Unified Modeling Language in History and Social Science Education

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***Abstract*— This paper addresses using Unified Modeling Language (UML), a proven and well supported technology, in teaching problem solving skills to middle and high school age students. UML has been successfully used by software industry as a standardized graphical modeling language in specification and design of software systems. The paper focuses on the phase of our project involving teaching history and social science. It advocates relevance of our approach and illustrates how modeling in UML can be effectively utilized in teaching of these subjects. Paper also addresses aligning of our approach with curriculum standards driving K-12 education.**

Keywords: analytical skills, problem solving skills, best practices, modeling, K-12,

I. Introduction (Heading 1)

Our project is part of a larger initiative launched by the Computer Science Department at the University of Massachusetts Dartmouth to improve problem solving skills of college freshman through collaborations with K-12 stakeholders by using information technologies in middle school and high school classrooms.

The overreaching goal of our project is to improve problem solving skills of students, by utilizing tools and methodologies successfully used by software industry in the process of software development. The idea was born from the realization that software is a solution to a problem addressing specific needs of a user/customer, and that frequently the description of the problem (need for particular software) is initially very brief, very general (expressed at high level of abstraction), and vague. The process that follows, called “requirements analysis and design”, aims at developing a precise model of requirements (what the system is supposed to do) in a form that can easily be understood by the developer, as well as by the customer/user. Only under these circumstances can the model be elaborated by both parties in the process of scoping the problem, and thus scoping its solution (software to be constructed).

The same tools and methodologies are used for domain modeling – the process of capturing information about a specific domain. A domain can be considered a system that consists of specific entities (objects, people, and institutions) that are connected through well-defined relationships and interact with each other through these relationships in a process aimed at achieving particular objectives/results. For example, the domain of banking can be described/modeled as a system of banking institutions regulated by federal agencies conducting business with each other, and with the customers (retail and commercial) in managing money. Constructing a precise model of a banking domain could serve many purposes:

- Questioning the correctness – discovering some constraints that are either not represented (we knew of them but did not capture them in the model), or are missing and should be there for the domain to function correctly (adding new knowledge of the domain).
- Asking hypothetical questions about possible scenarios under particular constraints (state of the system)
- Exploring the domain in teaching/learning/training

Models developed with a high level of precision can actually be executed by a computer. In such cases, the model itself represents a system/software to be built and the user, by interacting with the model, can determine if the functionality captured by the model meets the user’s needs/expectations.
For example, company developing software for an airplane can construct an executable model representing the control systems of an airplane (system to be built), attach the model to a user interface simulating the instruments of the plane’s cockpit, and ask the pilot to fly the airplane (model). Through this process, flaws can be discovered indicating deficiencies in requirements (captured by the model) and the behavior expected by the user. This approach, although expensive, may lead to the discovery of problems which, if left unnoticed until the actual system development phase, would result in huge cost and schedule overruns.

II. Addressing Chalanges of Using UML in K-12 Classrooms

Utilization of tangible and non-tangible representations of concepts in the process of teaching and learning is as old as humanity. Our ability to construct abstract models and manipulate them in our mind in the process of searching for answers is the basis for our ability to learn. Developments in computer technologies accelerated our ability of creating models at a rapid pace, at low cost, and at a high level of precision. This came with the additional benefit of automated, fast, reliable, and verifiable manipulation of these models.

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This project focuses on using Unified Modeling Language (UML) technology as an aid in improving students' analytical and problem solving skills. UML has been chosen for this purpose because of its proven success record as an analysis and design technology in software engineering and because of its relevance to problem solving.

While working on this project we had to consider the constraints of our K-12 partners. The priorities and use of resources in public school systems are driven by assessment, and the improvement process based on standardized testing mostly focused on two key areas: English and Mathematics. School districts are reluctant to engage in initiatives other than those directly related to the improvement of skills in these two subjects. The standardized testing in STEM subjects is emerging, but does not have the attention given to English and Mathematics. No matter what the area is, the true focus is on 10% of students who, by a small margin, do not meet the proficiency requirements in standardized testing. At national, state, and local school district levels, we focus all of our limited resources on intervention programs to bring this group of students over the required threshold level. The entire education system is driven by a goal of meeting the minimum proficiency requirements –"No child left behind!" This paper does not engage in the discussion of social policies or political aspects of the education system. The acknowledgment of these policies just sets the stage for discussion of our approach.

In our collaborations with public school systems we focused on teachers. To identify and gage their challenges and concerns in getting involved in this project, we conducted a pilot study through two graduate education courses attended by practicing teachers. The findings of this study are reported in [2, 3]

The biggest challenge for the teachers was to relate the proposed UML-based approach of teaching problem solving skills to existing K-12 curriculum. To address this issue, we conducted a series of projects addressing the mapping of UML modeling methodologies to the existing Massachusetts Curriculum Frameworks [1, 4]. The Frameworks define academic content, concepts, and the set of skills to be acquired by the students through their K-12 education.

Each Framework addresses a specific subject and is organized into Strands representing a highly cohesive set of specific Learning Standards, each with specific merit and purpose. Learning Standards address specific skills and outcomes students must acquire in order to demonstrate proficiency. For Frameworks for Mathematics, and Science and Technology/Engineering, we mapped the use of UML to specific Learning Standards [1]. In this paper, we address the use of UML in teaching History and Social Science. The approach used here was slightly different due to the nature of the discipline. Instead of focusing on specific learning standards, we chose to identify categories of analytical problems typical for study of subjects addressed in the History and Social Science Curriculum Framework.

III. RATIONALE FOR USING UML

UML allows for capturing concepts and their properties, and constraints. It makes provisions for modeling relationships between concepts, and for recording of the constraints on these relationships. Relationships such as association, aggregation, generalization/specialization, and dependency have distinct graphical representation. UML allows modeling of states of entities, and transitions between the states as caused by events or conditions. Processes and process flows (including concurrency) can be graphically represented as chains of activities controlled by events and logical conditions. Causal, temporal, and structural relationships between the entities can be represented to facilitate analysis.

UML facilitates effective and precise communication. It can be used in many capacities to create examples illustrating particular concepts. It can be used to aid live discussion on a specific topic, where the current diagram representing the findings of the discussion that took place until this point, serves as a baseline for the discussion to follow. UML makes concepts easier to understand, especially in cases of multifaceted problems. Use of UML improves comprehension and makes ambiguity, inconsistency, and incompleteness much easier to identify than in conventional non-graphical types of modeling techniques.

The study of History and Social Science involves the specification and analysis of relationships between people, organizations, and objects and events (processes) involving human race. It elaborates on historical perspective; and studies the dynamics of social, political, economic, and cultural systems created by people and impacting peoples' behavior.

UML offers several types of diagrams that can be used effectively in the study of History and Social Science. Class Diagrams could be used to demonstrate the level of abstraction (generalization, specialization), the relationship of containment and being contained (aggregation), awareness and knowledge (association), and the binding of concepts at their definition level (dependency) in the context of studying History. State Diagrams could be efficiently used to represent the transformation of an idea triggered by critical events and/or changes in conditions including passage of time. Activity Diagrams can be used to express the timelines or causal/effect flows of changes, and significant decision or condition change points attributing to the development of an idea. Furthermore, Activity Diagrams can also capture the notion of parallelism, and thus allow for the study of two or more concepts in comparison with each other, as they progress in time and impact each other. Use Case Diagrams can be used to describe stakeholders or participants and their roles as they interact with a system (For example: society, organization, movement) and impacting system's state and behavior. Sequence Diagrams can be utilized to represent a single sequence of activities taking place between several entities (For example: individuals, organizations, countries) in the context of specific historical events, or a particular thread of a social or historical process.

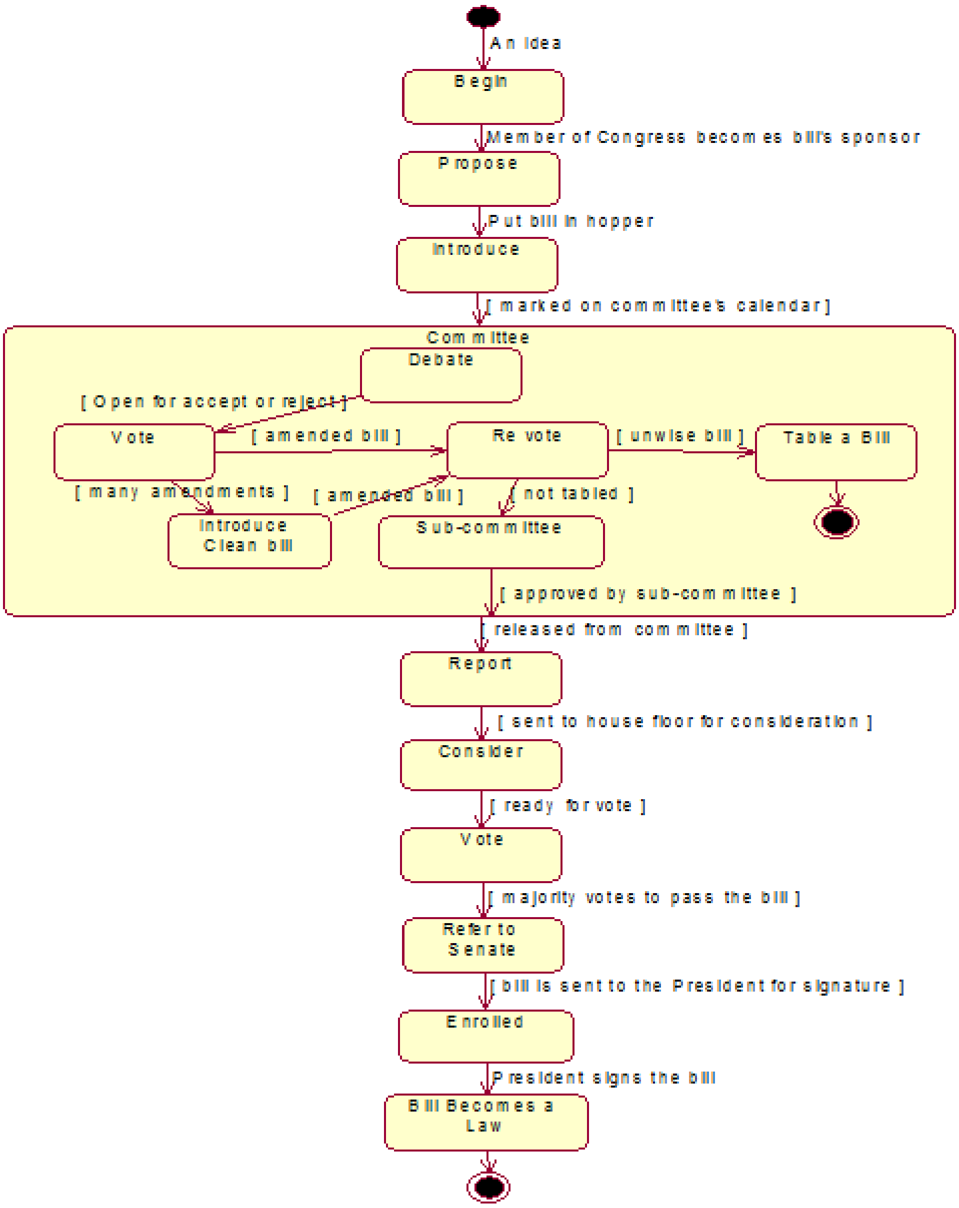

Figure 1 How a Bill Becomes a Law

The benefits of using Unified Mode4ling Language can be summarized as follows:

- Intuitive and easy to learn
- Supported by many free software tools with plenty of easily available literature
- Graphical – allows for faster and less error-prone verification in the context of analysis or testing students' knowledge and skills.
- Standardized – well-defined graphical representation of symbols and their semantics
- Precise – allows for the capture of precise facts and constraints that can be verified using logic
- Scalable – allows for modeling of information at various levels of abstraction and, through nested diagrams, allows traversal between these levels (analysis versus synthesis)
- Has a proven track record in software industry, and thus will be supported by tools in years to come.

- Allows for the modeling of the structural and as well as behavioral properties of a system

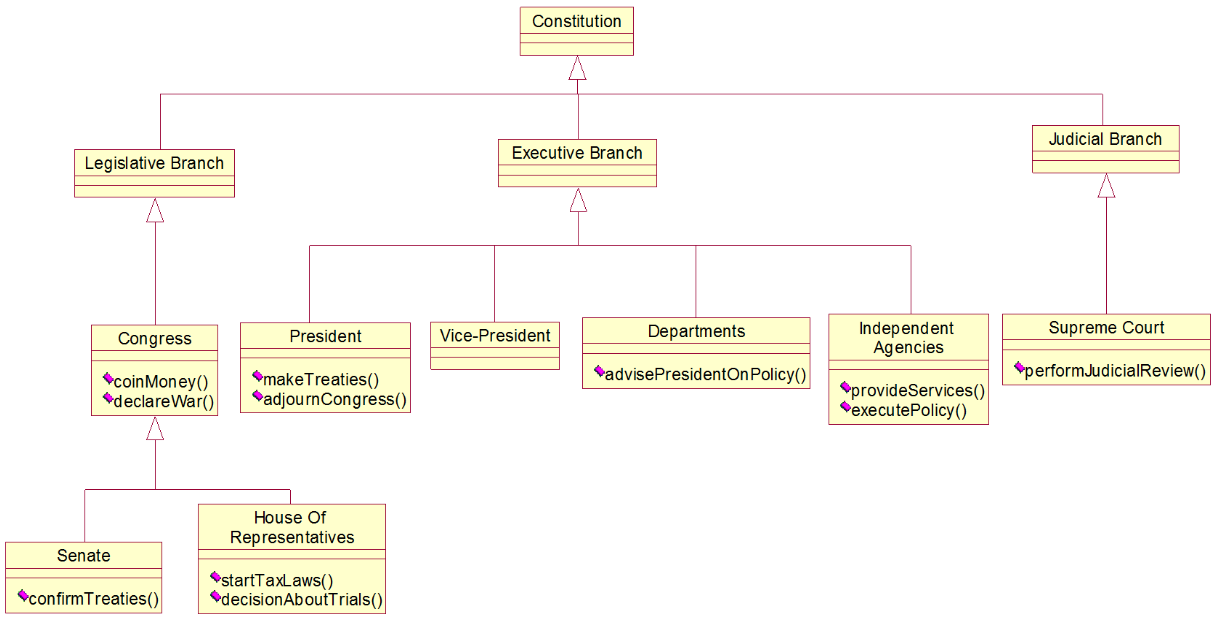

Figure 2 Branches of US Government

IV. Our Approach

Analysis of the Massachusetts Curriculum Frameworks, combined with the consultation of faculty teaching History at UMD, resulted in identifying the five categories of problems encountered in the study of History and Social Science. Each problem category was given a context in History and Social Science by stating more specific problems in these domains. For each problem category, a specific type of UML diagram was indicated as the most suitable tool for problem modeling and analysis. For each problem category, a case studies were provided to illustrate the use of the recommended diagram to visually represent results of analysis of a concrete problem in the History/Social Science domain.

Due to space limitations only three diagrams from our case studies are provided in this paper to illustrate the point.

*A. **Category I***

Expressing changes of states of an object, subject or process triggered by events, conditions or passage of time.

<u>UML Diagram</u>: State Diagram

<u>History/Social Science Context:</u>

- The change of opinion/position as it applies to some specific historic/social issue as held by an individual, group of people, government or organization.
- Changes that occur in a movement, or political or social action based on events, changing conditions or constraints (for example laws) or passage of time.
- Changes that occur to an entity (social contract, treaty, law) as result of interaction with stakeholders in a specific organization or domain.

<u>Case Studies:</u>

- How a treaty evolves. Nuclear Non-Proliferation Treaty.
- African-American Civil Rights Movement
- How a bill becomes a law – Figure 1

*B. **Category II***

Exploring concepts of a specific domain and how they relate to each other; expressing evolution of a concept in terms of specialization/generalization, study of the relationship between concepts, individuals and organizations as groups of individuals.

<u>UML Diagram</u>: Class Diagram

<u>History/Social Science Context:</u>

- Identify entities (individuals and/or groups of individuals and their mutual relationships in a specific social or legal system.
- Understand various aspects/facet of historical or social concepts

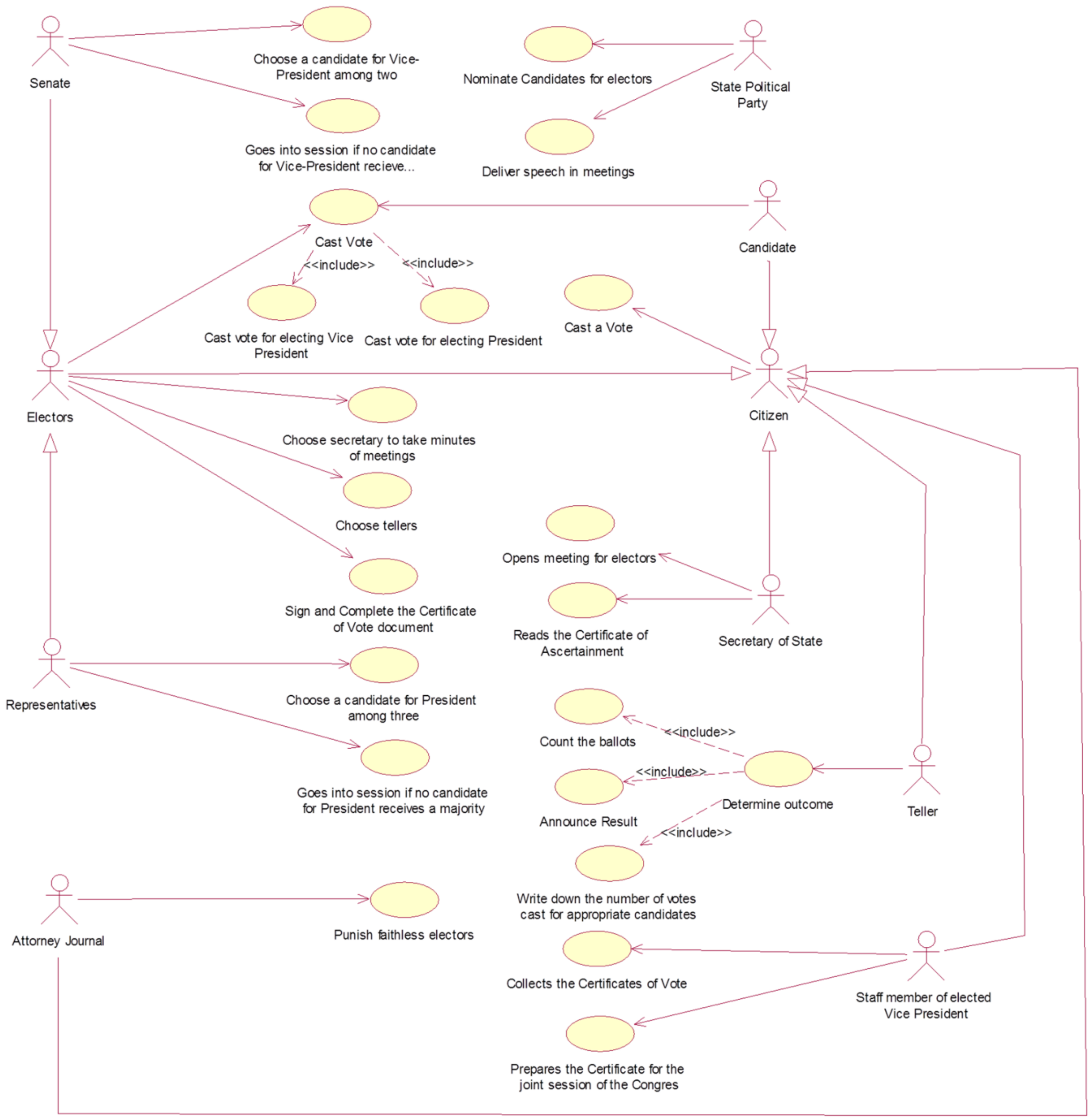

Figure 3 US Voting System

<u>Case Studies:</u>

- Relationships/Roles of Congress, President and other legal bodies pertaining to passing a bill
- Types of civil freedoms and how they are related.
- Branches of US Government – Figure 2

C. *Category III*

Exploring processes as chains of interrelated activities and events in the context of specific timelines. Examining participation/roles different stakeholders play in a process by performing specific activities and/or triggering specific events.

Exploring processes interleaved in time with a common set of stakeholders.

UML Diagram: Sequence and Activity Diagram; The Sequence Diagram is used to explore a single sequential path, while the Activity Diagram considers a parallel chain of events and their mutual interaction with possible mapping of activities of the process to specific stakeholders .

History/Social Science Context:

- Analyze historical/social process by decomposing it into a logical progression of individual events spread in time and connected by mutual relationships. (How a historic event evolved over a time period)
- Study chain of events and conditions with temporal or causal relationship leading to the event of interest.
- Study progression of a historic event in the context of the progression of other historical processes (chains of events)

Case Study:

- World War II

*D. **Category IV***

Analyzing Cause and Effect

UML Diagram: Activity Diagram (Activities and States)

History/Social Science Context:

- Explore the effects of a particular historic event on participants (including triggering of other processes or events).

Case Study:

- Effect of Industrial Revolution on American life

*E. **Category V***

Exploring roles of stakeholders in the context of their interaction with a system.

UML Diagram: Use Case Diagram

History/Social Science Context:

- Study of what different roles are possible in interaction with a system.
- Study the participation and interaction of different roles/ individuals/organizations with a specific social, political, and legal system.

Case Study:

- US Voting System – Figure 3

CONCLUSIONS

The advantage of our approach is that students can express, and learn an idea using a graphical representation (UML diagrams). They can use UML diagram as the backbone for the information about the idea and a road map for discussion and collaboration with others (students and teachers). Using representation that combines graphics and text (and allows for management of bindings between graphics and text) makes teaching and learning more efficient and effective. It is easier, not only to make modifications, but to also identify errors and omissions such as inconsistencies, contradictions, non-determinism, missing facts, and constraints. For teachers, the proposed approach drastically reduces the preparation time related to the development and production of class materials and allows for more efficient and meaningful use of time with the students in the classroom. It lends itself very well in facilitation of group projects and group discussions. Most importantly (for teachers), our approach drastically reduces the amount of time spent on grading. Analyzing students' answers to analytical problems is very time consuming as it requires: careful reading of large amounts of text in an attempt to follow a logical argument to determine its correctness (Are all the facts there in the right order and are they linked together through the correct relationships?), consistency (Are the facts used consistently and are the semantics of facts preserved throughout the argument?), and completeness (Is anything missing?). Grading answers provided by students in the form of UML diagrams can be done in a small fraction of time, in comparison to the time required for grading text-based answers.

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