IMPLEMENTING SYSTEMS ENGINEERING TECHNIQUES INTO HEALTH CARE: AN INVESTIGATION INTO USING PROBLEM BASED LEARNING IN MEDICAL SCHOOLS TO TEACH SYSTEMS ENGINEERING

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by

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled:

IMPLEMENTING SYSTEMS ENGINEERING TECHNIQUES INTO HEALTH CARE: AN INVESTIGATION INTO USING PROBLEM BASED LEARNING IN MEDICAL SCHOOLS TO TEACH SYSTEMS ENGINEERING

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ABSTRACT

Health care delivery in the United States needs improvement. Each year, between 44,000 and 98,000 people die as a result of medical errors and the United States is outranked by ¾ of developed countries in life expectancy and infant mortality. In a recent report, The National Academy of Engineering and the Institute of Medicine and Dr. Bin Wu's paper entitled "Healthcare Systems Engineering – An Interdisciplinary Approach to Achieving Continuous Improvement" recommend that implementing systems engineering and systems engineering tools should be used in health care to improve the industry. Systems thinking is a way to gain insight into an organization by looking at the interactions of the various processes within the whole, and systems tools are the means by which the organizations are constructed and analyzed. These tools have improved other complex industries, such as manufacturing.

A unique way to implement systems thinking in health care is to educate future caregivers in systems thinking so that they can recognize problems and make improvements from within. This method reduces the need for change management

within established organizations and emphasizes the importance using systems tools early in the career of a caregiver.

The implementation of systems skills into medical school curriculum was tested at the University of Missouri-Columbia School of Medicine. The medical school uses Problem Based Learning (PBL) to teach its students. This approach is different from traditional medical school instruction because it does not rely as heavily on lectures, instead using small groups of student to solve clinical problems. This setting is ideal for introducing systems design because of its flexibility in being able to simulate the complexities of health care. The students were given a case that was modified in such a way that the students would hopefully create objectives about systems engineering and health care. The objectives were compared to those of a previous year for the same case. If the new objectives titles included systems engineering terms, than PBL could be seen as an effective way to teach systems engineering to first year medical students. The lack of a resource for medical students to research health care systems engineering prompted the creation of a handbook entitled "Handbook of Health Care Systems Engineering for Medical Students."

There was not a major difference in the objectives with the addition to the case. The students were not familiar with the terms and did not place much importance on them. However, the addition did make a positive impact on the students and repeated exposure in future cases will hopefully result in the students leaning more about health care systems engineering. The research also identified key ideas that medical students should learn about systems concepts and a handbook for the students was created.

Chapter I: Introduction

1.1 Motivation

The cost of health care in the United States is rising every year while the quality of care is not improving. Improving the delivery of health care can decrease costs, reduce insurance premiums, and improve the quality of care. The improvements can lead to the improvement of millions of lives and can save billions of dollars (Wu et. al, 2006).

The theories of health care systems formulated by Dr. Bin Wu in his paper entitled "Healthcare Systems Engineering – An Interdisciplinary Approach to Achieving Continuous Improvement" and the recommendations given in the report entitled "Building a Better Delivery System: A New Engineering/Health Care Partnership" are the major influences that lead to this thesis. There are many ways to improve health care, but the above sources identify systems engineering as a critical element that needs to be included in any improvement initiative.

Health care is at a crossroads when considering its next steps taking into account the increase in medical information, increased customer demand, and the ever-increasing cost (Wu et. al, 2006). The soaring costs of care are directly affecting the competitiveness of the United States. The United States is outranked by ¾ of developed nations in life expectancy and infant mortality, 37th in health care performance, and 1/3 of the costs are administrative (Wu et. al, 2006). Something needs to change or the costs will continue to rise and the quality of care will continue to lag behind the rest of the developed world.

Wu proposes that systems engineering tools be used to improve the industry much like the same tools helped improve manufacturing. A need for understanding the underlying functions in a health care delivery system is vital for its survival, and systems engineering is a way to do this. Traditional methods for improvement focuses on isolated segments and were rarely viewed as part of a system of integrated components (Wu et. al, 2006). A more holistic approach will lead to more drastic improvement. Some components of this holistic approach are systems perspective, structural problem solving, and a closed loop of continuous system improvement (Wu et. al, 2006). These must be used to break down the system into three parts: physical items (tools and facilities), human and organizational items, and information and control items. Identifying these items is not enough, finding interactions between these three areas is vital in order to understand and improve the system. The analysis includes the function of a process, its structure, and the decisions surrounding the process (Wu et. al, 2006).

In order to analyze and improve a system, several tools have been developed. Some of these tools are Data Flow Diagrams, Entity Relationship Diagrams, function/data matrix, organizational/operation matrix, operational/data entry matrix, site/function matrix (Wu et. al, 2006).

Given the importance of improving health care and the need for systems engineering concepts in the field, future health care professionals must understand systems concepts and improvement tools. Dr. Wu focused on how engineers can understand and improve health care, but those in health care need to know how health care can use engineering. There are several ways to do this. Health professionals can receive on the job training, classes and seminars can be offered, etc. A unique approach is to teach medical students early in medical school. The University of Missouri – Columbia teaches medical students in a way that is flexible and effective: Problem Based Learning (PBL). This thesis will test if teaching systems engineering concepts is possible through a medical curriculum that utilizes PBL.

1.2 Problem Statement

Health care in the United States is in a crisis: the cost of care is escalating; the rate of spending is increasing at 7.2% annually (Wu et. al, 2006). There are between 44,000 and 98,000 deaths each year due to medical errors. This is from a country that is a leader in developing medical technologies, techniques, and practitioners. These highly developed resources are not being utilized to their full potential. In fact, the way in which they are implemented is often detrimental to the wellbeing of a patient.

According to a report written by the National Academy of Engineering and the Institute of Medicine, introducing systems engineering tools and systems thinking to health care is essential for the success of the medical industry. Some of these tools include Systems Design Tools, Modeling and Simulation, Enterprise Management Tools, Financial engineering and Risk Analysis Tools, and Knowledge Discovery in Databases (Reid, et. al, 2005).

Improving health care in the United States is a difficult task. The complexity, size, and importance of the industry must all be taken into account when attempting any improvement. In order to make the most effective, long-term impact, the next generation of practitioners should be involved in the necessary changes. They should be introduced to the above recommended tools as early as possible in their medical education in order for the students to assign importance to the skills and for the knowledge to be a foundation and a framework for their future careers.

1.3 Research Aim and Objectives

The research will provide a method of implementing systems tools and systems thinking into health care in the United States in order to improve safety and quality of care. The focus will be on including systems engineering content in first year medical school education through Problem Based Learning. This project examines whether inserting systems engineering concepts into medical education will change what the students learn in a PBL curriculum. In addition, this research will develop a handbook that can be used by the medical students to learn these concepts.

Dr. Bin Wu has outlined a framework for systems engineering and continuous systems improvement for health care from an engineering perspective. The goal of introducing this knowledge to medical students is to make them aware of their role in being able to use these tools and to be able to work with those who wish to improve health care.

1.4 Research Approach

Dr. Karen Cox, a Manager in the Office of Clinical Outcomes at University Hospital at the University of Missouri-Columbia, was consulted to learn common problems in the health care industry. All hospitals compile reports documenting common problems in the hospital. MU Health Care's Patient Safety Net provides an electronic way for patients, physicians, and nurses to report complaints or safety concerns. Reports are evaluated to determine which improvements might mitigate future incidents.

Dr. Michael Hosokawa has also been assisting in this project. He is the Associate Dean of Curriculum at the University of Missouri-Columbia School of Medicine and is a Professor of Family and Community Medicine. He is an expert in the developing PBL for medical education. He helped to bring PBL to the University of Missouri and continues to find ways to improve its effectiveness.

With the consulting parties, one PBL case will be analyzed to focus on what systems engineering material is appropriate to the altered case and how to best integrate systems engineering without sacrificing the other lessons the students need to learn. The students will receive the PBLs as usual and the effectiveness of conveying the systems engineering concepts will be evaluated.

PBL is a very flexible format for teaching, but the challenge will be in implementing the content about systems tools in the cases that the students are presented. Each case is modeled after an actual patient, so the changes will have to fit in seamlessly. The other elements in the case will have to be kept intact so that the other lessons the students have to learn are not harmed.

Each case lasts a week and the students have to complete learning "objectives" related to the case two times during the week. The students are given objectives from the tutor for the first semester, and then midway through the second semester, the students are expected to create their own based on the content of the case they are given. The students are expected to perform activities consistent with completing the objectives. Generally, each member of the PBL group agrees to complete an objective and presents the findings to the rest of the PBL group members. Self directed learning using PBL cases with learning objectives serves as the main mechanism of learning in the first two years of the four-year program. Given this context, measurement of the effectiveness of systems engineering concepts into the PBL curriculum would be evaluated from the student activities surrounding PBL objectives.

In summary, a case given to the PBL groups can include an error such as a treatment diagnosis or medication error. With a medical error in the PBL case, the students may create objective that deals with error investigations and investigations of systems analysis. This would imply that the students have some understanding of systems concepts and would build on them in the course of the developed objectives.

Alternatively, in the early PBL cases where objectives are given to the students, faculty generated objectives including systems engineering concepts could be articulated. The evaluation will consist of a comparison the student generated objectives between classes before and after integrating systems engineering into the PBL case.

The students could be directly asked how to improve certain situations such as a parent not being sure if their child has received all of the proper vaccinations. A documentation system could prevent these problems and the students could be asked to look into what is involved in the setup of such an initiative would entail. A similar problem would be, in a PBL case, to highlight a lack of communication between two health care organizations like a hospital and nursing home regarding the fact that the patient does not want any heroic measures taken. The students would see this as a problem and would propose a solution that would have to address the complexities of the problem. Further refinement of the problem may lead to the best route to take in implementing systems engineering concepts in health care.

As part of completion of a PBL case, students turn-in topic summaries (topics for objectives) for each case. These topic summaries from the previous year's PBL will be compared to the topic summaries from the case that was modified to see if the changes in the guiding questions stimulated the students to create systems engineering based topics.

The effect of altering the PBL case will be measured to detect differences in ability to effectively integrate systems thinking and systems engineering concepts into first year medical students. The need for improving health care is evident in the reported error rates, increasing costs and level of waste. Systems engineering concepts are identified as a needed addition to the health care field in order for sustained improvement. In order to implement systems engineering concepts, key players in the health care system need to collaborate in order to have an understanding of these concepts so that they can make improvements on their own and successfully work with others using these concepts to improve health care.

In 2001, MU Health Care developed an electronic error, close call, complaint, compliment, and suggestion program. The administration of the database of this system, the MU Patient Safety Net (PSN), is through the Office of Clinical Effectiveness. Dr. Karen Cox the manager of Quality Improvement and Patient Safety in the office of Clinical Effectiveness reported that, since the PSN was implemented in 2002, the average reporting rate has been 14 reports per day. Additionally, from her improvement work day to day and from studying groups of clinicians, she has observed multiple system and work design flaws that occur every day and may or may not be reported in the PSN. Common examples include:

- Assessing, reporting, and responding to patient condition changes
- Delays or confusion surrounding new medication orders
- Mix-ups of a procedure, test, and treatments
- Communication of treatment plans and priorities during patient handoffs

These sorts of examples confirm the recommendations from the report created by the National Academy of Engineering and Institute of Medicine stating that systems engineering would help with many of the problems in health care. It is clear that systems engineering concepts and tools can improve communications and process, thus alleviating preventable problems in health care.

1.5 Summary of Original Contribution

This study provides one approach to implementing systems engineering concepts into a Problem Based Learning curriculum in first year medical students. The research will also identify the best concepts to teach first year students given their skill sets in the form of a handbook. It will also test the extent to which Problem Based Learning is an appropriate medium for conveying systems engineering concepts to first year medical students. It will aim to begin the process of having first year medical students understand systems engineering so that they can use some of the tools themselves or be able to help others who are using these tools to improve the delivery of health care.

Chapter II: Literature Review

2.1 Systems Engineering

2.1.1 Definition

A system can be defined as a set of concepts or elements that satisfy a need. Systems engineering can be described as the set of skills and technology required to make a system (Miles, 1973). Another definition of systems engineering is "the art and science of creating a product or service, based on phased efforts that involve definition, design, development, production, and maintenance activities. The resulting product or service is functional, reliable, of high quality, and trustworthy, and has been developed within cost and time constraints (Sage and Rouse, 1999). Kossiakoff and Sweet define a system as a "set of interrelated components working together toward some common objective" (Kossiakoff and Sweet 2003, p. 23). The common thread of these definitions of systems engineering is taking into account the impact of outside factors and places importance on the interactions of processes within the system. System engineering looks at a problem in its entirety.

Systems exist at many different levels: the sciences, technologies, technical systems, civil systems, and social systems (Miles, 1973). Systems engineering controls the entire life of a system: definition, development, and deployment. This requires a wide variety of skills (Sage and Rouse, 1999). Traditional engineering disciplines are united in the systems engineering perspective; a multidisciplinary skill set is required. This is necessary because the scope of complex problems requiring systems analysis is very broad.

Systems engineering has been around since ancient Egypt, but most advances came as a response to World War II's demands for military technology and deployment. Computers and other digital controls have had a large impact on systems engineering and fundamentally changed the way information is handled and has allowed more complex systems to arise. Three factors have led to modern systems engineering: advancing technology, competition, and specialization (Kossiakoff and Sweet, 2003).

There are three interrelated parts of a system, the facilities and tools, the information and control aspects, and the human and organizational aspect. All of these must be understood in order to understand, create, and analyze a system. The physical elements include any item used in the system including equipment, buildings, tools, computers, etc. The information and control portion includes the method in which the information flows, what types of information is needed, and how the information is accessed. The human and organizational portion of a system involves the human in the system, job duties, training, and human resource policies. A diagram of the three layers of a system is shown below (Wu et. al, 2006). Not only do the three elements making up a system have to be understood, the interaction between the parts need to be understood as well.

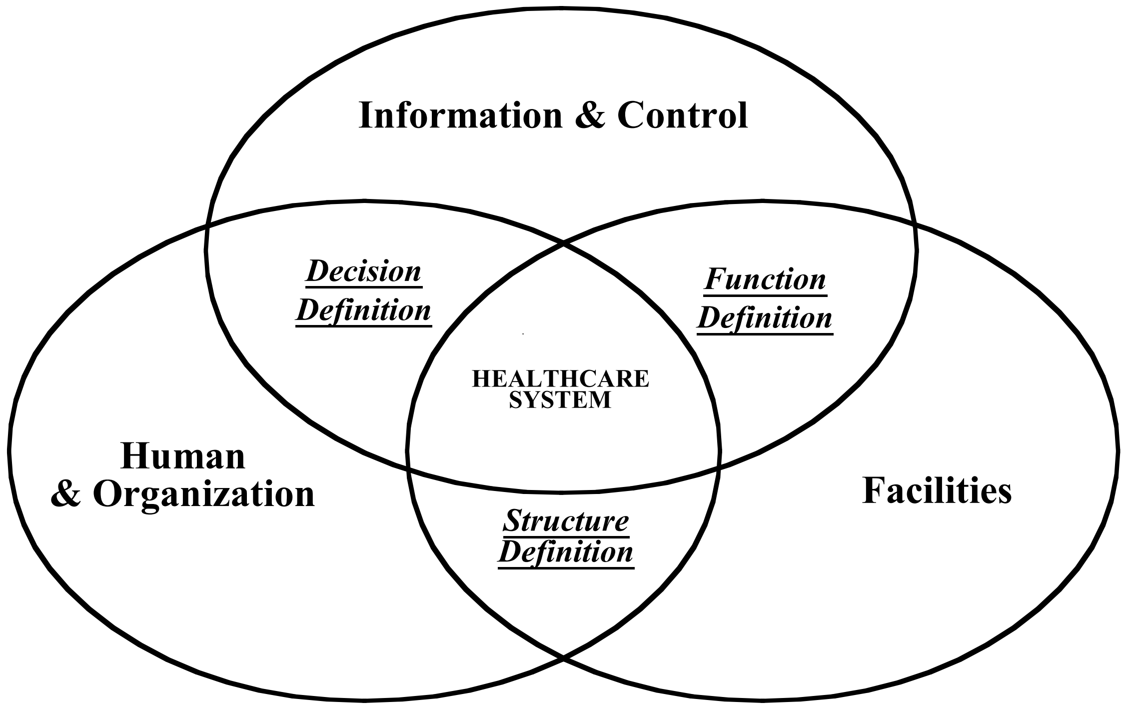

Figure 1: The three interrelated parts of a system (Wu et. al, 2006)

Systems engineering makes use of various tools in the stages of development, analysis, review, and improvement. Simulation is a method to observe the dynamic aspects of a system so that complex interactions can be analyzed. Data flow diagrams are used to model the flow of data and IDEF0 diagrams show the inputs, outputs, controls, and mechanisms of a process. These tools help to represent the often complex nature of systems and allow for improved analysis (Kossiakoff and Sweet, 2003).

2.1.4 Systems Framework and Medicine

A framework for a problem solving cycle is a necessary tool in order to solve complex problems in health care and should be taught to medical students. Generally, it would include the following steps:

- Obtain facts about the case/patient/problem
- Obtain facts about an ideal case/patient/problem
- Identify problems in the case/patient/problem
- Identify the gaps in the ideal situation and the given situation
- Identify special circumstances in this case (anything that would cause unexpected results, i.e. old age)
- Develop ideas on how to solve the given case/patient/problem
- Fix the case/patient/problem in general terms so it does not happen again in any situation

The key in the above proves is the last step, solving the problem so it does not happen again. This is the step that is currently missing in many health care environments. In order to complete this step, a deeper investigation must be performed. Instead of, for instance, just making sure Patient X gets the proper medication after he/she received the incorrect medication; try to fix the problem so that it does not happen to any other patient. The following diagram outlines a similar procedure developed by Dr. Bin Wu. The problem solving cycle incorporates feedback to make the process iterative until an acceptable solution is made.

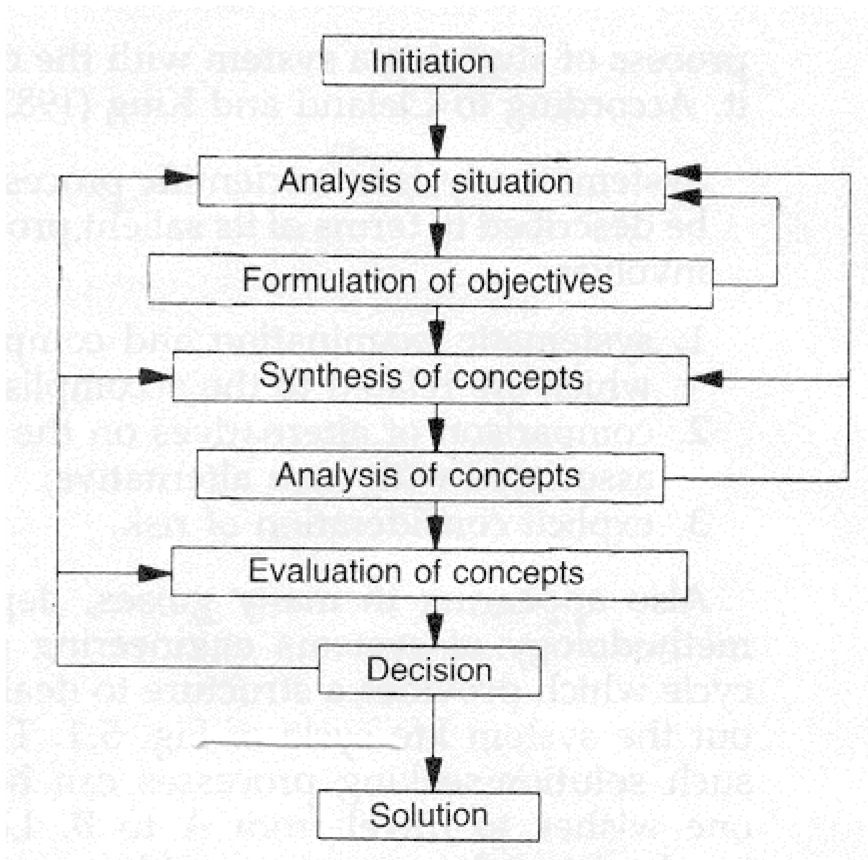

Figure 2: Problem Solving Cycle

When a system is created, considerable work should be invested in the design so that the system produces desired outputs with minimal problems. Once the system is running, there are tools that can keep it running smoothly. If the system is not designed correctly, many problems will arise during the life of the system. This is the case with health care, it is an aggregate of many old systems and not much care has gone into the integration. With the current state of the health care system, systems analysis tools are more important than systems design tools and systems control tools.

2.2 National Academy of Engineering and Institute of Medicine Report on the Collaboration of Engineering and Health Care

A recent report created by the National Academy of Engineering and the Institute of Medicine (IOM) provides a comprehensive analysis of many of the problems facing health care in the United States. The report provides general recommendation that systems engineering and systems tools should be used in order to make health care more effective. Systems engineering tools should be used to "address the crisis in health care and improve the quality and productivity of the health care system" (Reid, et. al, 2005, p. 11). In 2001, the IOM identified six dimensions of quality in health care: safe, effective, patient-centered, timely, efficient, and equitable. Many engineering techniques can be used to improve on these six dimensions, but there have only been isolated attempts. A new partnership between engineering and health care is encouraged. In the past, engineering has aided healthcare in the development of new technologies and pharmaceuticals. Much more could be done to implement engineering tools and techniques to aid in the operational and delivery shortcomings of the industry (Reid, et. al, 2005).

Justification for health care needing change is the estimated 98,000 preventable deaths annually and injuries to more than one million patients annually caused by medical errors, half of patients receiving "best practice" for their illness, health care costs rising at three times the rate of inflation, and the rising costs of health insurance (Reid, et. al, 2005). A cause cited for these problems in the unwillingness or inability to incorporate systems engineering tools for the design, analysis, or management of health care delivery (Reid, et. al, 2005). Clinicians are seen as independent agents in the fragmented, highly specialized world of health care (Reid, et. al, 2005). These clinicians are not able to see the scope of their actions and how they fit into the system as a whole. Their understanding is often limited to their specialty. Because health care involves the coordination and management of many highly specialized people, multiple streams of material and information, systems engineering tools can be effectively used. These tools have helped many industries, including manufacturing, which share many of the complexities with health care (Reid, et. al, 2005). There is a "desperate need for systems engineering tools" (Reid, et. al, 2005 p. 15). The tools can optimize performance, increase safety, and measure productivity and effectiveness of new techniques.

Three families of systems tools have been identified: Systems Design Tools, Systems Analysis Tools, and Systems Control Tools (Reid, et. al, 2005). Systems Design Tools aim to design a robust system and include Quality Functional Deployment (QFD), Human Factors Engineering, and tools for failure analysis. QFD is a technique that identifies factors that determine the quality of actions that ensure the desired performance. It assures customer needs influence the design and process of a good or service. Human factors research involves how humans interact with their environment and how to best design products or processes to make them easy to use for humans. This can include making sure instructions given to patients are clear or that the controls on a hospital bed are easy for a patient to use. Failure analysis is the process of finding ways in which a procedure can fail, then fixing the process so the process will not fail. Several tools can be used to facilitate this process including Failure Effect Models Analysis (FEMA) and Root Cause Analysis (RCA) (Reid, et. al, 2005).

Systems Analysis Tools include many tools that can be broken into four sub categories: Modeling and Simulation, Enterprise Management Tools, Financial Engineering and Risk Analysis Tools, and Knowledge Discovery in Databases (Reid, et. al, 2005). Modeling and simulation include methods to test alternatives in many different applications while including many real-world complexities. Examples of this include determining what the best layout for a nurse's station is or which type of paper form is most accurate and fastest. Supply chain management is an Enterprise Management Tool. Supply chain management tracks every step of a product or process to ensure timely delivery. It can be used to track inventory, improve ordering policies, or streamlining a process. Financial Engineering and Risk Analysis includes stochastic analysis to quantify risk by creating forecasts with systems with random outputs (Reid, et. al, 2005).

Systems Control Tools attempt to keep a system with a set of prescribed bounds. Statistical process control can be used in the form of a control chart. This chart plots a variable and the level at which it will be out of control. At this point, action should be taken to put the process back in control. Scheduling can also be used to control a system. Optimizing a schedule can save resources and ensure a health care organization is properly staffed so that the most effective care can be given (Reid, et. al, 2005).

The applications of systems engineering tools to health care must take into account the unique elements and complexities of health care in order for them to be successful (Reid, et. al, 2005). In the application of these tools, there are several barriers to overcome. There may be inadequate information and technology to support the tools, organizational and managerial barriers, policy and market barriers, and educational barriers (Reid, et. al, 2005). The way in which health care professionals are taught does not facilitate the necessary skill sets to operate a health care delivery organization as a system. With the explosion of medical knowledge in the last fifty years, physicians were required to specialize, narrowing the focus of medical doctors not only in their area of medicine, but the view of a health care delivery organization as well. Physician education was focused on treating individual patients and not necessarily public health or the structure of health care delivery. "No substantive perspective on the entire system of health care or training in the uses and implications of systems tools and information/communication technologies for managing and improving the system is included in medical education (Reid, et. al, 2005). The industry was not created as a system and is not run like one (Reid, et. al, 2005). Few in the industry have been trained to handle the necessary analytical tasks required by many systems engineering tools (Reid, et. al, 2005).

The IOM report expresses the belief that in order to make the most change, the introduction of systems engineering tools should "begin in the formative years of professional education" (Reid, et. al, 2005). New skills will have to be taught so that physicians and nurses will be able to communicate with and begin to deploy systems tools (Reid, et. al, 2005). The report further recommends that the training of physicians should be changed in order to include systems engineering concepts as new courses and within existing courses (Reid, et. al, 2005). From Recommendation 5-3: "Health care providers and educators should ensure that current and future health care professionals have a basic understanding of how systems-engineering tools and information/communications technologies work and their potential benefits" (Reid, et. al, 2005 p. 6). Educators of health professionals should develop curricular materials and programs to train graduate students and practicing professionals in systems approaches to health care delivery and the use of systems tools and information/communication technologies (Reid, et. al, 2005). They also recommend that systems engineering be taught as a requirement for the accreditation of graduate medical institutions.

2.1.1 Systems Engineering in Health Care

Health care is at a crossroads when considering its next steps taking into account the increase in medical information, increased customer demand, and the ever-increasing cost of health care (Wu et. al, 2006). The soaring costs of care are directly affecting the competitiveness of the United States. The United States is outranked by ¾ of developed nations in life expectancy and infant mortality, 37th in health care performance, and 1/3 of costs are administrative (Wu et. al, 2006). Something needs to change or the costs will continue to rise and the quality of care will continue to lag behind the rest of the developed world.

Wu (2006) proposes that systems engineering tools be used to improve the industry much like the same tools helped improve manufacturing. A need for understanding the underlying functions in a health care delivery system is vital for its survival, and systems engineering is a way to do this. Traditional methods for improvement focused on isolated segments and were rarely viewed as part of a system of integrated components (Wu et. al, 2006). A more holistic approach will lead to more drastic improvement. Some components of this holistic approach are systems perspective, structural problem solving, and a closed loop of continuous system improvement (Wu et. al, 2006). These must be used to break down the system into three parts: physical items, human and organizational items, and information and technology items. Knowing these items are not enough, finding interactions between these three areas is vital in order to understand and improve the system (Wu et. al, 2006).

In order to analyze and improve a system, several tools have been developed. Some of these tools are Data Flow Diagrams, Entity Relationship Diagrams, function/data matrix, organizational/operation matrix, operational/data entry matrix, site/function matrix (Wu et. al, 2006).

2.4 Problem Based Learning (PBL)

Problem Based Learning (PBL) is a method of teaching that has gained popularity in medical education since its first incarnation at McMaster Medical School in the mid 1960's. This approach is different from traditional medical school instruction because it does not rely as heavily on lectures, rather using small groups of students to solve clinical problems. Each group has a tutor that guides discussions and aides in determining learning objectives (Chung & Chow, 2003). Over fifty medical schools, such as Harvard Medical School and the University of Missouri-Columbia School of Medicine (MU), have adopted a PBL curriculum. Justification for using PBL as a method of instruction can be found in learning theory: a student will remember something better when it is learned in the context in which the knowledge will be used in the future (Dacre & Fox, 2000). PBL allows students to learn information in a clinical setting, the same setting in which it later will be applied. PBL is not limited to medical schools; many other disciplines are utilizing this method of instruction.

2.4.1 PBL at MU

The MU School of Medicine implemented PBL in the fall of 1993. It took $1.2 million in facilities improvements, an enthusiastic faculty, and two champions: the Dean of the School of Medicine, Dr. Lester Bryant, and medical education expert Dr. Michael Hosokawa. The University of Missouri-Columbia School of Medicine utilizes PBL for first and second year students. Each group has eight students and a tutor. The facilities for each group contain study carrels, computers, microscopes, an x-ray view box, audiovisual equipment, and a telephone. The PBL sessions are supplemented with lecture appropriate to the PBL case. The school year is divided into 'blocks", two 8 week blocks per semester, and there is a new PBL case every week (University of Missouri School of Medicine Learning Environment).

2.4.2 PBL Strengths

One of the greatest benefits of PBL is the ability of the students to adapt quickly to clinical situations they face in their third and fourth years. They begin to think like a physician as a result of their PBL experiences. The students have experience in establishing a diagnosis and treating a patient from their first PBL in medical school. In a recent study comparing the performance of these students to students who have had the traditional curriculum, PBL students did significantly better in clinical performance, knowledge and clinical reasoning, and non-cognitive behavior. They also received a higher proportion of honors and in no way performed worse than those who had a traditional medical education (Distlehorst, et. al, 2005).

A curriculum largely consisting of lecture emphasizes memorization and lacks the development of problem solving or self-sustaining learning. Much of the knowledge being taught at medical schools today will be outdated when the students begin practicing. PBL instills not only the requisite knowledge, but also, more importantly, how to acquire that knowledge. This better prepares students to be able to learn on their own in the future. Several studies have shown that PBL students perform better not only on clinical evaluations, but also on tests of factual knowledge. The study also determined that PBL develops better clinical reasoning skills and time-management. Performance based testing was also cited as being a more effective measure of a student's ability than a multiple-choice test (Schwartz & Burgett, 1997). PBL can also promote students' critical thinking and independent learning (Chung & Chow, 2003).

Barrows (1986) identified four educational objectives. Students participating in PBL instruction:

1. Develop an effective clinical reasoning process
2. Organize a knowledge base for use in clinical contexts
3. Develop effective self-directed learning skills
4. Increase their motivation for learning

The University of Missouri-Columbia School of Medicine has seen its mean scores for the USMLE (the "boards") improve in the years after the PBL curriculum was introduced. The quality of the students in the two groups shared very similar GPAs and MCAT (Medical College Admissions Test) scores, so it can be assumed that the students in each group were of equal ability. The PBL revisions did not decrease the performances of the students; rather it may have contributed to the higher scores (Blake, et. al, 2000). Lecture, the traditional format for medical school education, is seen as a poor way to address new issues and student learning styles. This format does not allow students to think critically and problem solve. PBL better addresses these concerns (Schwartz & Burgett, 1997).

Eighty-five percent of students at MU get their first or second choice of residency programs and score above average on licensing exams, a testament to the quality of education received from the Medical School. MU is one of the first medical schools to implement a PBL curriculum and has become the model for other medical schools that have also implemented PBL (http://www.muhealth.org/~medicine/dean.shtml).

2.4.3 PBL Weaknesses

Maintaining a PBL curriculum is very expensive; instead of compensating one instructor for lecturing to an entire class, many more faculty are needed when doing small group work, which PBL demands. Student complaints include high levels of stress and demanding activities, no control over what they wanted to learn as a result of the tutor's guidance, and limitations of the tutors themselves (Chung & Chow, 2003). PBL at MU alleviates some of these concerns; only qualified instructors are chosen for each PBL case and students, within four months of from beginning medical school, develop their own learning objectives. High levels of stress and demanding activities are common to every medical school across the country, so this concern is likely to be seen in schools with a traditional curriculum as well.

2.4.4 Implementation

The following steps were created as a general framework for creating a PBL curriculum:

1. Give the rationale for the curriculum and form a curriculum-planning group
2. Generate general educational objectives of the curriculum

3. Assess the educational needs of future students
4. Apply the educational principles of PBL to the curriculum
5. Structure the curriculum and generate a curriculum blueprint
6. Elaborate the unit blueprints
7. Construct the units
8. Decide on student assessment methods
9. Consider the educational organization and curriculum management
10. Evaluate the curriculum and revise it (when necessary)

This process is not necessarily linear (Wiers, et. al, 2002). In order for a medical school to switch from traditional teaching methods to a PBL based approach, a champion is necessary. This champion must have the ability to motivate and influence a great number of people in order to successfully make the change.

2.4.5 PBL Summary

PBL has been shown to be a highly effective method of teaching medical students. Students who have participated in PBL not only have performed better on knowledge-based exams than their traditionally taught counterparts, they have also outperformed them in a clinical setting as well. PBL students are not taught *what* to learn, they are taught *how* to learn. This set of skills is an invaluable tool in the life of a physician. Though the costs for implementing PBL are high and resistance to change is certain, PBL can be beneficial. Its flexibility allows curriculum developers to inject new ideas and concepts easily into cases. This flexibility increases the adaptability of the curriculum so that the ever-changing field of medicine can be effectively taught.

2.6 Literature Review Conclusion

There is a pressing need for improving health care in the United States. Costs are increasing and the quality of care must be greatly improved. Systems engineering techniques have been cited as necessary for health care improvements and costs reduced. Finding a way to implement this knowledge and skills health care will be a challenge.

PBL is a flexible and effective format for teaching medical school students. Instilling systems engineering concepts into the medical education at MU via PBL can help introduce systems engineering concepts in the health care industry.

The implementation of systems concepts was used on medical students for several reasons. Medical schools produce physicians, and physicians are vital to the health care industry. Medical doctors are the center of many activities in a health care setting. They order tests, they diagnose patients, and they perform procedures. All of these actions begin a process that can be analyzed as a system. Physicians begin the engagement of many systems when they admit patients to health care facilities for tests and treatment.

Teaching medical students has another advantage. They can be taught without previous bias or resentment. If they are presented systems concepts in medical school, they are likely to regard the subject matter as important. This is in contrast to trying to teach a well-established physician a new way to look at health care processes and indeed health care as a whole. The experienced physician is less likely than medical students to assign these skills as important. Therefore, teaching medical school students these skills will hopefully lead to their use in the medical community in the near future.

Currently, medical students receive little to no training in systems theory and are not equipped to identify problems and solve them by looking at them in a systems perspective. Many of the challenges in the health care industry are very complex and can be understood only by looking at them in a systems perspective. Being a key player in a health care setting, a physician is in a position to identify problems. Currently, many physicians accept the limitations and failures of activities around them. They do not give much thought as to why, for example, a test that was ordered did not get resulted. Some accept these systems failures as common and unavoidable. Giving physicians the tools to understand and solve system problems, or at least assist others tasked with solutions, is an exciting possibility.

No publication could be found demonstrating integration of systems engineering concepts into a medical school curriculum or even a curriculum, such as a handbook designed to teach medical students systems engineering concepts.

Chapter III: Project Plan

3.1 Overview of Medical School Education at the University of Missouri-Columbia

The Medical School at the University of Missouri-Columbia is a four-year institution that prepares students to become physicians. The first two years consist of PBL supplemented by lectures and other activities such as anatomy labs or patient interview seminars. The year is broken up into four eight-week “blocks”. Each week, a new PBL case is presented, and at the end of the block, a week of tests is administered. Each test consists of a PBL section where students are given a new case and are asked to come up with a diagnosis, a multiple-choice knowledge based section, and a section that tests the students' practical abilities in a clinical setting.

The third and fourth years of medical school allow the student to apply their knowledge in a clinical setting. They make rounds in the University Hospital for different departments such as neurology, psychiatry, and cardiology. Near the end of the third year, every student takes a national standardized test commonly referred to as "The Boards". The student applies to three programs in the country and the results of this test, along with the performance while in school, influence which program will accept them into post-graduate residency education. The residency is necessary to practice medicine. It can be thought of as an apprenticeship lasting anywhere from three to seven years, depending on the chosen specialty.

The concepts of systems engineering need to be taught to health care providers. Teaching these concepts to medical students at the University of Missouri-Columbia is necessary so the student understands its importance. Additionally, PBL curriculum allows for a flexible medium that can accommodate new demands of medical school such as systems engineering and other important concepts.

3.2 Project Overview and Procedure

A meeting to introduce the key members involved in the research and to discuss operational details included Drs. Bin Wu, Karen Cox, and Michael Hosokawa, along with the researcher and Dr. Cox's colleague, Kat Nelson. Dr. Hosokawa is the Associate Dean of Curriculum at the University of Missouri-Columbia School of Medicine and is a Professor of Family and Community Medicine. He is an expert in medical education and is an integral part of the PBL curriculum at MU. He has helped other medical schools introduce PBL into their curriculum and continues to improve MU's curriculum.

Dr. Cox is the manager of Quality Improvement and Patient Safety at MU Health Center. She is an expert in health care systems engineering, continuous quality improvement, patient safety, and has been involved in other internal quality/safety curricular adjustments designed for medical students, residents, and practicing health care professionals.

After the initial meeting, past PBL cases were reviewed in order to get an understanding of their structure and content. Consultation with a fourth year medical student, Ravi Komatireddy, who had completed the PBL process, and the expertise of Dr. Karen Cox were used in an attempt to insert a realistic medical error into a PBL case that would elicit the students to develop an objective about systems engineering. Dr. Cox oversees a large database containing medical errors and close call reports. Reports are categorized by type and severity. These data were used to develop a list of common, thus plausible medical. The error types were presented at the next meeting with Drs. Wu, Cox, and Hosokawa. The ideas presented were generic suggestions of what could be developed for introducing error into an existing PBL case. Upon analysis of the cases, one was chosen because the case already had an error. The error involved physicians prescribing a patient drugs that, given together, interact and cause harm to patients. The PBL patient's reaction to the medications is described and the students are expected to see that the medication combination caused the new problems the patient experienced.

A seminar series entitled "Interprofessional Curriculum in Teamwork, Patient Safety and Quality" was attended. This seminar series consisted of second year medical students, seventh semester nursing students, final semester masters in Health Administration students, and third year respiratory therapy students. The seminar included analysis into how medical professionals worked in a team environment and how medical errors occurred and could be stopped. See Appendix A for a curriculum outline. The seminar included breakout sessions with small groups solving a problem by using all of the students' perspectives. The seminar was valuable because it demonstrated how various health professionals approached problems, how they acted in a group situation, and how their expertise helped the group. The medical students seemed to always think of the patient first, and everything else stemmed from the patient's needs or problems.

An actual PBL was observed in order to get an understanding of what went on during the sessions. The insight was very helpful in understanding what the students look for in creating objectives and how they approach the case. After the observation, a meeting with Dr. Andrew Simpson was arranged. Dr. Simpson, an associate professor of medicine, is in charge of the PBL cases during the block (Block Director) in which this researcher's case was altered. The discussion revolved around the case that Dr. Hosokawa recommended (the one that already had an error). Using this case would minimize impact on the rest of the objectives and the objectives were more appealing to Dr. Simpson than any other case. In order to teach systems concepts though PBL, a careful integration of existing content and new content had to be established. The addition of content to lead the student to make objectives containing systems engineering techniques should not interfere with the case. The lessons of the case should not be jeopardized; the impact of the changes to the case should be minimal. The PBL changes were made and sent to Dr. Simpson for approval. Once he approved, and the case was given to the students on schedule.

3.3 PBL Observation

Upon observing a second year medical student's PBL session, many insights were gained into the dynamics of the problem solving process and where students place importance when selecting objectives. A second year medical school class was observed and while they had more experience with the PBL process than the first year students, their ability levels are basically the same, as noted by several PBL tutors. The second year students have a different procedure from the first year students. The first year students have PBL three days a week and a new case is introduced on Monday and completed on Friday. The second year students have PBL Tuesday and Thursday, ending a case on Tuesday and beginning the next one the same day. The following is a description of the experience of observing a second year PBL on a Tuesday.

The room contained desks for all students, a large flip chart and easel, a black board, a computer, and a large table with chairs. Eight medical students, one tutor (an MD), and the researcher were present. The atmosphere before the session started was very relaxed and informal and this carried over to the entire time in the lab. The session opened with the students presenting their objectives they created in the previous class. All had printouts that were two to three pages, double sided, summarizing their objectives. Some students whose objectives included medical imaging presented their objective on the computer while the other students gathered around. Every student was engaged during the presentation and the tutor occasionally added comments to make sure the students understood the main points of the objective. The students often referred to past cases when presenting their objectives. The eight students took a total of one hour to present their objectives with each student's presentation varying in length.

After the objectives were completed, a new case was introduced. The case was introduced by the "quarterback" reading the first page of the case given from the tutor. The quarterback is the designated leader of the students for a particular case and has the duties of reading the case as it is given to them from the tutor (the pages are given one at a time when the tutor determines the students have hit on all of the major points on the page and the tutors all attend a review session about the case so that they are familiar with the material), and gets the first pick of objectives at the end of the class. As the case is read, another student, the "scribe", writes key points on the flip chart. The scribe wrote "patient", "hypotheses", and "management" as headings on the board and information was listed below them. The patient heading included information about the patient such as age, weight, symptoms, etc., the hypotheses heading included what the students thought was wrong with the patient, and management was what they would do the patient to manage the pain, disease, or problem. These headings were continually updated as more pages were handed out from the tutor. This is the way the students are instructed to approach the problem from their first week of PBL during their first year and is the way in which all groups operate.

The tutor was fairly quiet during the case presentation time only occasionally speaking up to ensure the students include all of the hypotheses brought up at the tutor meeting. The tutor also noted what the actual physician did in the real case. The students didn't communicate with the tutor too much either; they mostly relied on each other to answer questions. One page of the case instructed the students to look at an ultrasound on an online resource set up for PBL cases. Other pages included an EKG, blood test results and vital statistics such as blood pressure and pulse.

When all of the pages for the case were handed out, the students discuss what they do not know and make objectives to assign to each student so the group can explore the diagnosis for the patient. The objectives are decided on as a group and the students assigned to work on specific objectives between PBL sessions. The objectives created for the case observed were directly related to the case. The tutor helped to expand a narrowly defined objective.

After observing a PBL, it was determined that it would be very difficult to elicit an objective about systems engineering because all of the objectives created in the observed case were directly related to the patient and her condition and were not about the aspects of her care such as lab tests, databases, hospital layout, etc. A creative way to incorporate an error of some kind is necessary to introduce systems engineering by way of PBL. PBL is not so much about teaching as it is guiding the students so that they discover the information on their own.

3.4.1 Change in the PBL Case

Due to the sensitive nature of a PBL and its importance to the Office of Medical Education at the University of Missouri, the entire PBL cannot be included in this research report. All relevant information from the case will be presented and selected excerpts included giving more than enough information to understand the case as it pertains to this study.

The case that was marked for changes contained a section that described a problem resulting from drug interactions. This error occurred because the interactions of medications were not taken into account nor was there a warning about the dangerous interactions by a person or computer system when the two medications were prescribed to the patient. After this of the PBL section, the following questions were posed:

> What is your diagnosis?
>
> What treatment would you provide?
>
> Could this illness and its complications have been prevented? Discuss strategies that may be useful to reduce medical mistakes.

Since some students have created objectives about medical error, changing the last question a bit should not impact the case and could lead to systems engineering in the objectives. The following question was formed and inserted into the case:

> Could this illness and its complications have been prevented? Discuss strategies that may be useful to reduce medical mistakes **including systems engineering concepts and tools**.

This is a very simple way to elicit systems engineering objectives from the students without interfering with the case. Many more complicated ideas about how to best change the case were developed, and an example of one of these can be found in Appendix B. This was not a smooth integration with the selected PBL case, but it could be used in most any case. It was not used because it did not fit seamlessly into the case, seemed abrupt and out of place. Since objectives are already being created based on the question being altered, it can be reasonably assumed that there will continue to be objectives based on the question, and if the question is changed, the objectives will be changed accordingly.

The students will hopefully create a general approach to solving medical problems using systems engineering rather than just try to solve the problems in the case at hand. PBL is a good means to get the students to think about topics in general terms, so the objectives shouldn't be too specific.

The results of making the PBL alteration was made by comparing the objective topics from 2005 class with the objective topics from 2006 class. If the 2006 objective topics include systems concepts in their objective topics, than the PBL change can be considered effective in introducing these ideas. If objective topics do not include systems engineering, than the PBL change may not have been an effective change to introduce these skills.

3.4.2 Information Students Should Learn

Having health care professionals understand and use systems engineering concepts in order to improve health care is the eventual goal and introducing medical students to the material is just a first step. Eventually, health care professionals should understand and use the following:

- Systems Concepts – basic systems structure, control, communication, and use of technology
    - Systems perspective
    - Systems structure
    - Systems operation
- Systems perspective of health care operations
    - How systems engineering concepts relate to health care
    - Solutions to health care problems using systems engineering
    - Process modeling (IDEF charts, DFD, etc.)
    - Modeling (simulation)

- Structured Problem Solving
    - Overall process
    - Problem solving cycle
    - Evaluation of decision

3.4.3.1 Systems Concepts

There are three interrelated parts of a system, the physical elements, the information and control aspects, and the human and organizational aspect. All of these must be understood in order to understand, create, and analyze a system. The physical elements include any item used in the system including equipment, buildings, tools, computers, etc. The information and control portion includes the method in which the information flows, what types of information is needed, and how the information is accessed. The human and organizational portion of a system involves the human in the system, job duties, training, and human resource policies. Not only do the three elements making up a system have to be understood, the interaction between the parts need to be understood as well. Systems engineering makes use of various tools in the stages of development, analysis, review, and improvement.

Health care professionals must be able to determine how health care systems work so that they can maintain an efficient system and create successful new systems. The operation of a system should be given thought in the design of the system so that operation is easy and effective. System operation should use feedback control loops in order to assess the effectiveness of a system and resolve any problems before they become crippling.

3.4.3.2 Systems perspective of health care operations

Health care involves the coordination and management of many highly specialized people, multiple streams of material and information. Systems engineering tools can be effectively used in health care to manage and improve processes. The tools can optimize performance, increase safety, and measure productivity and effectiveness of new techniques.

The applications of systems engineering tools to health care must take into account the unique elements and complexities of health care in order for them to be successful. Understanding the underlying functions in a health care delivery system is vital for its survival, and systems engineering is a way to do this. Some components of the systems approach are using a systems perspective, structural problem solving, and a closed loop of continuous system improvement. Knowing these items is not enough, finding interactions between these three areas is vital in order to understand and improve the system. All of these components have to be tailored to health care and must be understood by the health care professionals. Manufacturing organizations have customized many tools and ideas to fit their needs and many are using systems concepts and health care can do the same.

Modeling and simulation include methods to test alternatives in many different applications while including many real-world complexities. Examples of this include determining what the best layout for a nurse's station is or which type of paper form is most accurate and fastest. Data flow diagrams are used to model the flow of data and IDEF0 diagrams show the inputs, outputs, controls, and mechanisms of a process. These tools can help represent the often complex nature of systems in health care and allow for improved analysis.

3.4.3.3 Structured Problem Solving

A framework for a problem solving cycle is a necessary tool in order to solve complex problems in health care and should be taught to medical students. Medical professionals should understand the process well able be able to carry out the process without much assistance. The key steps in structured problem solving are:

- Obtain facts about the case/patient/problem
- Obtain facts about an ideal case/patient/problem
- Identify problems in the case/patient/problem
- Identify the gaps in the ideal situation and the given situation
- Special circumstances in this case (anything that would cause unexpected results, i.e. old age)
- Ideas on how to solve the given case/patient/problem
- How to fix the case/patient/problem in general terms so it does not happen again in any situation

The key in the above proves is the last step, solving the problem so it does not happen again. This is the step that is currently missing in many health care environments. In order to complete this step, a deeper investigation must be performed. Instead of, for instance, just making sure Patient X gets the proper medication after he/she received the incorrect medication; try to fix the problem so that it does not happen to any other patient. Once a decision has been made, the decision must be evaluated for its effectiveness and if the solution should be maintained, altered, or replaced. This evaluation should be a done on a regular basis.

3.4.3.4 Considerations for this Research

Given several limiting factors (time, space in curriculum, etc.), the medical students will not be able to master all of these topics. Rather, the students will be expected to gain a basic understanding of these concepts. PBL is the mechanism that will allow the students to gain an understanding of systems concepts and how they relate to health care. With the limitations in mind, the medical students should learn the basics of systems engineering and how it relates to health care. In the objective created by the students, the following items should be included:

- Identified need for systems engineering tools to fix a problem in the case
- Definition of systems engineering
    - Identify ways in which it can help health care
    - Determine appropriate aspects of systems engineering that can be uses in health care
    - Stating ways in which systems engineering concepts can be put into practice
- Systems tools that can help in health care
    - Process flow charts
    - Root Cause Analysis
    - Simulation
    - Human Factors considerations

The following is an example of what an objective could contain:

> Systems engineering involves taking into account the impact of outside factors and places importance on the interactions of processes within a system. System engineering looks at a problem in its entirety.

Systems engineering tools can optimize performance, increase safety, and measure productivity and effectiveness of new techniques. There are three families of systems tools: Systems Design Tools, Systems Analysis Tools, and Systems Control Tools. Systems Design Tools aim to design a robust system and include Quality Functional Deployment (QFD), Human Factors Engineering, and tools for failure analysis. QFD is a technique that identifies factors that determine the quality of actions that ensure the desired performance. It assures customer needs influence the design and process of a good or service. Human factors research involves how humans interact with their environment and how to best design products or processes to make them easy to use for humans. This can include making sure instructions given to patients are clear or that the controls on a hospital bed are easy for a patient to use. Failure analysis is the process of finding ways in which a procedure can fail, then fixing the process so that it will not fail. Several tools can be used to facilitate this process including Failure Effect Models Analysis (FEMA) and Root Cause Analysis (RCA).

Systems Analysis Tools include many tools that can be broken into four sub categories: Modeling and Simulation, Enterprise Management Tools, Financial Engineering and Risk Analysis Tools, and Knowledge Discovery in Databases.

Modeling and simulation include methods to test alternatives in many different applications while including many real-world complexities. Examples of this include determining what is the best layout for a nurse's station or which type of paper form is most accurate and fastest. Supply chain management is an Enterprise Management Tool. Supply chain management tracks every step of a product or process to ensure timely delivery. It can be used to track inventory, improve ordering policies, or streamlining a process. Financial Engineering and Risk Analysis includes stochastic analysis to quantify risk by creating forecasts with systems with random outputs.

Systems Control Tools attempt to keep a system with a set of prescribed bounds. Statistical process control can be used in the form of a control chart. This chart plots a variable and the level at which it will be out of control. At this point, action should be taken to put the process back in control. Scheduling can also be used to control a system. Optimizing a schedule can save resources and ensure a health care organization is properly staffed so that the most effective care can be given.

The application of systems engineering tools to health care must take into account the unique elements and complexities of health care in order for them to be successful. In the application of these tools, there are several barriers to overcome. There may be inadequate information and technology to support the tools, organizational and managerial barriers, policy and market barriers, and educational barriers. The way in which health care professionals are taught does not facilitate the necessary skill sets to operate a health care delivery organization as a system. With the explosion of medical knowledge in the last fifty years, physicians were forced to specialize into one area, narrowing the focus of physicians not only in their area of medicine, but their view of a health care delivery organization narrowed as well. They were focused on treating individual patients and were not concerned with public health or the structure of health care delivery. Few in the industry are trained to handle the necessary analytical tasks that are required by many of the systems engineering tools.

Systems engineering tools can be used to improve the health care industry much like the same tools helped improve manufacturing. A need for understanding the underlying functions in a health care delivery system is vital for its survival, and systems engineering is a way to do this. Traditional methods for improvement focused on isolated segments and were rarely viewed as part of a system of integrated components. A more holistic approach will lead to more drastic improvement. Some components of this holistic approach are systems perspective, structural problem solving, and a closed loop of continuous system improvement. These must be used to break down the system into three parts: physical items, human and organizational items, and information and technology items. Knowing these items is not enough, finding interactions between these three areas is vital in order to understand and improve the system. In order to analyze and improve a system, several tools have been developed. Some of these tools are Data Flow Diagrams, Entity Relationship

Diagrams, function/data matrix, organizational/operation matrix, operational/data entry matrix, site/function matrix.

A consideration for what the students should include in their objective is their ability to get this information. This information is available on the Internet and in online journal databases, all of which are common resources the students use when creating objectives, so the students should have no problem finding the information. Eventually, a more thorough understanding and ability to apply this knowledge are desired, but the foundation must be created in young medical professionals.

Having students identify and understand systems concepts is the first step to having them use these ideas in the health care industry. Just as those who aim to improve health care with engineering, those in health care should be able to embrace and fully utilize the tools that can lead to improved care. Engineers need to focus on using their skills and tools to an unfamiliar area and medical professionals should be equipped with the knowledge to understand these tools and concepts so that a partnership can be established to facilitate the improvement of health care delivery.

3.4.3.5 Creation of a "Handbook of Health Care Systems Engineering for Medical Students"

Currently, there is not a resource for medical students that can provide the information deemed important for their understanding systems concepts as it relates to health care. The following is a proposed handbook about systems engineering as it relates to health care and is designed for medical students. After the handbook, the PBL case that was altered will be addressed to see how the handbook can be used. The diagrams from the handbook were created by Dr. Bin Wu and can be found in Manufacturing Systems Design and Analysis: Context and Techniques.

Handbook of Health Care Systems Engineering for Medical Students

Section 1: Introduction

What is a system?

How does it relate to health care?

Why should I care, I'm going to be a physician?

These questions and more will be explored in the following pages. The purpose of this handbook is to introduce you, a future physician, to the concepts behind systems engineering so that you can improve health care delivery and reduce medical errors. Health care costs in the United States are rising, insurance costs are increasing, and the quality of care is not improving. Institute of Medicine and the National Academy of Engineering have recommend that implementing systems engineering concepts and using systems engineering tools can improve the health care industry. Errors occur when a part of a system fails. These errors, in health care, are very costly (even deadly), and identifying and eliminating these errors can reduce costs and improve the quality of care. Knowing a little about what a systems can help you to improve health care.

The United States has access to the best medical equipment in the world and trains the most knowledgeable physicians and health care workers. The problem with health care is the way in which the knowledge and equipment are delivered. The effect of systems deficiencies in health care causes the inefficient delivery of the knowledge and equipment. A recent Time Magazine article put it nicely, “It requires almost a stroke of luck to enter a U.S. hospital and receive precisely the right treatment . . .” (Gibbs. 2006 p. 25).

Systems thinking is a way to gain insight into an organization by looking at the interactions of the various processes within the whole, and systems tools are the means by which the organizations are constructed and analyzed. These tools have improved other complex industries, such as manufacturing, and many of these same techniques can be adapted to health care. As a future physician, you will be an integral part of a health care system, but you will not be able to stand alone. You need the support of others within the system, specialized knowledge, and equipment. Knowing how these things work together very important, and thinking in terms of systems, can help.

Section 2 Basic Systems Concepts

Lets start with some definitions. A system simply transforms inputs into outputs. In a very simplified view, a health care system has the inputs of sick people and (hopefully) outputs of healthy people. A system boundary is the designated place where the limits of the system are established; everything outside of the system is considered its external environment. Of course, the details and organization are very complex in real life, but we’ll start simply. Within a system, there are several components, the most important of which are: inputs, outputs, processes, and feedback control. All of these components must work together properly in order for a system to function properly. It only takes one misbehaving component to cause a system to run sub-optimally and sometimes even dangerously. We already talked about input and output, so let's look at the other components

A system can have several sub-systems and in turn these sub-systems can have sub-systems themselves, and so on (Figure H 1). The sub-systems have to communicate with the systems above them. A hospital usually has several departments such as neurology, cardiology, etc. which can be thought of as sub-systems. Each department can have several sub-systems themselves. Each department must communicate with the hospital as a whole, usually be following guidelines set up by the hospital administration. Output from on sub-system can be the input of another. For example, a patient from an internist can be sent to a cardiologist as needed.

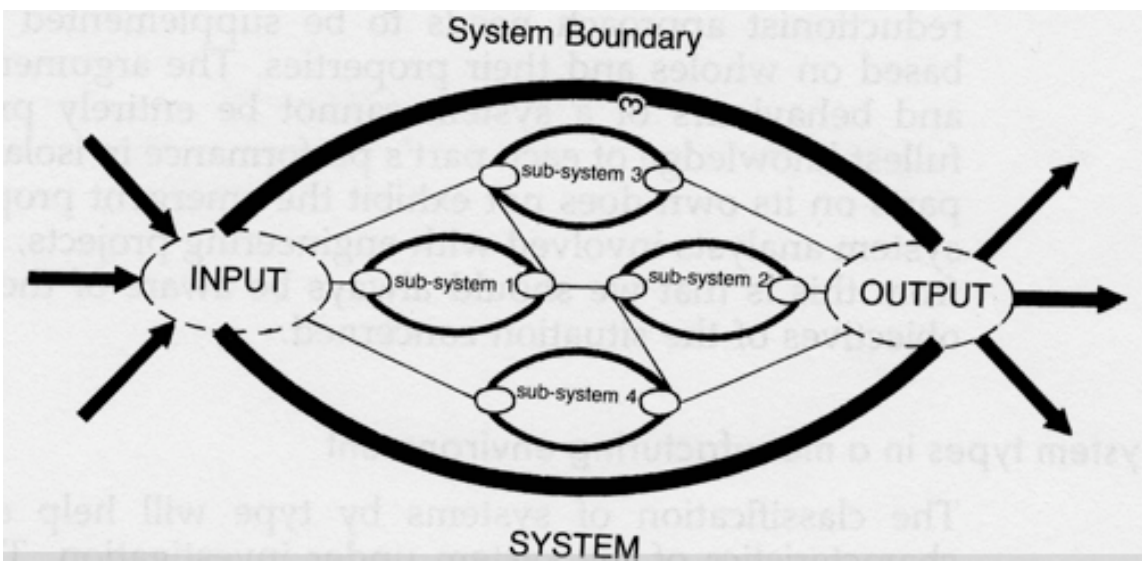

Figure H 1: A system and its sub-systems

A process can be a surgery, an immunization, or even a conversation with a physician. It requires inputs, produces outputs, and is the heart and soul of a system. Often, processes can be broken down into smaller sub-systems depending on the need for detailed analysis. Feedback control compares the output with what an acceptable output should be. It also reports the results to the relevant systems above in the hierarchy within the health care system (Figure H 2). If the output is not what is desired, a decision has to be made to correct the system. If too many patients are leaving a hospital still sick, an investigation will likely be started to see where the problems are so that more people leave the hospital in good health. These feedback control loops can be formal or informal and are often determined by a higher level within the overall system. The feedback can come from outside the system of from within the system depending on how the feedback loop is designed as seen in Figure H 3.

Figure H 2: **System Hierarchy**

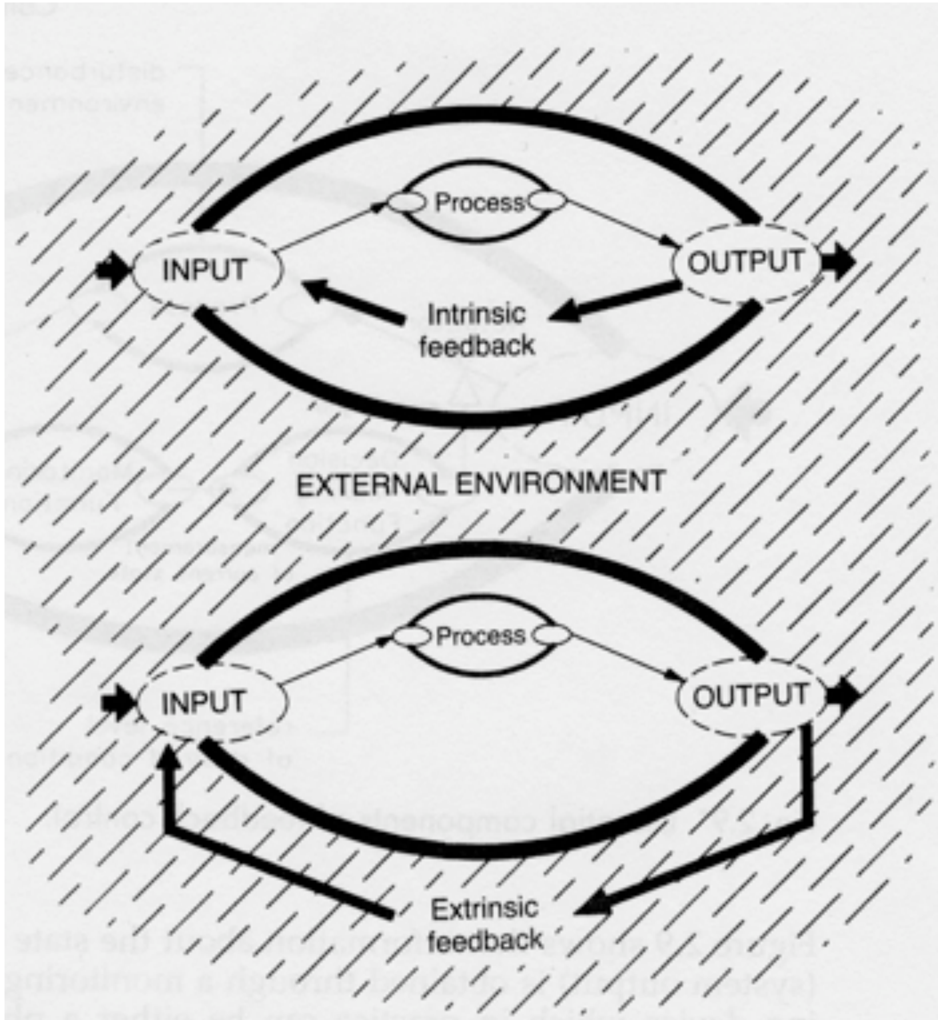

Figure H 3: A feedback control loop in a system

Section 3 Preconditions for a successful system

Throwing together a couple of processes and identifying inputs and outputs doesn't mean that the systems will do what you want. There has to be some preconditions in order for a system to operate. The following preconditions can help to determine where a system can be improved or determine where a system needs to be fixed. If a precondition is not met, than it should be brought to a satisfactory level of performance, then have the system re-evaluated.

Scanning the environment

The wider health care environment must be addressed. New knowledge about medical information and practices must be disseminated to the sub-systems so that the patients receive the best care. New government regulations and laws must be followed as well to prevent legal troubles. Changing customer demands and new technology should also be observed and acted upon if necessary.

Deal with disturbances

Health care systems should have plans and resources to deal with external disturbances. Disturbances can be an outbreak of a deadly virus or an unusually high number of car accidents during a given period: anything out of the ordinary. There should be plans in place to deal with these situations. There also should be a way to report the occurrence of unusual events to the proper personnel so that the situation can be properly identified and an appropriate response can begin.

Clearly defined objectives

The overall mission and goals of a health care system should be easy to determine by its employees so that all are working towards the same goal. This mission and goals should be evident through the sub-systems; they should be the same as the wider system.

Adequate overall structure

All parts that make up a system must be present (inputs, outputs, feedback control, etc.) and adequately address the need for which it was created. It must be able to communicate with its sub-systems properly.

Adequate sub-system structure

All parts that make up a sub-system must be present (inputs, outputs, feedback control, etc.) and adequately address the need for which it was created. If must be able to communicate with the other sub-systems and the wider system properly.

Effective Communication

Sub-systems must be able to communicate with their sub-systems, with other sub-systems, and the wider system. The wider system must be able to communicate with the employees in the sub-systems, patients, the regulatory agencies, and other entities outside the system boundary.

Identifying problems in a system can be difficult, and there is a set of questions that can be used to help in determining problems. These questions are meant to be the starting point in solving a problem related to a system.

What is happening?

This question aims to identify any problems.

Why should I be interested?

This question aims to determine in there is a need to try and fix any problem found in the first setup.

Can the problem be described in systems terms?

This question aims to see if the problem can fit into the systems definitions given earlier in this handbook.

Which systems are of interest?

This question aims to identify the problem systems or sub-systems and determine which processes or components of the system are causing problems.

What am I actually concerned with?

This question aims to find a way to describe the problem, often in graphical terms.

Section 4 Ideal system model for health care

Health care can be though of as a system with three interrelated parts: Information and Control, Health Care Facilities, and Human and Organization. Each section has an interaction with the other, as shown below. These three main parts are able to describe every aspect of a system, whether it is a physical element, a piece of information, or a rule. If there is a part missing in the inter-relationships, the system may produce errors, and in health care systems, errors often mean death. Thus, determining the proper inter-relationships and maintaining them in a health care system is critical. Figure H 4 shows a diagram of three main sections of a well-designed system and their interactions.

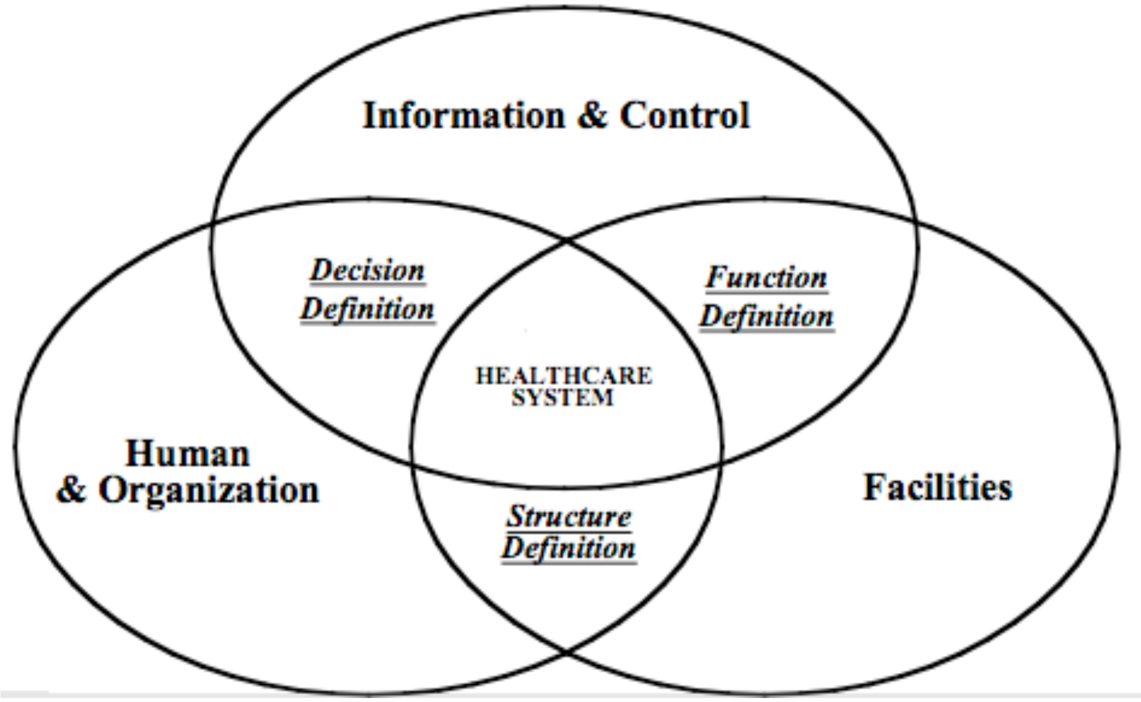

Figure H 4: The three parts of a system and their inter-relationships

Facilities: This section of the diagram includes everything dealing with the physical elements of health care delivery. This includes medical instruments, hospital rooms, the hospital itself, any medical instruments or equipment, among others. This section not only includes the physical equipment, it also includes the layout of the equipment. This area deals with the tools that are used to transform an input, such as a sick patient, into an output, a healthy patient.

Human and Organization: This area includes all of the personnel that are in the system. This would include physicians, nurses, techs, administration, etc. The relationships and hierarchy of personnel is also addressed in this area. Job descriptions, training procedures, and HR policies are also included.

Information and Control: This section includes all of the information necessary for the system to function. This information is in the form of patient records, governmental regulations, any software system used to store data, and the flow of data. This flow of data is very important in a health care system. The data often must be kept confidential but must be available to the right people at the right time so that the patient is not harmed. Information about a patient's allergies, past medical history, and what procedures are to be done to them must be communicated from person to person in a manner in which the integrity of the data is maintained. Databases often do a good job of this, but when the data is passed from person to person in the heat of a medical emergency, errors occur. This section of the diagram should include a robust method of keeping track of the information surrounding a patient's procedures.

The interactions of the three main areas are important. The interactions must be organized so that the areas communicate efficiently and effectively. Communication between areas allows for a physician to know which patient to operate on, ensures the proper personnel will be present, and that the surgery follows the guidelines set up by the hospital. If one area of communication is missing, a patient could end up with the wrong leg amputated (it has happened!).

Information and Control - Facilities: This crosschecking area ensures that each medical process is provided the necessary and correct information. This includes which leg to cut off in an amputation, which instruments to use for certain procedures, and how to report the results of a lab test.

Human and Organization - Information and Control: This crosschecking element determines who plays what role in a medical process. It ensures a qualified health care professional is assigned for every role in a process. This element defines employee responsibilities and their access to medical information.

Human and Organization – Facilities: This crosschecking area determines which employees are assigned to each area of the hospital. This ensures that each department is appropriately staffed. It also maps who will do a certain procedure or action a given time.

The center of the diagram is the point at which all parts overlap. This section includes the strategic requirements and performance targets. These items are shared throughout the entire system and should impact all three main areas.

Section 5: Summary

When looking at health care from now on, try to think of it as a collection of systems and sub-systems. This can help in creating new systems that are needed in a health care environment that run properly. Using the information in this handbook can also be useful in identifying and solving errors. You can look at what is going on surrounding a process and identify what is missing or what is not working properly. You understand that the parts of a system must communicate with each other and several preconditions that must be met in order for a system to function properly. This handbook is not meant to enable you to solve every problem you encounter in your career in health care, it is meant to enable you to start looking at health care as a system.

3.4.3.6 Using the Handbook of Health Care Systems Engineering for Medical Students to fix the error in the PBL case

The PBL case that was given to the students included an error in medication. This error will be explored using the Handbook of Health Care Systems Engineering for Medical Students. The analysis will not be as complex as an investigation to this problem should be if it were to be conducted at a hospital, but it will illustrate the helpfulness of the handbook to medical students for identifying problem in systems terms.

Mr. Smith was given a medication that caused an adverse reaction (seizure). The medication was not appropriate. The contributed factors to this error were a breakdown of communication and the best practice not being administered.

From the handbook, the student should start with the questions that aid in error determination. *What is happening?*: the patient had an adverse reaction to a medication administered while at the hospital. *Why should I be interested?*: the patient had a seizure as a result of medication. This should not happen while a patient is administered care at a hospital in his condition and this error should not happen again. *Can the problem be described in systems terms?*: yes, the input was the patient, the process was the administration of medicine, the output was the patient having a seizure, and the feedback was the staff identifying the seizure and giving other medicine to stop it. *Which systems are of interest?*: the systems of interest are the administration of the medicine that caused the adverse reaction and the information and communication surrounding the patient. *What am I actually concerned with*?: the concern is why the patient received medication that caused a seizure.

The PBL case does not give much detail surrounding the error, so the actual cause is indeterminate. However, several causes can be speculated. Using the preconditions of a successful system, Section 3, the system did not have effective communication. The medication was known to cause seizures in people like Mr. Smith, but no flags were raised to stop him from getting the medication. The problem could be attributed to an inadequate database, improper reporting by the staff, or a breakdown in communication with a wider systems that deals with complications of medication. The sub-systems structure may also have inadequate sub-system structure. There may be a feedback loop missing or unable to alert the proper personnel or the communication with a wider systems may be lacking. Looking at Section 4, the Information and Control – Facilities crosschecking element may not be adequate. The medical process did not provide the necessary and correct information.

The problem has been identified; the system must be changed so that the error does not happen again. The PBL does not have many details about the surrounding system, so some general recommendations must be made. The overall theme of the improvements should be improved communication. The databases must be updated so that medications which can cause such adverse effects as seizures be flagged when they are to be administered. There needs to be a way to get the latest information about the medications to the people administering them. The medical processes must be provided more information about the components of the process so that interactions between elements are known.

3.4.3.7 Ideal System Formulation

The case above will now be analyzed to see how it should be set up using the three interrelated components of a system and their interactions. The system boundary will be defined as the delivery of medications in the hospital and all relevant surrounding activities.

Facilities: The facilities of this system should include all rooms and equipment necessary to administer medicine. These resources will likely overlap with other systems within a hospital. The room used will likely be part of a department within the hospital rather than be a dedicated room only used to administer medicine. The equipment should include sterilized tools for administering medicine and the necessary hardware for keeping accurate records and looking at patient history. The layout should aim to reduce clutter, be very organized, and be able to maintain patient confidentiality and safety.

Human and Organization: The system has to have qualified personnel and a clear chain of command so that the proper decisions can be made in an emergency. Clear duties among the staff must be assigned and periodical training on the latest knowledge should be conducted.

Information and Control: This section is very important in the administration of medicine. Drug interactions must be analyzed, proper doses must be calculated, and proper records must be kept. Any applicable regulations imposed by the hospital, government, or other entity needs to be communicated in this section. Patient records must be kept confidential yet be easy to modify or use as a reference. A relational database tied into the hospital's central database can be a good tool to use for this task.

The interactions between these sections must be considered.

Information and Control - Facilities: Each time medication is issued, it needs to be given in the correct dosage, by the correct method, and to the correct person. The information about the patient needs to be sent to the correct location so that the staff can access the information. Reporting the administration of medicine also is addressed in this crosschecking area. There must be a way for the staff to report what has been done in a timely and accurate manner so that it can be reflected in the patient's records. Any warnings about drug interactions and patient allergies (or any other adverse affects) must have a mechanism to communicate with the staff before an error takes place.

Human and Organization - Information and Control: When administering medicine, a qualified staff member should be the only one able to do the procedure.

Human and Organization – Facilities: The system of administering medicine should have adequate staffing to deal with fluctuations in overall demand of demand of a particular qualification. Shortages in personnel can result in delayed or incorrect treatment.

The systems of administering medicine should reflect the strategic goals of the wider system, the hospital. When critical decisions must be made, there should be tools present that direct the outcome to carry out the mission and objective set by the hospital.

3.4.4 Analysis of Past Objectives

The objectives from 2005 can be seen in Appendix C. The students received the same case as the one describes previously without the change to the PBL probing question. Out of eleven PBL groups in 2005, eight created an objective relating to reducing medical mistakes or improving health care. Two others had a portion of the objective dealing with the level of care but were not focused on improving medical care safety. None of the objectives included any mention of systems concepts, systems engineering, or related terms. The objectives titles relating to medical error/improvement were:

- Strategies for reducing medical mistakes.
- Discuss strategies to prevent medical errors.
- What are the effects and prevalence of medical errors?
- Discuss prevention of medical mistakes and strategies to combat them. Also know how to know when to move a person from a nursing home into a hospital
- Discuss the strategies that may be useful to reduce medical mistakes?
- Discuss strategies to reduce the incidence of medical mistakes.
- Understand the main causes of medical errors and what can be done to prevent them.
- Strategies to reduce medical mistakes.

The following two objectives include a small portion about the level of care:

- Address the cost considerations patients' face when considering Long Term Care Facility residence. In addition, discuss what infectious diseases are common in this setting, and what preventative strategies are employed.
- Discuss the psychological effects, methods of payment, and varying levels of care involved with life in long term care facilities.

The content of the objectives is not available but the titles give strong evidence that the students did not focus on investigating how systems engineering can help improve health care delivery. The inclusion of the altered case ideally would cause every group to create an objective about improving health care using systems concepts.

Chapter IV: Results

The student generated objectives for the PBL case with the changes made can be found in Appendix D. Ten of the twelve groups created an objective about medical error, though none included any direct mention of systems engineering. The objectives related to medical error are below and are followed by the objectives from the previous year:

Objective titles from new (changed) case (2006)

- Discuss medical error/malpractice and the associated institute of medicine report
- Strategies for the reduction of medical mistakes.
- Discuss strategies that may be useful to reduce medical mistakes.
- How do you control and limit medical errors
- Describe the methods hospitals and physicians use to prevent medical mistakes, including the Office of Clinical Effectiveness at MU.
- Discuss strategies that may be useful to reduce medical mistakes.
- Strategies that are useful to reduce medical mistakes
- Discuss strategies to reduce medical mistakes
- How to decrease medical mistakes
- Discuss the epidemiology of medical errors and the various strategies used to reduce medical mistakes.

Objective titles from old case (2005)

- Strategies for reducing medical mistakes
- Discuss strategies to prevent medical errors.
- What are the effects and prevalence of medical errors?
- Discuss prevention of medical mistakes and strategies to combat them. Also know how to know when to move a person from a nursing home into a hospital
- Discuss the strategies that may be useful to reduce medical mistakes?
- Discuss strategies to reduce the incidence of medical mistakes.
- Understand the main causes of medical errors and what can be done to prevent them.
- Strategies to reduce medical mistakes

The most encouraging objective title is the one that includes "the various strategies used to reduce medical mistakes." This could include systems engineering concepts. Another promising objective title is the one that mentioned the Office of Clinical Effectiveness. This office deals with improving health care delivery and uses some systems concepts. This objective likely included systems concepts. The rest of the objectives seem to be very similar to the 2005 objectives, many use the first part of the question about medical error in the objective title, "strategies to reduce medical mistakes."

An interview with Dr. Andrew Simpson, Block Director and PBL tutor, revealed some insight into the dynamics of the groups during the case. The students seemed to shy away from the unfamiliar terms and not focus on them while discussing the questions about the case. The addition to the PBL case did, however, spark some discussion about systems engineering and concepts, but was not deemed important enough to be the focus of an objective which is why it was not included in the title. The students focused on what is currently done to stop medical errors, not necessarily the theory or new techniques, such as systems engineering.

Chapter V: Conclusions

The students did not include any terms related to systems engineering in the titles of their objectives as hoped in this study design. Many valuable steps were taken in determining the best way to educate medical student about health care systems engineering and how it can be used to improve health care deliver. In addition, a relationship was formed between the Office of Clinical Effectiveness, the School of Medicine, and the College of Engineering, which could result in future collaboration.

There are many explanations why the objective titles did not reflect the change in the case. The case has been used for a while, and many tutors were the same as in previous years. They could have done the same thing they had been doing in the past and not place much importance on the additional material. Systems engineering is not a type of medical issue that the students have ever dealt with or have been tested on, so they could have focused on items they thought were more important.

The content of the objective could have included systems engineering, but the terms did not appear in the title. Dr. Simpson said this was likely the case as the student were not too familiar with the terms and concepts and neglected to put the terms in the title of the objective. It was not possible to get the actual objectives, the Office of

Medical Education only has the objective titles, they do not collect the actual objectives form the students. Having the objectives would have certainly helped in determining the extent to which the students researched the area and what they found important. A thorough briefing of all of the PBL tutors may have resulted in the tutors coaxing more discussion out of the students because the tutors would be more familiar with the terms.

Repeated exposure to the terms would be a good way to have the students place importance on the ideas of systems concepts and how they can improve health care. If several cases mentioned systems concepts, students would realize that it was an important concept, be more familiar with the terms, and go into more depth about the ideas. Dr. Simpson said the way the terms and ideas were presented "is probably the best way" to have the students lean them in a PBL curriculum. He is looking at changing other cases because he believes the addition of the new concepts made a positive contribution to the students' learning. Because many PBL groups used the terms from the question about medical mistakes in their objectives, repeating systems engineering terms should result in the students using these terms not only in their objective titles, but in the content of their objectives as well.

Using PBL to teach a specific idea is a challenging task. Students are not taught directly what to learn; they determine what is important and what they will learn. Trying to force them to learn about a specific topic, especially one that they are not used to seeing is difficult. The PBL format allows for the introduction of new ideas rather easily, but the students might not consider them important. Repeated exposure to topics may be an effective way to make sure students learn a desired topic.

Another way to get students to learn about systems concepts is to have a faculty generated objective about systems engineering early in the year then having a case later that has a problem with a system and see if the students use what they have learned in the previous case. Testing this would have to be done in another manner than in this research. Another way to change the case would be to add a different phrase to the same question that was changed in this research. More subtle language could be used, such as using "medical processes" instead of "systems engineering". The students could learn about systems engineering when researching medical processes.

In addition to adding systems concepts to more cases, future work would aim to expand the depth and breadth of student's understanding. The goal is to have physicians and other health professionals understand the importance of systems engineering, how it can be applied to health care, how they can use systems engineering concepts to improve the delivery of care, and be able to help those who are using systems engineering to improve care. The education of these topics should be ongoing through medical professionals education and career as a caregiver. The first two years of medical school at MU could include cases that force the students to make objectives on the topic in appropriate cases, but the third and fourth years should have some way to reinforce this knowledge, perhaps in a more clinical setting.

Having a resource for health care systems would also be beneficial to students and practicing health professionals. The resource should have basic systems concepts as well as case studies of how systems engineering has helped health care delivery so that continued improvement can be made.

The teaching of health care systems engineering should be expanded from future physicians to all health professionals. Continuing education should be required so that health care professionals are made aware of the latest advances in systems techniques as they relate to health care. Engineering schools should also offer classes, possibly a minor or major, in health care systems engineering. Health care is a complex specialty that cannot be understood without proper training. Bringing the health professions and engineers closer together by educating each other about their respective disciplines, should allow them to work more effectively in teams in order to improve the state of health care in the United States and worldwide.

The Handbook of Health Care Systems Engineering for Medical Students should be improved and expanded. There can be several volumes aimed for students as they progress through medical school. They will be exposed to more and more complex systems concepts as they progress through the series of handbooks.

PBL can be an effective way to teach systems engineering concepts if it is done in the proper way. The terms need to appear in several cases so that the students become familiar with the terms. The repeated exposure to the terms will encourage student to consider these topics important. The flexible format of the curriculum and method of teaching make this a potentially effective way to teach systems concepts to medical students.

APPENDIX

Appendix A

Interprofessional Curriculum in

Teamwork, Patient Safety and Quality

Monday, January 30, 2006 The Health Care Team	
10:00 – 11:00 AM Combined Learning Session - Bryant Auditorium	• Building functional teams • Health care team member roles • Interview with CF patient – Medical team
11:10 AM – 12:00 Noon Small Group Learning Sessions	• Introductions • Teambuilding activity with debrief • Information-sharing, re: professional training • Introduction to asthma case study

Monday, February 6, 2006 Improving Care With the Health Care Team	
10:00 – 11:00 AM Combined Learning Session - Bryant Auditorium	• Six IOM aims for good health care • Identifying the quality gap in health care • Introduction to the improvement model • Mapping out the flow of care
11:10 AM – 12:00 Noon Small Group Learning Sessions	• Review homework from asthma case • Review asthma patient's care in light of IOM aims • Choose one aim to design aim and measurement

Monday, February 13, 2006 Making Care Safer	
10:00 – 11:00 AM Combined Learning Session - Bryant Auditorium	• Introduction to patient safety • Human fallibility; theories of causation • Designing system interventions to improve safety
11:10 AM – 12:00 Noon Small Group Learning Sessions	• Review of aim/measurement for asthma intervention • Flow mapping exercise – Review of ER visit • Recognizing opportunities for improvement

Monday, February 20, 2006 Learning from Adverse Events in our Systems of Care	
10:00 – 11:00 AM Small Group Sessions	• Root cause analysis of medical error – medication error (delayed antibiotic therapy) in asthma patient with pneumonia
11:10 AM – 12:00 Noon Larger Group Debrief Session	• Debrief of root cause analysis exercise

Appendix B

Other Proposed Changes to PBL Cases

The following is a proposed change for a PBL case that can be applied to almost all cases. The bold text includes the answers to the questions and would only be available to the tutor. The last part of this Appendix includes concepts the students should cover when making an objective based on the narrative.

> Physicians have recently complained about errors coming from the lab. They have received lab results that were incorrect, for patients other than their own, and sometimes have not received any results at all. A consultant specializing in systems engineering was brought in and recommended several tools to improve the process including root cause analysis (RCA), data flow diagrams (DFDs), and creating process flow charts. These tools are usually used in manufacturing, but the consultant thinks they can be useful in health care. The goal was to determine the problems with the lab reporting process so that the errors would be reduced.
>
> What would you do to investigate the problems with the lab?
>
> **Analyzing the path taken by an order for a lab, how the order is processed, which people handle the request, what each person does with the request, what medium the lab is transferred on, and how the info is transferred and how it is transferred from the lab to the doctor. Each step could be drawn out and sources for error can be hypothesized – improper handoff of data, mixing up patient names while at the lab, incorrect**

transcription. Communicating with the people involved with the procedure is also important, as is determining if there are standard operating procedures and if these procedures are followed.

How would fixing the problem for this patient differ from fixing the problem so that it does not happen again?

Fixing the above lab may be as easy as reordering the test. It does not ensure the problem won't happen again, but it will satisfy the needs of the patient at hand. Fixing the problem so that it does not happen again is a bit more involved. Analysis into the process, as described above, is necessary. A collection the characteristics of similar errors would be helpful for identifying the main areas where the process fails. The process can be mapped then analyzed for bottlenecks, data transfer locations, human interference, and other sources of error.

What are possible consequences of these types of errors?

Some consequences of a faulty lab process include compromised patient safety, delays (increased patient stay), increased cost, decreased job satisfaction, and a backup at the lab.

Objective:

The students will hopefully produce an objective including:

Identifying a need for systems engineering tools to fix a problem in the case

Definition of systems engineering

- Identify ways in which it can help health care
- Determine appropriate aspects of systems engineering that can be uses in health care
- Stating in which they can be put into practice
- Systems tools that can help in health care
    - Process flow charts
    - Root Cause Analysis
    - Simulation
    - Human Factors considerations

Appendix C

Student Generated Objectives from 2005 (boldfaces objectives are those related to health care improvement)

Lab 1	-Drugs in the case – interactions & coverage -Interpretation of chest x ray -The diagnostic criteria & pathology of Streptococcus pneumoniae -Epidemiology of S. pneumoniae -Treatment of S. pneumoniae -Microlab overview -Mechanisms of antibiotic resistance -Etiology of seizure -Bacterial gene exchange -Overview of pharmakinetics -Antibiotic coverage and quiz -Discuss exotoxins **-Strategies for reducing medical mistakes** -Discuss laboratory values in the LP & how it is performed -Case 1-3 visual aids -Case 4-7 visual aids
Lab 2	-Provide an overview of histoplasmosis with a focus on epidemiology, diseases and diagnosis. -Review the etiology, pathophysiology, clinical manifestations and treatment of Parkinson's disease. -Know the mechanism of action, clinical uses, adverse effects, drug interactions and metabolism of the drugs used in the case. -Review the anatomy of the lung and relate it to the appearance of the lung on chest xray. -Describe the difference between rales and crackles. -Know the biochemical characteristics, virulence factors, and diseases of Streptococcus pneumoniae. -Describe the characteristics and biochemical necessity of vitamins E and C. -Discuss the different types of seizures. Provide a differential diagnosis for seizures. -List the causes of pneumonia and differentiate between community-acquired and nosocomial pneumonia. -Know the prevalence of pneumococcal resistance to penicillin and describe the mechanisms of resistance. -Know the distinguishing clinical and pathophysiolgoical features of the different bacterial causes of pneumonia. **-Discuss strategies to prevent medical errors.** -Know the criteria for hospitalizing elderly patients.

	-Know the normal opening and closing pressure for an LP. Would an LP still be performed if a CT shows increased intracranial pressure? -Discuss the significance of an elevated BUN:creatinine ratio with attention to dehydration and renal failure. -Distinguish viral and bacterial pneumonia based on their epidemiology and pathology. -Describe how a lung exam can localize pneumonia. -Know the appropriate empiric treatment of pneumonia. -Know the pathophysiology of the neurotoxic side effects of ciprofloxacin. -Know why ciprofloxacin does not reach adequate serum concentrations while levofloxacin does.
Lab 3	-Describe the mechanism of action of Serzone, Seroquel, and Vitamin E. -Why did the patient have pitting edema on the dorsum of his feet? -Describe the mental status changes occurring naturally as a person ages? In Parkinson's disease? -Describe lung anatomy. -Determining the severity of pneumonia, hospitalization vs. nursing home care, and overview of treatment. -Differential of a Grand Mal seizure. -Characteristics of Streptococcus pneumoniae. -What are the common causes of pneumonia in infants, children, adults, elderly? -What are the indications to do a CT before performing an LP? **-What are the effects and prevalence of medical errors?** -Nursing home overview (cost, requirements).
Lab 4	-Describe diagnostic course of action in the event of a sputum sample that is contaminated -Discuss the findings on the CXR and review the basic lung anatomy and breath sounds. -Know the relevant microbiology for S. pneumoniae -Discuss Grand Mal seizures and their relevance to this case -Know the clinical uses, MOA, and adverse effects of the drugs used in this case -What are the biggest risks associated with Parkinson's and nursing homes -Discuss polypharmacy in the elderly -Explain the drug coverage for beta lactams, agents that inhibit protein synthesis, nucleic synthesis inhibitors, and folic acid synthesis inhibitors **-Discuss prevention of medical mistakes and strategies to combat them. Also know how to know when to move a person from a nursing home into a hospital.** -Review pharmacokinetics -Review the microorganisms discussed by Dr. Thai -Reveiw the relevant microbiology of the organisms from the PBL cases -Discuss the most common causes of common infections: UTI, pneumonia, meningitis, etc. -Review the viruses discussed by Dr. Salzer.

	-Review common parasitic infections
Lab 5	-Understand the guidelines for hospital admission in patients with pneumonia (PORT score) -Describe the laboratory diagnosis, treatments, resistance mechanisms, and possible complications of Streptococcus pneumoniae -Describe the classifications, age-related causes, risk factors, epidemiology, clinical symptoms and presentations for pneumonia. -Discuss the radiological findings of pneumonia based upon microbial etiology. -Describe the bronchopulmonary segmentation of the lungs. Define what is meant by crackles in the lung fields. Correlate the findings to the correct bronchopulmonary segment. -Describe the drugs in this case including possibility of drug-drug interaction. -What is the significance of Vitamin E in the clinical setting? -Describe the common infections of long term care facilities. -Understand the common age-related causes of bacterial meningitis. Should dexamethasone be used for all patients with acute bacterial meninigitis? **-Discuss the psychological effects, methods of payment, and varying levels of care involved with life in long term care facilities.** -Discuss polypharmacy in the elderly. -Discuss the pathophysiology of seizure in meningitis.
Lab 6	- Provide a brief review of Parkinson's Disease and discuss later complications associated with PD. Are you more susceptible to infection if you have PD? - Discuss the MOA, indication, and side effects of drugs in the case - Discuss the excretion and metabolism of drugs, and discuss possible drug/drug interactions in this case - discuss infections and complications that are associated with the elderly, as well as with residents of a nursing home. discuss additional risk of infection and complications in patients who are incontinent, non-ambulatory, etc. - discuss streptococci pneumonia and its role in causing pneumonia - describe the differences between community acquired, hospital acquired, and nursing home acquired pneumonia, including risk factors, common pathogens, and treatment for each - discuss the etiology, diagnosis, pathophysiology, and treatment of seizures - discuss hot to differentiate the most common causes of community acquired bacterial pneumonia - discuss the clinical presentation of typical and atypical pneumonia and list the most common causes of each - describe the pathophysiology of necrotizing pneumonia, aspiration pneumonia, lobar pneumonia, and interstitial pneumonia - could this illness and its complications have been prevented? **- discuss the strategies that may be useful to reduce medical mistakes?**
Lab 7	-Penicillins -Quinolones and Metronidazole -Aminoglycosides and Tetracycline -Case drugs, possible interactions, and efficacy for treating S. Pneumoniae

	-Optimal Treatment for Streptococcus Pneumoniae -S. Pneumonia: CAP and Nursing home Management/ admission guidelines -Atypical and Typical Pneumonia -Seizures -Coagulation Cascade and Algorithms
Lab 8	-Discuss the choice of antibiotics used in this case's patient. -Review the anatomy of the lung and discuss the localization of pneumonia based on lung sounds. -Explain the causes of bacterial pneumonia and differentiate them by age. -Explain the techniques for recovering sputum samples and evaluate their efficacy. -Discuss the pathogen, S. pneumoniae, with emphasis on the diseases caused by this organism and ways to treat it antibiotically. -Discuss the criteria for hospitalizing patients with pneumonia. -Classify grand mal seizures and explain potential causes of this event. -Discuss cyanosis and differentiate between cyanosis that is central and peripheral. -Explain the different methods of vaccination and the way in which they transfer immunity. **-Discuss strategies to reduce the incidence of medical mistakes.** -Explain the criteria for diagnosing dementia, the difference between dementia and delirium, and discuss the format of a mini mental exam. -Discuss the methods of payment for nursing home costs and the role that medicare plays in covering any costs incurred. -Review and summarize the important antibacterial drugs discussed in block 4's lectures and cases. -Explain the process of isotype switching and review the structures and functions of antibodies. -Explain the process of coagulation and discuss the various disorders associated with coagulation deficiencies. -Explain the role of MHCs in the immune system.
Lab 9	-Describe the morphology, diagnostic tests, and pathogenesis of Streptococcus pneumoniae. -Discuss the epidemiology, clinical manifestations, and treatment of an S. pneumoniae infection. -Describe the radiological findings identified in cases of S. pneumoniae induced pneumonia. -Know the indications, mechanism of action, and adverse effects of Seroquel, Serzone, Sinemet, and Valium. -Discuss potential side effects of Ciprofloxacin; specifically describe the neurological side effects, and address which pharmacological treatment would have been more effective in this case. -Discuss the current vaccinations employed for protections agains pneumococcal infection. **-Address the cost considerations patients' face when considdering Long Term Care Facility residence. In addition, discuss what infectious diseases**

	are common in this setting, and what preventative strategies are employed. -Discuss the pathogenesis of pneumococcal meningitis. -Describe known causes of typical and atypical pneumnia. -Discuss the mechanism of prevalence of resistance of S. pneumo to: beta-lactam antibiotics, fluoroquinolones, doxycycline, trimethoprim-sulfamethoxazole, macrolides, azalides, lincosamines, and ketolides.
Lab 10	-Is pitting edema seen in DVT? -Review the anatomy of the lung. -Discuss elder abuse and the use of restraints. -Describe the methods of payment for nursing home facilities. -Discuss causes of the patient's seizure. -Discuss the pharmacological agents administered to this patient. Include levodopa/carbidopa, quetiapine, nefazodone, Vitamin E, omeprazole, ciprofloxacin, and diazepam. -What are the major causes of nosocomial and community acquired pneumonia? Discribe their microbiological properties. -Discuss the microbiology of S. pneumoniae. -Is corticosteroid therapy useful in adults with bacterial meningitis? **-Understand the main causes of medical errors and what can be done to prevent them.** -Describe the clinical uses, MOA, resistance and adverse events of the following antibiotic classes: -Macrolides and Clindamycin -Penicillins -Cephalosporins, Vancomycin, Carbapenems, Monobactams -Aminoglycosides -Quinolones/Fluoroquinolones -Sulfonamides and Diaminopyrimidines
Lab 11	-cold vs. flu, clinical presentation, causes, etc. -peripheral vs. central cyanosis -nfectious complications of Parkinson's -common infections in nursing homes -ung auscultation - anatomy, locations, meaning, interpretation in our case -Drugs from this case - increased or decreased risk of infection; was ciprofloxacin right or wrong in this case? -Hypersensitivity reaction (to catch up with other groups) -When to treat in nursing home vs. hospital -Grand mal seizures - why in this case? -Pathogenesis of pneumonia - causes, ages, acquired -Financing nursing homes - Medicare, Medicaid **-Strategies to reduce medical mistakes** -Could this disease have been prevented? -Staph micro, epidemiology, diseases, virulence, pathology (to catch up with other groups) -Von Willebrand, other factor defficiencies

	-Causes of nursing home pneumonia, hospital-acquired -Abuse and neglect in nursing homes -Agars, colonies, tests for bugs, seelective/differential media, TSI, urease, etc.

Appendix D

Student Generated Objectives from 2006 (boldfaces objectives are those related to health care improvement)

Lab 1	-Review Common Nursing Home / Opportunistic Infections -Give the indications, MOA, Side Effects of the Drugs Used in the Case -Review Nursing Home Neglect / Abuse -Discuss the similarities and differences between atypical and lobar pneumonia -Discuss the clinical symptoms, treatment, complications, pathogenesis, virulence factors, and diagnosis of Streptococcus Pneumonia -Provide a general overview of the antibiotic classes and their MOA -Review the pathogenesis of bacterial meningitis -Discuss the normal host immune response of the respiratory tract. -Discuss the connection between Cipro and seizures -Differentiate between interstitial, lobar, and broncho pneumonia including: Pathological differences, Causes, and different symptoms and imaging **-Discuss medical error/malpractice and the associated institute of medicine report**
Lab 2	Drugs: quetiapine fumarate and nefazodone HCl. Drugs: vitamine E and diazepam Drugs: Ciprofloxacin in the treatment of pneumonia. Types, causes, treatment of seizures. Causes and treatment of tonic-clonic seizures and post ictal effects. Hospital Acquired Pneumonia. Community Acquired Pneumonia. Lung Anatomy and its relationship to pneumonia. Friday: Mechanisms of Spread and Prevention of Health Care-Associated Infections. Common Fungal Infections. Overview of Antifungal Drugs. Liver Structure. Liver Function. Drug Metabolism and the cytochrome P450 system. Quiz over aspects of case. **Strategies for the reduction of medical mistakes.**
Lab 3	Describe the mechanism of action, use, classification and side effects of the drugs used in this case - Sinemet, Seroquel, Serzone, omeprazole, Vitamin E, Ciprofloxacin, diazepam, penicillin -G, oxacillin, Gentamicin, TMP/SMX, Cefotaximine, Ceftriaxone. Describe mechanisms of susceptibility of antibiotics. Describe how these medications may place him at an increased or decreased risk for infection.

	-Describe the physiological changes that are associated with aging. -What are the criteria for hospital admission for a patient with pneumonia. -What are the classifications of seizures and what infections can cause them. -Strep pneumoniae - describe the microbiology, virulence factors, disesaes caused by, complications. -Describe the bacterial causes of pneumonia and outline the pathophysiologic mechanisms of infection with S. pneumo. -Describe the viral causes of pneumonia and outline the pathologic mechanisms with H. influenza. -Describe the fungal causes of pneumonia and outline the pathologic mechanisms of Histoplasma capsulatum. -Describe the practice of medicine in nursing homes and long term care facilities. -Discuss the mechanisms of microbial resistance. -What is the approach to the patinet with pneumonia. -what are the chest x-ray findings in patients with pneumonia? Differentiate between atypical and typical pneumonia on the CXR and clinically.
Lab 4	-Discuss the presentation and cause of Grand Mal Seizures. Discuss other types of seizures. -Discuss the medical care of a nursing home patient. -Discuss the epidemiology, pathogenesis, diagnosis, manifesting diseases, treatment, and prevention of Streptococcus pneumoniae. -Know the MOA, clinical uses, adverse effects, and resistance (if applicable) of levodopa/carbidopa, quetiapine, nefazodone, vitamin E, omeprazole, ciprofloxacin, diazepam, oxacillin, and TMP-SMX. -Know the clinical utility and characteristics of different generations of cephalosporins. -Discuss sputum samples, chest x-rays, and evaluation of lung sounds. Understand the differences between lung sounds heard on physical exam. -Explain the diagnostic approach for a patient with suspected pneumonia. -Know the differential diagnosis of the presenting symptoms in this case. -Understand the epidemiology, causes, and management of atypical pneumonia. -Understand the epidemiology, causes, and management of typical pneumonia. **-Discuss strategies that may be useful to reduce medical mistakes.** -Know the most common causes of pneumonia in different age groups. -Understand the pneumococcal vaccines. -Discuss the anatomy of the lungs. Explain the mechanisms of innate immunity in the lungs. -Describe the pathophysiology of pneumonia and how it relates to the clinical manifestations. -Review meningitis as it pertains to elderly patients. Explain the predisposing factors (is Parkison’s one?) and specific causative organisms in this age group. Describe the differences in the clinical presentations of meningitis and meningoencephalitis.
Lab 5	-Review Parkinson’s disease. Could this patient’s Parkinson’s be contributing

	to his dementia? -Describe the types of seizures. How are seizures classified? Describe some common causes of seizures. -What causes a widened pulse pressure? What is the underlying physiology behind a widened pulse pressure? Relate intracranial pressure and wide pulse pressures. -Describe mechanism of action, side effects and indications for all drugs in this case. -Describe differences in community acquired and nosocomial pneumonia. Include epidemiology and common causes. -Know important characteristics, how to identify using diagnostic tests, transmission, pathogenesis, and common diseases of Streptococcus pneumoniae -Describe presentation and management of community acquired pneumonia. Compare CAP between infants/children and the elderly. Include the criteria for hospitalization. -Know signs and symptoms on the physical exam as well as radiological findings for different causes of pneumonia (include the difference between typical and atypical presentations) -Know characteristics of both endotoxins and exotoxins. -Describe the psychological aspects of being wheel-chair bound and the psychological aspects of restraints. -Review the enteric bacteria, how different organisms present clinically, and how to identify them using diagnostic tests. -Describe treatment of pneumonia for the most common different causes.
Lab 6	-Overview of influenza virus with particular attention on clinical presentation -Pneumonia - causes, clin. pres., complications, pathophys -MOA, indications, side effects of drugs in the case -Discuss the pitting edema, what does it mean, how do you grade edema -Where was the pneumonia located anatomically in the case, know lung anatomy and its relationship to the heart -Know the typical findings on chest X-ray for pneumonia -Procedure, sensistivity, specificity of the sputum culture -Details of Strep. pneumo - morphology, characteristics, virulence, syndromes -Know the criteria for admitting a patient with pneumonia -Overview of grand mal seizures, acute treatment -Overview of antibiotic classes -Know the mechanisms of bacterial resistance. -Know the structure of nursing homes, payment, medical care offered there, criteria for staying in one, common infections/dangers in a nursing home -General overview of seizures, focusing on causes and classification **-How do you control and limit medical errors** -Explain the pneumococcal vaccine - efficacy, basic mechanism
Lab 7	-Describe the mechanism of action, clinical indications, and adverse effects of Quetiapine fumarate, nefazodone hydrochloride, omeprazole, vitamin E, levodopa/carbidopa, ciprofloxacin and diazepam.

	-Describe the clinical manifestations, epidemiology, and etiology for community acquired pneumonia -Describe the clinical manifestations, epidemiology, and etiology for nosocomial pneumonia -Describe the progression of Parkinson's disease. -Describe the normal lung sounds and explain abnormalities found on auscultation. -Explain the pathogenesis, virulence factors, diagnosis and treatment of *S. pneumoniae*. -Describe the approach to a patient with suspected pneumonia, including physical examination, laboratory and radiologic diagnosis and treatment. -Explain the pathogenesis, virulence factors, diagnosis, treatment and diseases caused by *M. catarrhalis* and *Chlamydia pneumoniae* -Explain the pathogenesis, virulence factors, diagnosis, treatment and diseases caused by *Legionella pneumoniae* and *Mycoplasma pneumoniae*. -Describe meningitis in the elderly. -Compare drug clearance by the liver and the kidney. -Compare atypical pneumonia vs. typical pneumonia, including presentation, etiology, diagnosis and laboratory findings. -Describe the innate/normal defense of the respiratory system. -**Describe the methods hospitals and physicians use to prevent medical mistakes, including the Office of Clinical Effectiveness at MU.**
Lab 8	-Know the MOA, adverse effects, and clinical uses of the drugs used in this case, emphasizing the possible poly-pharmacy side effects shown in the patient. -Understand the different types of media, whether they are selective or differential, and which ones are specific for which organisms. Also, be familiar with the TIU tests. -Be familiar with a differential of pathogens that cause CAP, nosocomial pneumonia, and CAP from long-term care facilities. -Understand the types of infections commonly seen in residents of long-term care facilities and the organisms that cause them. -Briefly review the pertinent principles of pharmacokinetics. -**Discuss the epidemiology of medical errors and the various strategies used to reduce medical mistakes.** -Explain the development of genetic and non-genetic mechanisms of resistance to antimicrobial agents -Give a general overview of seizures and review the etiologies of seizures in the elderly. -Discuss common antiviral and antifungal treatments available. -Known the Clinical Presentation of Typical and Atypical Pneumonias -Know the Guidelines for Empiric treatment of CAP and LTCF pneumonia -Be familiar with the colony morphology, virulence factors, and associated diseases of S. pneumo and Mycoplasma pneumoniae. -Describe the complications of pneumonia -Determine the pathology associated with a Pneumococcal pneumonia

	infection. -Demonstrate the normal lung anatomy and the associated areas of auscultation, as applies to this case.
Lab 9	-Drugs: Vit E, classes of anti-depressants, last q. on page 2, cipro and association w/ seizures -Emperic treatment for: hospital and community acquired pneumonia -Evaluate tx given in case and determine next steps for management in the patient -Diagnostic workup for suspected pneumonia: PE findings, presentation (specific to age groups) -Epidemiology: what etiologic agents are common to certain age groups, common causes in community acquired vs. hospital acquired pneumonia, classification of CA vs HA -Complications of pneumonia, hypoxia w/ pneumonia -Seizures: classification, why it occurred w/ this pt, brief approach to pt w/ seizures -Interpret CXR and common findings in pneumonia -"Typical pneumonia"—common agents, pathopys, overview of "atypical" versus "typical" pneumonia **-How to decrease medical mistakes** -Location of crackles and association w/ radiographic location -Algorithn for treatment of pneumonia -Review coag lecture -Pharmakokinetic lectures -Antiviral review -Antibiotic book use and quiz -Dr. Thai spreadsheet (first 6 bugs)
Lab 10	-Discuss the clinical use, mechanism of action, and side effects of the drugs introduced in the case: Levodopa/carbidopa, Quetiapine, Nefazodone, Omeprazole, and Vitamin E. -Discuss the clinical presentation and common bacterial pathogen found in Community Acquired Pneumonia and Hospital Acquired Pneumonia -Discuss the different options available for senior citizens who are unable to live independently without assistance. Be sure to address cost, options for financial assistance, and psychosocial issues associated with senior living facilities. -Be familiar with the pathogenic etiology of community-acquired pneumonia, nosocomial/healthcare-associated pneumonia, and the etiologic differences between adult and pediatric pneumonia pathogens. -Describe the common causes of seizure in the elderly -Describe what is necessary for medical consent especially for the unconscious patient -Know the guidelines for a good sputum sample. Discuss immunizations for the elderly, especially before entering a long term care facility. Know the protocol for restraining non-ambulatory nursing home residents. Discuss the admission guidelines for nursing home patients.

	-Know the characteristics of the common pathogens for viral and fungal pneumonia -Describe the pathophysiology of pneumonia -Outline the MOA and adverse effects for ciprofloxacin and diazepam. Also, describe the empirical treatment for pneumonia in the elderly, including whether Mr. Smith's physician's gave him the proper treatment. **-Discuss strategies that may be useful to reduce medical mistakes.** -Discuss the morphology, epidemiology, clinical presentation, and treatment of infections with *Streptococcus pneumoniae*. -Review the basics of CXR interpretation. Discuss the films pertinent to the case and interpret the abnormal findings. -Review normal breath sounds. Discuss the clinical significance of abnormal findings during the PE and their relevance to localizing pathological processes present in the lungs.
Lab 11	-Discuss nursing home medical care, including common illnesses in that setting. -Know the complications of Parkinson's and the common drugs used in - Parkinson's patients (levadopa/carbidopa, quetiapine fumarate, nefazodone) -Know the epidemiology, virulence factors, diseases, and laboratory tests associated with *streptococcus pneumoniae.* -Be familiar with the MOA, indications, pharmacokinetics, and adverse effects of ciprofloxacin -Know the epidemiology, presentation, diagnosis of pneumonia. Know the guidelines for admitting patients with pneumonia. -Discuss the various etiologies of pneumonia. Include their presentations and treatment. -Know the pathophysiology of pneumonia, including complications and how hypoxia develops. -Review Acid/Base balance. -Evaluate the findings of the patient's chest x-ray. -Understand what composes grand mal seizures. Know the differential diagnosis and the role of diazepam. as a treatment **-Discuss strategies to reduce medical mistakes** -Review the classes of antibiotic classes, particularly noting their mechanisms of action and clinical uses. -Review the antiviral medications. -Know the pathophysiology of encephalitis -Discuss physical exam findings of pneumonia -Be familiar with the principles of bacterial resistance
Lab 12	-Mechanism of action, complications, indications for Sinemet, Seroquel, Serozone, Vitamin E, Omeprazole, Ciprofloxacin, Diazepam. -Complications of polypharmacy. -Signs of normal aging and meningitis in the elderly -Streptococcus pneumoniae: identificaiton, virulence factors, clinical presentation, pathophysiology, and treatment -Community Acquired Pneumonia: epidemiology, signs and symptoms, labs,

	radiology, treatment5 -Hospital Acquired Pneumonia: epidemiology, signs and symptoms, labs, radiology, treatment **-Strategies that are useful to reduce medical mistakes** -Long-term care facilites and pneumonia. -Nosocomial infections -Atypical pneumonia: Mycoplasma, Legionella, Chlamydia, Viral pneumonia -Lung anatomy, normal sounds, crackles, what to expect with pneumonia -Algorithm for pneumonia treatment -Permission for emergency treatment in an unresponsive patient -Seizurs: classifcations and causes

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