumbersome. So, I think that it's easier to access …" (Interviewee 5)

Subtheme 2: Registration/Access Issues with PDMP State Website. Providers in the control group that used the state's website for access to the PDMP reported logon issues of logging onto the site in general, finding the website's URL online often after using a search engine, having to remember, or frequently forgetting their username and password, and the PDMP state website requiring password changes too frequently. One provider explained a common PDMP state website logon inefficiency by explaining, "I might type in PDMP [into the search engine], but it's a little haphazard what course I took to find it . . . just however you can find it that day."

Theme 2: Ease of Use

Providers reported that they had difficult locating and navigating the state website, the PDMP was more user friendly when using the link, that they used workarounds to locate and access the PDMP state website, that the state website was not user friendly, that the link made the PDMP easier to locate, and that they didn't feel the state website caused any workflow issues.

Subtheme 1: Difficulty Locating and Navigating the PDMP State Website. Providers in both the treatment and control groups had difficulty locating and navigating the state website. One provider reported that they couldn't locate the website on a shared hospital computer, because they could not save the site or their logon information on the local computer. This provider explained their experience by saying "… In the hospital the way we use this system where we badge in … I can't save bookmarks, and you can't store logins. So, I always had to use my personal device [laptop when available] to do that." (Interviewee 7) The analysis also showed that some providers found the state PDMP to be clunky and difficult to navigate. One interview summarized several of the providers' sentiments by saying, "So, before it was put into the UAB EMR, I would not check it because it was too clunky, hard to navigate." (Interviewee 4)

Subtheme 2. More User Friendly with PDMP EHR-integration Link. One provider in the control group who used the link after the study period commented that the link was "super user friendly". (Interviewee 5)

Subtheme 3: Workaround to Locate Website. Multiple providers in the control group reported workarounds such as bookmarking the PDMP state website on their personal computers as was just one step in the process of accessing the PDMP state website; they did not see going to the state website as an access issue, just as an additional step in the process. One provider explained their process of finding the PDMP state website, saying "Yes, it [PDMP state website] is one of my favorites." (Interviewee 6). Some providers even considered being able to bookmark the site on their personal computer, a facilitator to accessing the PDMP state website.

Subtheme 4. No Ease of Use/Workflow Issue with PDMP State Website. The

analysis of the control group's interviews found that some providers did not consider switching between screens or patient data entry to be issues with the website. They explained their experience by saying, "And so, I could just open up multiple charts. You know, 3 at a time, you can have open in our EMR. And so, I could open 3 patients that I was scheduled to see that day, very quickly type in all of their demographic information into the website and then that way just not have to worry about kind of clicking each individual chart and kind of having that link separately." (Interviewee 6)

Subtheme 5. Less User Friendly with Website. One provider in the treatment group and multiple providers in the control group that used the intervention after the study period commented that switching screens between the EHR and PDMP state website was a workflow issue. Other providers in the control reported that switching between screens was just a part of the normal workflow of using the PDMP and not workflow issue. One interviewee explained the common issue of having to switch between screens, by saying, "So, it's not user friendly because you have to go back and forth between the patient record and the PDMP, or like the actual state, website." (Interviewee 5)

Subtheme 6: Easier to Locate with PDMP EHR-integration Link. The analysis revealed that providers in the treatment group and providers in the control group who used the link in the post-study period found the PDMP easier to locate with the integrated link. One interviewee summed up many of the providers' attitudes toward the PDMP EHR-integration link by saying, "It's just like way easier to have it in the PDMP, click on the PDMP tab, and have it pulled up for me." (Interviewee 5)

Theme 3: Patient Data

Subtheme 1. Additional Steps for Out of State Patients with the PDMP State Website. The data analysis revealed that there were additional steps they had to take to see the controlled substances prescribing history of an out of state patient when using the PDMP state website. One interviewee summed up the additional steps, saying, “If someone lives near the border you had to pick the neighboring state. So, if you forgot to do that … then those might be missed.” (Interviewee 12)

Subtheme 2. Inaccurate/Missing Patient Data for Out of State Patients with PDMP State Website & PDMP EHR-integration Link. The data analysis revealed that some providers in the treatment group found the patient data in the PDMP state website to be missing, but they were not sure why. One interviewee explained their experience with missing data by saying, "Just discrepancies between patient reporting and data being pulled over. I'll never know if it was just patient dishonesty trying to get away by like saying they're prescribed in a far-off state and hope to seek more opioids. Or, if it was genuine that they had been prescribed, and we just weren't getting the data we needed. Hard to tease out in that population, but that would be the issue we have." (Interviewee 14)

Subtheme 3. No Patient Lookup with PDMP EHR-integration. Providers in the treatment group noted that not having to look up patient data when they used the link, because the link was embedded in a patient’s record and took them directly to that patient’s controlled substances prescribing history, was a workflow improvement. An interviewee explained the benefits of not having to look up a patient in the PDMP state website by saying, “When you click on it [the integrated link] if you already have the

patient selected, … it'll take you to that patient. It's going directly from the patient's medical record. So, it opens up their record. So, I click on that link, and it pops up so easy for my clinic patients." (Interviewee 10)

Subtheme 4. Patient Matching Issues with PDMP State Website. Matching patients between the EHR and PDMP State website was reported to be a workflow issue by the treatment group. For example, one provider reported, "Usually it's inaccuracies … as it relates to the name and date of birth they are registered with. So, finding a patient basically." (Interviewee 11)

Theme 4: Time Commitment

Subtheme 1. Delay in Displaying Data with PDMP EHR-integration Link. Multiple providers in the control group that used the intervention in the post-study period reported that the data did not populate as quickly using the link as it did in the EHR. One provider explained this by saying, "Every now and then there would be a patient where they would say I got my prescription filled 2 weeks ago, and it wouldn't be listed where I think there was probably some more delay, as pharmacies were, kind of rolling that out, or it was becoming more part of their process." (Interviewee 10)

Subtheme 2. Time Consuming Process with PDMP State Website. Multiple providers in the treatment group reported that they had issues with time commitment of the process of accessing the PDMP through the state's website. One interviewee gave a nice summary of those reports, saying,

"… so, then I would have to go through the whole password reset thing, which is time consuming. And then I'm like, well, maybe you know I've got 10 other patients to take care of, a critical patient over here, trauma over here, and it just was an extra 5

minutes to figure out my password and login oftentimes. It didn't feel worth it, and so I probably only did it when I was able to recall my password consistently, and maybe had a little bit of extra time …" (Interviewee 8)

Subtheme 3: Faster Access with PDMP EHR-integration Link. The data analysis showed that providers in the treatment group reported the link to allow for faster access to the PDMP, "So with that, it just takes no time at all …" (Interviewee 10)

Subtheme 4: Faster Patient Lookup with PDMP EHR-integration Link. The data analysis showed that providers in the treatment group reported the link to be faster and less time consuming as one provider elaborated on by saying, "So certainly much faster to get the information than it used to be." (Interviewee 12)

Theme 5: Validation

Providers were asked to discuss the reasons they used the PDMP, and their responses revealed that most of them were checking the PDMP to validate a variety of diverse types of information. Specifically, providers in both the treatment and control groups reported they checked the PDMP when there was a possibility that the patient was misusing drugs and to validate prior or outside patient prescription drug or dose.

Subtheme 1: Possible Drug Misuse. The data analysis showed that providers checked the PDMP if they suspected drug misuse or diversion. One provider explained this by saying, "[I check the PDMP] if I'm sensing there are red flags for opioid misuse." (Interviewee 3)

Subtheme 2: Validate Medications. Several providers stated that they check the PDMP to validate medications the patients said they were taking prior to being admitted to the hospital. One interviewee summed up the sentiments of several providers by

saying, “So the primary reason that I would check that is so that we could get a better understanding of how much either pain medication or other controlled substances that folks were getting at home.” (Interviewee 2)

Theme 6: Ordering/Prescribing

The second most common reason the providers checked the PDMP, reported by both the control and treatment groups, was to aid them in their ordering or prescribing decisions.

Subtheme 1: Help with Opioid Ordering/Prescribing Decision. Several providers explained a common reason to check the PDMP was because they needed information to help make an opioid ordering decision. One provider summed this up by saying “[We checked it] to verify what their prescriptions were outside of the hospital setting to ensure that we were prescribing the appropriate medications.” (Interviewee 1)

Subtheme 2: Patient Indicates They Have Pain: Several providers stated that they would check the PDMP if they patient indicated that they had pain during their hospital stay or at discharge. One provider explained this by stating, “[I would check the PDMP] if someone comes in for a painful complaint.” (Interviewee 4)

The interview questions led to additional findings that were not consistently or sufficiently reported to allow themes to emerge or that aligned with the conceptual framework, but they may be useful to PDMP users and administrators and are, thus, reported below.

Most of the interviewees in the treatment group found the PDMP’s data to be complete or fairly complete prior to the integration. A small number of providers felt the data were only complete for in-state residents along with residents of GA, MS, and FL.

Most of them felt that the data completeness did not change when switching from the PDMP state website to the PDMP EHR-integration link. A minority reported that the data completeness was the same post intervention except the data completeness worsened post-intervention for patients residing in TN, and FL; these states were not available using the integration link for reasons listed in Chapter 1.

The interview protocol included questions about data completeness due to the link using PMP InterConnect data which does not include data from certain states. Most of the interviewees in the control group were confident in the PDMP data's completeness while a small number were either not confident or not confident with the data completeness for out of state patients. Four interviewees in the control group reported using the link after the study period, and half of them reported there was no change in data completeness while one reported the data were less complete for out of state patients during the post-intervention period.

Most of the providers in the treatment group reported there was no change in their opioid ordering or prescribing post intervention, while one increased their amount ordered or prescribed, one decreased their amount ordered or prescribed, and one could not recall what occurred due to the lapse of time since the study period.

When asked to discuss anything else about the PDMP EHR-integration, the treatment group reported that the daily oral morphine equivalents (OME) patient calculator was not entirely accurate, that the link helps identify possible drug diversion, that the link impacted outpatient prescribing of non-opioid controlled substances, that it improved individual confidence of patient care decisions, and that it led to honest discussions with the patient. The control group responded to this same question that it

was a habit to use the state PDMP site instead of the link, that the PDMP link needs more historical data, that they were aware of the integration's benefits, that they used the wrong link in the PDMP, and that they were not aware of the link. Three providers in the control group who did not use the integrated link in the post period reported that they had been made aware of the link by word of mouth from residents, two by email, one by onboarding training, and one could not recall.

When asked to discuss what could have been done better with the integration, providers suggested to announce the intervention in department meetings, to announce the benefits of using the link, to better communicate that the link is very helpful versus just an option to use, to demonstrate its efficiency, to emphasize its benefit for outpatients, to provide information on best practices how to use the link, to provide an information sheet on how to use the link, which had been provided by the OSC at the time of implementation but this provider was not aware of or did not recall that information, to make a push icon instead of a drop down when using the link, to announce the link more when it went live including sending an email. The OSC did send an email when the intervention went live, but this provider was not aware of, or did not recall, that email.

The interviewees were asked to discuss their thoughts about the quantitative findings of the average MME per patient per day immediately increasing post-intervention. Most of the treatment group responded that they were not surprised with this finding, because the implementation of the integration allowed them to control their patients' pain more adequately. Or some respondents speculated that the MME immediate increase occurred because providers were more comfortable, confident, felt it

more appropriate, or had less fear to prescribe opioids due to using the PDMP more frequently or at all after the integration link was implemented. Most of the control group speculated similar findings to the treatment group, that the quantitative results occurred due to providers being more comfortable, confident, or felt more appropriate to prescribe opioids due to using the PDMP more frequently or at all after the link was implemented. The other few providers in the treatment and control group were surprised to find that the average opioid amount per patient immediately increased which aligned with the direction of this study's quantitative hypothesis, but, after reflecting on the findings, several of them said that the quantitative results could have occurred for the same speculative reasons mentioned above.

Integration and Meta-inferences

The quantitative strand's results revealed an immediate increase in the average MME ordered per patient per day after the PDMP EHR-link was implemented, while there was no statistically significant over time increase. As this was a sequential mixed methods study, part of the qualitative interview questions were formed, or connected, around the quantitative results by providing the interviewees with these quantitative results and then asking them to discuss their thoughts.

Meta-inferences made from combining the quantitative results with qualitative results, themes, and subthemes, are also listed in the joint display below that is separated into control and treatment study groups. The joint display was naturally organized by theoretical construct, as the quantitative strand measured the relationship between the change in TTF due to the intervention's implementation and performance, or appropriate opioid ordering, and the qualitative strand explored the intervention's impact on the

TTF's subthemes of access, workflow, and data completeness. The joint display provided understanding about the link between the change in TTF and opioid ordering, which is PDMP use. The treatment group increased their PDMP use, which was related to the intervention's positive impact on access and workflow, and this use increase impacted their opioid ordering on average. The control group used workarounds like bookmarks and emails to locate the PDMP state website and did not see patient data entry or switching between screens as an issue; they, in turn, did not use the PDMP link in the EHR.

Table 7

Interrelation of the intervention's impact on opioid ordering

Quantitative Results			**Qualitative Results**		**Meta-Inferences**		
Construct = Performance			**Construct = TTF**		**Relationship between quantitative construct and qualitative themes**		**Construct = Use**
Group	**Measure**	**Coeff (P-value)**	**Theme**	**SubTheme**	**Construct**		**PDMP Use via Link**
T	Immediate Impact on Average MME Ordered per Patient per Day	15.9613 (0.0677)*	Registration/ Access Process	Easier to Access with Link	TTF - Access Improvements	Using the link made accessing the PDMP easier, which was associated with increased PDMP use with the link	Increased
				Registration/Access Issues with Website	TTF - Access Issues	There were issues with registering and accessing the website which deterred PDMP use prior to implementation	Increased
			Ease of Use	Difficulty Locating and Navigating Website	TTF - Access Issues & Ease of Use/Workflow Issues	There were issues with locating and navigating the website which was associated with little or no PDMP use prior to implementation	Increased

				More User Friendly with Link	TTF - Ease of Use/Work flow Improvements	The link made using the PDMP more user friendly, which was associated with increased PDMP use with the link	Increased
				Less User Friendly with Website	TTF - Ease of Use/Work flow Issues	The website was less user friendly, which was associated with increased PDMP use with the link	Increased
				Easier to Locate with Link	TTF - Access Improvements	The link made using the PDMP easier to locate, which was associated with increased PDMP use with the link	Increased
			Patient Data	Additional Steps for Out of State Patients with Website	TTF - Data Completeness Issues	There were additional steps for out of state patients with the website which deterred PDMP use prior to the link being implemented	Increased
				Inaccurate/ Missing Patient Data with Website & Link	TTF - Data Completeness Issues	There was inaccurate and missing data reported with the website and link which deterred PMDP use prior to the link being implemented	No Change
				No Patient Data Entry/Look up with Link	TTF - Ease of Use/Work flow Improvements	The link did not require patient data entry or look up, which was associated with increased PDMP use with the link	Increased
				Patient Matching Issues with Website	TTF - Data Completeness Issues	There were issues with matching patients between the EHR and website which was associated	Increased

						with deterred PDMP use prior to implementation	
			Time Commitment	Delay in Displaying Data with Link	TTF - Ease of Use/Work flow Issues	There was a delay in displaying data with the link which was associated with deterred PDMP use prior to implementation	Decreased
				Time Consuming Process with Website	TTF - Access Issues & Ease of Use/Work flow Issues	Using the website was a time consuming process which deterred PDMP use prior to implementation of the link	Increased
				Faster Access with Link	Task-Technology Fit - Access Improvements	The link made accessing the PDMP faster, which was associated with increased PDMP use with the link	Increased
				Faster Patient Lookup with Link	Task-Technology Fit - Ease of Use/Work flow Improvements	The link made identifying the correct patient faster which was associated with increased PDMP use with the link	Increased
C	Immediate Impact on Average MME Ordered per Patient	-6.1093 (0.3205)	Ease of Use	Workaround to Locate Website	TTF - Access Elements (Neutral)	Workarounds were used to locate the website which decreased some benefits of using the link	Decreased
				No Ease of Use/Workflow Issues with Website	TTF - Ease of Use/Work flow Elements (Neutral)	Switching between screens to enter patient data into the website was not considered an issue which decreased some benefits of using the link	Decreased

			Time Commitment	Delay in Displaying Data with Link	TTF - Ease of Use/Work flow Issues	There was a delay in displaying data with the link which was associated with increased PDMP use with the link	Decreased

Summary

This qualitative portion of the study was performed to investigate the impact of implementing PDMP EHR-Integration via access integration on opioid ordering in an inpatient setting. Two protocols were developed for the control and treatment groups with the intent to answer this question around the adapted TTF conceptual framework. A variety of participants were purposefully selected from the quantitative clinical data then recruited via email. Fourteen providers were interviewed with 7 in the control group and 7 in the treatment group. The audio recordings were transcribed, validated, and thematically coded with NVivo 12, a qualitative software, using the TTF constructs as *a priori codes* while also adding new themes as appropriate. This was an iterative, constant comparative process. Six themes and 20 subthemes were identified from this coding. Themes include Registration/Access Process, Ease of Use, Patient Data, Time Commitment, Validation, and Ordering/Prescribing. Additional findings include that most providers felt the intervention did not impact data completeness, that most providers felt or speculated that the immediate increase in opioids prescribed in the post-period was due to the providers feeling more comfortable or confident to prescribe opioids, feeling it was more appropriate to order opioids, having a greater awareness of existing opioid tolerance, and/or having less fear of over ordering or prescribing opioids. The results of the two strands were integrated in a joint display to form meta-inferences.

CHAPTER 5

DISCUSSION

Introduction

A mixed methods sequential Quan → Qual study was performed to explore the impact of a PDMP EHR-integration implementation at UAB Hospital on opioid ordering and providers' attitudes toward using the PDMP before and after the implementation. The quantitative strand explored the impact on opioid ordering, a more objective approach, while the qualitative strand focused providers' attitudes towards the PDMP and intervention's implementation, a more subjective approach. Clinical provider and patient opioid ordering data were analyzed in the qualitative strand; an interrupted time series analysis was performed. Semi-structured, one-on-one provider interviews were conducted and thematically coded in the qualitative strand. Each strand's results were mixed to synthesize overall findings, also known as meta-inferences; a joint display was used as a tool to assist this synthesis.

Summary of Major Findings

A conceptual framework adapted from TTF theory guided the study which contained the 5 main constructs: task characteristics, technology characteristics, TTF fit, utilization, and performance impacts. Specifically, the study set out to find if the intervention improved the TTF fit between the PDMP's technological characteristics, and the tasks users must perform to check patients' controlled substances prescribing history in the PDMP and if the change in TTF impacted providers' opioid ordering and attitudes

toward the PDMP.

The quantitative strand, performed using an interrupted time series OLS statistical analysis, showed a clinically significant increase of 15.933 average MMEs per patient per day trending toward statistical significance immediately following the implementation of the PDMP link in the EHR. These results helped inform the quantitative strand's interview protocol. The qualitative strand's thematic analysis revealed that most providers that used the link in the EHR saw an improvement in PDMP access and ease of use after the intervention was implemented but did not see a change in data completeness, which indicated an improved TTF due to the intervention. These results further supported the previous literature that PDMP EHR-integration is a facilitator to common challenges to the PDMP's success from an IS standpoint such as lack of time, access issues, and workflow issues (Martin, Modi, Feldman). The qualitative results also showed that the improved TTF led to an increase in PDMP use for many providers that were interviewed. Interestingly, some providers in the control group did not see the additional steps a user had to take to use the PDMP state website compared to using the intervention as challenges to their workflow and continued to use the state website because of this.

The connection between the providers' responses to the quantitative results, mentioned above in the Qualitative Strand's Results section, and the meta-inferences found in the joint display table is that providers in the treatment group used the PDMP more frequently or at all, for the first time, in the post-intervention period compared to the pre-intervention period due to the reasons listed in the meta-inferences column found in Table 5. For example, since providers in the treatment group no longer had the workflow process issues of having to switch between screens or having to enter patient

data in the PDMP, they used the PDMP more. And using the PDMP more made most of the providers more comfortable, confident, or have less fear to order opioids. In short, the access and workflow improvements (improved TTF) from the intervention led to the providers using the PDMP more frequently, which gave them more confidence to manage their patients' pain with opioids. Therefore, the dependent construct Performance Impacts, measured by appropriate opioid prescribing in this study, did improve with the intervention if appropriate opioid ordering considers properly managing patient pain.

Some providers in the control group did not use the intervention in the post-period due to them perceiving the extra steps required to use the PDMP State website as just part of the process, not as issues compared to the treatment group. These subthemes are listed in the meta-inferences' column of the joint display table for the control group. For example, most providers in the control group saw switching between screens or entering patient data into the PDMP to be just a part of the process of using the PDMP, not workflow issues compared to the treatment group, and, therefore, they did not use the link in the post-period because they did not perceive their current process to have any issues.

The qualitative results also revealed that the amount of opioids a provider intends to order rarely impacts the frequency at which a provider checks the PDMP; providers check the PDMP for any intention of ordering opioids and for validation purposes regardless of the opioid amount they intend to order.

Most of the providers in the treatment group reported no change in their opioid ordering pattern or prescribing post intervention, when in fact the quantitative results revealed a significant increase in average MME ordered per patient per day for the

treatment group. This divergence in the results indicates that some providers' perceptions of their opioid ordering after the intervention was immediately implemented did not reflect their actual change in opioid ordering.

The quantitative analysis revealed an unexpected finding that the average MME per patient per day decreased 0.1412 for every additional person admitted to the hospital on a given day during the study's time period.

Theoretical Contributions

TTF has been used to evaluate technological interventions. These evaluations of user performance or IS use can be used to measure the value an IT investment adds to an organization and/or help target TTF problem areas for improvement (Goodhue, 1995; Goodhue & Thompson, 1995). This study builds upon the TTF theory by showing that TTF theory can be used to measure the change in TTF due to an intervention's implementation along with that change's impact on performance.

It's important to note that the direct relationship between the TTF construct and the Performance Impact construct that is relayed in TTF theory and the adapted TTF conceptual framework for this study was not observed. Performance impacts, or appropriate opioid ordering, only improved after there was an increase in PDMP use via the integration link after the TTF improved with the link.

TTF theory implies that a higher TTF increases utilization, because the TTF is one determinant of the user's belief of IT usefulness (Goodhue & Thompson, 1995). This study showed that there is an element missing from this concept, because several providers in the control group indicated they did not use the intervention because they were not aware of its benefits, or positive impact on TTF. In other words, a user will not

increase a technology's utilization solely due to an improved TTF from an intervention implementation. An improved TTF must be coupled with an awareness campaign of the intervention's benefits to maximize its utilization.

Practical Contributions

The qualitative analysis revealed that the main issue with the PDMP state website is difficulty remembering one's username and password. A password manager may help with this, and the technical infrastructure and training could be given to providers on how to use a password manager along with its benefits.

Several providers in the control group did not consider having to find, log in, and switch between screens to be a hinderance to PDMP use. This may be due to them being accustomed to inefficient technology in health care. This thought is further supported by several providers suggesting that they need to be shown the benefits of the integration link to promote them using it.

Providers in both the control and treatment groups reported that they were not aware of the intervention at the time it was implemented, nor did they remember how they became aware of the intervention. And some who were aware of it did not use it, because they were not aware of its benefits. The OSC may find it beneficial to provide a summary of this study's results around the benefits of the PDMP EHR-integration link to its providers to promote awareness and use. Future efforts for similar interventions could also be made to promote awareness of the link and its benefits through department or unit meetings, which aligns with the provider feedback given in this study.

Policy makers may find this study's results counterintuitive to supporting PDMP EHR-integration as an additional tool to battle the opioid epidemic in the U.S. However,

policy intended to curb opioid prescribing to improve the opioid crisis has been shown to have negative impact on some patients' pain management. This study shows that policy makers should support PDMP EHR-integration in an inpatient setting, because it gives providers more confidence to order opioids when necessary to better manage their patients' pain.

Limitations

The results of this study need to be considered among the limitations. First, nurse practitioners were not included in the research sample. Including nurse practitioners, who also order controlled substances may result in different findings in terms of perspective and workflow. Few studies currently examine the controlled substance practices of nurse practitioners when using PDMP EHR-integration and this represents an important area of future research. Second, due to data limitations, direct access to the PDMP was not available. While this is not possible in AL, it may represent an area of future research for states that allow direct access to their data. Third, two covariates were examined to control for external factors. This likely did not capture all possible covariates and doing so may impact the results. For example, the UAB OSC may have taken steps during the study to curb opioid ordering in the hospital that was not accounted for with these two covariates. Fourth, the quantitative data sets were matched based on information given anecdotally by a provider in the hospital. While this matching hierarchy was suggested to be how most providers order opioids, there may have been cases where the matching was not accurate for every provider. Fifth, interview responses were not validated for intercoder reliability, which may bias the results. Lastly, since the intervention was implemented in 2019, and the interview responses were collected in 2022, our qualitative

results are subject to recall bias. This time discrepancy may have caused providers to not accurately remember what occurred, or they may have changed their perceptions or opinions since the quantitative strand's time frame.

Implications for Future Research

Future research should consider measuring the intervention's impact on outpatient opioid prescribing where data is available. There is potential for the statistical results to differ due to the higher level of diagnosis acuity and, thus, pain of inpatients versus outpatients. Other integration types may lead to different results also and should be investigated.

The quantitative analysis revealed the average MME per patient per day decreased 0.1412 for every additional person admitted to the hospital on a given day. Hospital admissions can be considered a proxy for clinician workload. There is some evidence in the literature that clinician workload can be associated with opioid prescribing including causing opioid prescribing errors and issues with safely prescribing chronic opioid therapy (Carroll, Colasanti, Lira, Del Rio, & Samet, 2019; Heneka, Shaw, Rowett, Lapkin, & Phillips, 2018). But there is a need for future research around the relationship of providers' workload and their ability to appropriately order opioids for pain management.

Conclusion

This study sought to understand the impact PDMP EHR-integration had on opioid ordering and providers' attitudes in a hospital in AL. A mixed methods Quant → QUAL design was used with an adapted form of the TTF framework guiding the study. And interrupted time series, OLS analysis was used in the quantitative strand, and a thematic

analysis was used in the qualitative strand. There was an immediate clinically significant, trending toward stastical significance, increase of 15.933 MMEs per patient per day (p-value = 0.0667) in opioid ordering in the treatment group following the intervention's implementation, while all other immediate and over time statistical measures were found to not be statistically significant in the control and treatment groups. These results informed a portion of the interview protocol in the qualitative strand where 14 providers were interviewed to better understand the quantitative findings, and their attitude toward the intervention. Six themes and 20 subthemes emerged around the conceptual framework's dimensions of access, use, workflow, and data completeness. The themes identified were Registration/Access Process, Ease of Use, Patient Data, Time Commitment, Validation, Ordering/Prescribing. Mixing the two study strands led to 24 meta-inferences. Providers chose to use the PDMP to either validate patients' existing medications or when they intended to order opioids for the patient. Most providers in the treatment group felt the integration improved the PDMP TTF due to improved access, ease of use, and workflow but not due to a change in data completeness. and the implementation of the link in the EHR increased their frequency of PDMP use because of these improvements. Many providers in the control group felt that the access, ease of use, and workflow components of using the state PDMP website without the integration link were not issues and did not see a benefit of trying to use the intervention. Most providers in both groups experienced or speculated that opioid ordering decreased immediately after the intervention due to providers being more comfortable, confident, or feeling more appropriate to prescribe opioids due to using the PDMP more frequently or at all after the link was implemented. This study's results can be used to improve uptake of the

intervention at the UAB inpatient health system and also at other organizations that plan to implement or have implemented the PDMP link in their EHR using access integration.

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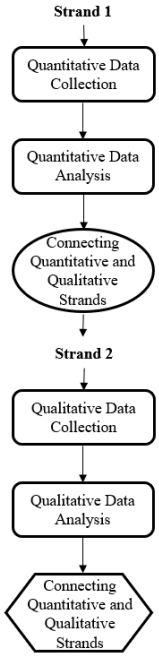
APPENDICES

APPENDIX A

SEQUENTIAL MIXED METHODS DESIGN LOGIC



	Procedure	Product
Strand 1		
Quantitative Data Collection	• Clinical Data (N = 365) • 12 months of clinical data: 6 months pre-implementation & 6 months post-implementation • Provider demographics: Department & their patients' race, gender, residential state • Intervention use → control and treatment groups	• Performance = opioid ordering = average MME prescribed per patient per day • Intervention's statistical immediate and over time impact on opioid ordering • Control and treatment groups
Quantitative Data Analysis	• Interrupted time series analysis, ordinary least squares (OLS) • SAS Enterprise Guide 8.1 statistical analysis software	
Connecting Quantitative and Qualitative Strands	• Protocol development	• Treatment group protocol: 16 questions • Control group protocol: 18 questions
Strand 2		
Qualitative Data Collection	• Interviews (N = 14): control group (N = 7), treatment group (N = 7)	• 14 audio recordings • 14 interview transcripts
Qualitative Data Analysis	• Thematic coding • Nvivo 12 qualitative analysis software	• 12 themes • 52 subthemes • Additional practice implications
Connecting Quantitative and Qualitative Strands	• Mixing of the quantitative and qualitative results • Joint display	• Meta inferences: synthesis of findings

APPENDIX B

PROVIDER RECURITMENT LETTER

Dear Dr. _____,

You are invited to be interviewed for a study to understand the impact of Prescription Drug Monitoring (PDMP) EHR-integration on inpatient opioid ordering. A $50 e-gift certificate for Amazon will be emailed to each participant completing the interview. The interview will take place virtually, last approximately 30-45 minutes, and, with your consent, be audio-recorded. The audio recordings will be used for transcription and analysis purposes, stored in a secure location, and only accessed by the research team. All data will be reported in aggregate, and confidentiality will be maintained. The results of the research will be published for scientific purposes; however, no practitioner's name will be identified. Participation in this research is voluntary, and you can choose to withdrawal at any time. If you choose to do this, none of the data collected from you will be used for the research.

Please contact me if you have any questions about the interview or study. If you have questions about your rights as a participant, or concerns or complaints about the research, you may contact the UAB office of the IRB (OIRB) at 205-934-3789 or irb@uab.edu. Regular office hours for the OIRB are 8 a.m. to 5 p.m., Monday through Friday.

If you would like to participate, please let me know which dates and times below

are convenient for you, and I will send you a Zoom invite along with the list of interview questions for you to review ahead of time. If these dates and times do not work for you, please send me your availability, and I will do my best to work around it.

APPENDIX C

INTERVIEW PROTOCOLS

Control Group:

Dr. _____, thank you for meeting with me today.

*Will you please enter a non-uabmc email address in the chat where I can send your e-gift certificate?

Introduction:

(Participant name), thank you for taking the time to meet with me today. I am conducting a study to explore your perceptions of or experiences with the Prescription Drug Monitoring Program (PDMP) and the PDMP EHR-Integration implementation. PDMP EHR-integration in the UAB Health System refers to being able to access the state PDMP directly after logging into the EHR, without leaving UAB's EHR and logging into the state PDMP website; this functionality was implemented at the UAB Health System on August 1st, 2019.

Everything we say during today's interview will be audio-recorded unless you request otherwise, and I will also be taking notes. If at any time you would like for me to stop the recording, please ask me to do so. The audio recordings will be transcribed in their entirety to ensure accuracy for analysis. The time period being considered for this study is 6 months before and after the PDMP EHR-integration was implemented on August 1st, 2019, which is February 1st, 2019, to January 31st, 2020. All data will be

reported anonymously and will be kept completely confidential. This time frame is being used in today's interview to help capture the PDMP EHR-integration's immediate and sustaining impact.

Interview Questions

1. To ensure accuracy during analysis and in case I have questions, can you please state your name and your role at UAB during the period from February 1, 2019 to January 31, 2020?
2. During that time period, February 1, 2019 to January 31, 2020, did you treat primarily inpatients, outpatients, or both?
3. Please describe some of the reasons why you checked the PDMP for inpatients, if you did check it.
4. Please describe some of the reasons why you did not check the PDMP for inpatients, if you did not check it.
5. Before the PDMP EHR-integration was implemented, so the period prior to August 2019, practitioners had to access the PDMP from the state website. Thinking about your experiences and your workflow; can you please tell me about the process of accessing the PDMP from the state website.
6. How confident were you that the PDMP data were complete for both in state and out of state patients prior to August 2019?
7. Are there any other technological characteristics of using the PDMP that you would like to tell me about?
8. How often and at what points did you check the PDMP for inpatients from February to August of 2019, if at all? Tell me about your thoughts of the PDMP

being made available within the EHR on August 1st, 2019.

9. Is there anything that could have been done better that would have led you to use the PDMP link within the EHR from August 1st, 2019 to Jan 31st, 2020?
10. In your opinion, what other factors may have impacted the utilization of the PDMP, if at all? Analysis of the average MME ordered per inpatient per day suggests that average medication orders per inpatient increased after the PDMP EHR-integration was implemented. What are your thoughts on this finding?
11. In your opinion, what other factors may have impacted the amount of opioids you ordered per inpatient, if at all?
12. Is there anything else that you can tell me about the PDMP EHR-integration that we did not already cover that you think is important?
13. May I have your permission to reach back out to you to follow up on any of the points that you made today, if necessary?
14. Is there anyone that you can think of that would be good for me to interview?

Note: Please be sure to provide a non-uabmc.edu email address in the chat during the interview to avoid your e-gift card being filed directly to junk mail.

Treatment Group:

Dr. _____, thank you for meeting with me today.

*Will you please enter a non-uabmc email address in the chat where I can send your e-gift certificate?

Introduction:

(Participant name), thank you for taking the time to meet with me today. I am conducting a study to explore your perceptions of or experiences with the Prescription Drug Monitoring Program (PDMP) and the PDMP EHR-Integration implementation. PDMP EHR-integration in the UAB Health System refers to being able to access the state PDMP directly after logging into the EHR, without leaving UAB's EHR and then logging into the state PDMP website; this functionality was implemented at the UAB Health System on August 1st, 2019.

Everything we say during today's interview will be audio-recorded unless you request otherwise, and I will also be taking notes. If at any time you would like for me to stop the recording, please ask me to do so. The audio recordings will be transcribed in their entirety to ensure accuracy for analysis. The time period being considered for this study is 6 months before and after the PDMP EHR-integration was implemented on August 1st, 2019, which is February 1st, 2019, to January 31st, 2020. All data will be reported anonymously, and your responses will be completely confidential. This time frame is being used in today's interview to help capture the PDMP EHR-integration's immediate and sustaining impact.

Interview Questions

1. To ensure accuracy during analysis and in case I have questions, can you please state your name and your role at UAB during the period from February 1, 2019 to January 31, 2020?
2. During that time period, February 1, 2019 to January 31, 2020, did you treat primarily inpatients, outpatients, or both?
3. Please describe some of the reasons why you checked the PDMP for inpatients.
4. Before the PDMP EHR-integration was implemented, so the period prior to August 2019, practitioners had to leave UAB's EHR and access the PDMP from the state website. Thinking about your experiences and your workflow, can you please tell me about the process of accessing the PDMP from the state website.
5. How confident were you that the PDMP data were complete for both in state and out of state patients prior to August 2019?
6. Now turning to the period of time after PDMP EHR-integration, so the period of time after August 2019, how did your experience with accessing the PDMP change after the PDMP was made available within the EHR in August of 2019?
7. How often and at what points did you check the PDMP for inpatients from February to August of 2019, if at all?
8. In your opinion, what other factors may have impacted the utilization of the PDMP, if at all?
9. How did implementing the PDMP EHR-integration in August 2019 impact the amount of opioids you ordered per inpatient, if at all?
10. Analysis of the average MME ordered per inpatient per day suggests that average medication orders per inpatient increased after the PDMP EHR-integration was

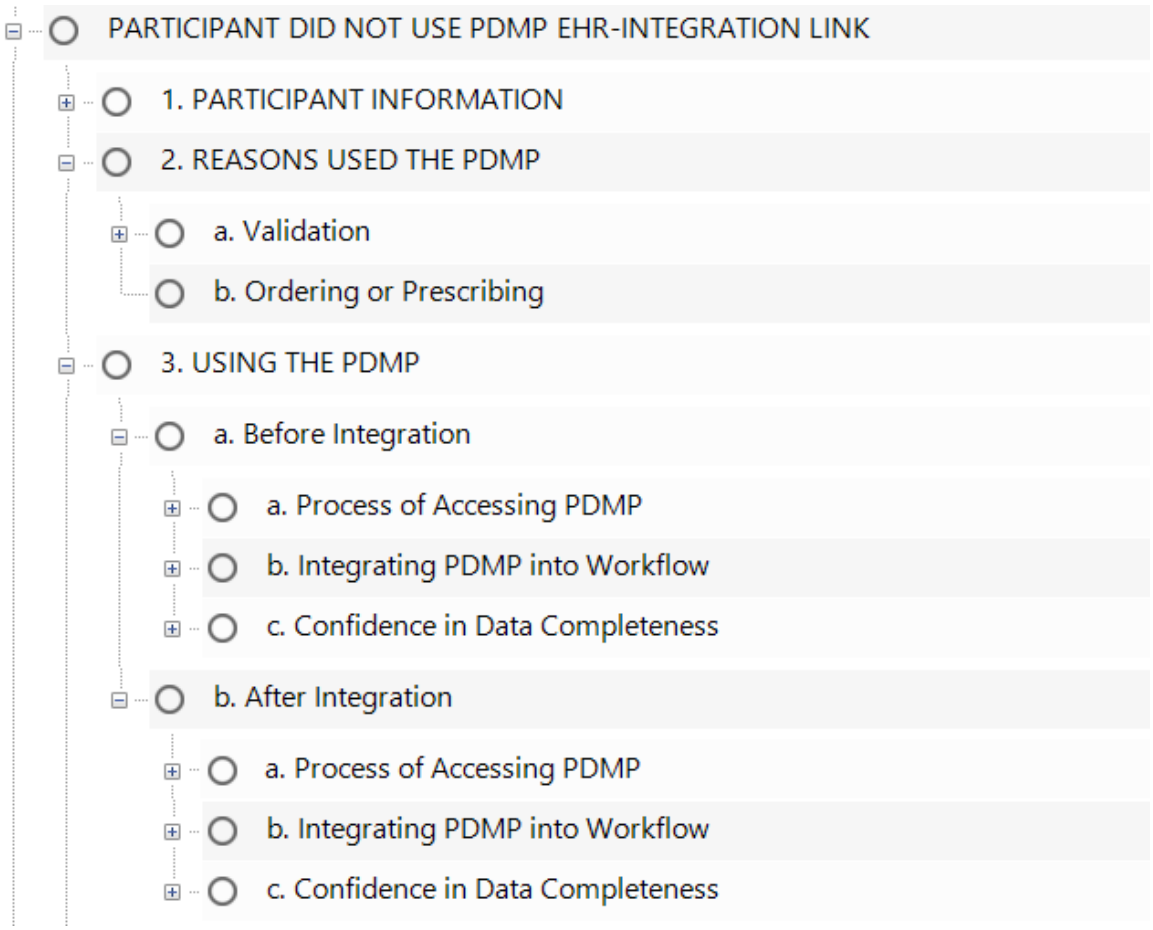
implemented. What are your thoughts on this finding?

11. In your opinion, what other factors may have impacted the amount of opioids you ordered per inpatient, if at all?
12. Is there anything else that you can tell me about the PDMP EHR-integration that we did not already cover that you think is important?
13. May I have your permission to reach back out to you to follow up on any of the points that you made today, if necessary?
14. Is there anyone that you can think of that would be good for me to interview?

Note: Please be sure to provide a non-uabmc.edu email address in the chat during the interview to avoid your e-gift card being filed directly to junk mail.

APPENDIX D

NVIVO CODING STRUCTURE


PARTICIPANT DID NOT USE PDMP EHR-INTEGRATION LINK
1. PARTICIPANT INFORMATION
2. REASONS USED THE PDMP
a. Validation
b. Ordering or Prescribing
3. USING THE PDMP
a. Before Integration
a. Process of Accessing PDMP
b. Integrating PDMP into Workflow
c. Confidence in Data Completeness
b. After Integration
a. Process of Accessing PDMP
b. Integrating PDMP into Workflow
c. Confidence in Data Completeness

- 4. WHEN USED THE PDMP
  - a. Before Integration
    - a. How Often Used the PDMP
    - b. At What Points Checked the PDMP
    - c. Checking PDMP for Inpatients vs. Outpatients
    - d. Other Factors that Impacted PDMP Utilization
  - b. After Integration
    - a. How Often Used the PDMP
    - b. At What Points Checked the PDMP
    - c. Checking PDMP for Inpatients vs. Outpatients
    - d. Other Factors that Impacted PDMP Utilization
- 5. INTEGRATION'S IMPACT ON MEDICATION ORDERS
  - a. Integration's Impact on Opioid Ordered Amount
  - b. Thoughts on Avg MME Ordered Per Day Per Patient Increase
  - c. Other Factors That Impacted Amount of Opioids Ordered
  - d. How Integration Impacted Opioid Ordering or Prescribing
- 6. ADDITIONAL INFORMATION
  - a. Anything Else About PDMP EHR-Integration

- PARTICIPANT DID USE PDMP EHR-INTEGRATION LINK (2)
  - 1. PARTICIPANT INFORMATION
  - 2. REASONS USED THE PDMP
    - a. Validation
    - b. Ordering or Prescribing
  - 3. USING THE PDMP
    - a. Before Integration
      - a. Process of Accessing PDMP
      - b. Integrating PDMP into Workflow
      - c. Confidence in Data Completeness
    - b. After Integration
      - a. Process of Accessing PDMP
      - b. Integrating PDMP into Workflow
      - c. Confidence in Data Completeness
  - 4. WHEN USED THE PDMP
    - a. Before Integration
      - a. How Often Used the PDMP
      - b. At What Points Checked the PDMP
      - c. Checking PDMP for Inpatients vs. Outpatients
      - d. Other Factors that Impacted PDMP Utilization

- b. After Integration
  - a. Change in PDMP Use
  - b. At What Points Checked the PDMP
  - c. Checking PDMP for Inpatients vs. Outpatients
  - d. Other Factors that Impacted PDMP Utilization
- 5. INTEGRATION'S IMPACT ON MEDICATION ORDERS
  - a. Integration's Impact on Opioid Ordered Amount
  - b. Thoughts on Avg MME Ordered Per Day Per Patient Increase
  - c. Other Factors That Impacted Amount of Opioids Ordered
- 6. ADDITIONAL INFORMATION
  - a. Anything Else About PDMP EHR-Integration

APPENDIX E

INSTITUTIONAL REVIEW BOARD APPROVAL

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
Office of the Institutional Review Board for Human Use

470 Administration Building
701 20th Street South
Birmingham, AL 35294-0104
205.934.3789 | Fax 205.934.1301 |
irb@uab.edu

APPROVAL LETTER

TO: Martin, Heather D

FROM: University of Alabama at Birmingham Institutional Review Board
Federalwide Assurance # FWA00005960
IORG Registration # IRB00000196 (IRB 01)
IORG Registration # IRB00000726 (IRB 02)
IORG Registration # IRB00012550 (IRB 03)

DATE: 20-Dec-2021

RE: IRB-300008426
IRB-300008426-002
A MIXED METHODS APPROACH TO ASSESS THE IMPACT OF PRESCRIPTION DRUG MONITORING PROGRAM EHR-INTEGRATION ON INPATIENT OPIOID PRESCRIBING

The IRB reviewed and approved the Initial Application submitted on 14-Dec-2021 for the above referenced project. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services.

Type of Review:	Expedited
Expedited Categories:	5, 7
Determination:	Approved
Approval Date:	14-Dec-2021
Approval Period:	Expedited Status Update (ESU)
Expiration Date:	13-Dec-2024

Although annual continuing review is not required for this project, the principal investigator is still responsible for (1) obtaining IRB approval for any modifications before implementing those changes except when necessary to eliminate apparent immediate hazards to the subject, and (2) submitting reportable problems to the IRB. Please see the IRB Guidebook for more information on these topics.

Please note the following:

Prior to receiving identifiable prescriber information, and before commencing with any prescriber recruitment or interviews, please submit an amendment to this project to include:

o Interview questions / guide

o Recruitment email/letter language

o Informed Consent Document or Information Sheet

o Update the IRB ePortfolio to answer the questions not currently addressed in regards to recruitment, consent, and interviews

Documents Included in Review:

- IRB EPORTFOLIO
- IRB PERSONNEL EFORM

To access stamped consent/assent forms (full and expedited protocols only) and/or other approved documents:
1. Open your protocol in IRAP.
2. On the Submissions page, open the submission corresponding to this approval letter. NOTE: The Determination for the submission will be "Approved."
3. In the list of documents, select and download the desired approved documents. The stamped consent/assent form(s) will be listed with a category of Consent/Assent Document (CF, AF, Info Sheet, Phone Script, etc.)

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
Office of the Institutional Review Board for Human Use

470 Administration Building
701 20th Street South
Birmingham, AL 35294-0104
205.934.3789 | Fax 205.934.1301 |
irb@uab.edu

APPROVAL LETTER

TO: Martin, Heather D

FROM: University of Alabama at Birmingham Institutional Review Board
Federalwide Assurance # FWA00005960
IORG Registration # IRB00000196 (IRB 01)
IORG Registration # IRB00000726 (IRB 02)
IORG Registration # IRB00012550 (IRB 03)

DATE: 23-Jul-2022

RE: IRB-300008426
IRB-300008426-003
A MIXED METHODS APPROACH TO ASSESS THE IMPACT OF PRESCRIPTION DRUG MONITORING PROGRAM EHR-INTEGRATION ON INPATIENT OPIOID PRESCRIBING

The IRB reviewed and approved the Revision/Amendment submitted on 06-Jul-2022 for the above referenced project. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services.

Type of Review:	Expedited
Expedited Categories:	5, 7
Determination:	Approved
Approval Date:	23-Jul-2022
Expiration Date:	22-Jul-2025

Although annual continuing review is not required for this project, the principal investigator is still responsible for (1) obtaining IRB approval for any modifications before implementing those changes except when necessary to eliminate apparent immediate hazards to the subject, and (2) submitting reportable problems to the IRB. Please see the IRB Guidebook for more information on these topics.

Documents Included in Review:

- IRB EPORTFOLIO

To access stamped consent/assent forms (full and expedited protocols only) and/or other approved documents:
1. Open your protocol in IRAP.
2. On the Submissions page, open the submission corresponding to this approval letter. NOTE: The Determination for the submission will be "Approved."
3. In the list of documents, select and download the desired approved documents. The stamped consent/assent form(s) will be listed with a category of Consent/Assent Document (CF, AF, Info Sheet, Phone Script, etc.)

APPENDIX F

OPIOID STEWARDSHIP COUNCIL APPROVAL

LL Leal, Laura M. <lleal@uabmc.edu>
To Martin, Heather Duran

Reply

You replied to this message on 7/23/2022 10:01 PM.

Hi Heather!!

These look great. I have sent to 5 leadership members and 3 of us have approved/signed-off. I am awaiting the 2 providers and hope to have their review and approval no later then end of day Monday 7.11. That ok as far as timeline for you?

Great job!

-Laura

From: Martin, Heather Duran <martinhd@uab.edu>
Sent: Tuesday, July 5, 2022 12:39 PM
To: Leal, Laura M. <lleal@uabmc.edu>
Subject: Documents to be Reviewed by OSC for PDMP EHR-integration study

Hi Laura,

Will you please ask the Opioid Stewardship Committee to review these documents as they requested in the letter of support they gave for the study: A MIXED METHODS APPROACH TO ASSESS THE IMPACT OF PRESCRIPTION DRUG MONITORING PROGRAM EHR-INTEGRATION ON INPATIENT OPIOID PRESCRIBING?

Will you please send me an email confirmation once they have reviewed them?