Using Technology to Enhance Education in Saudi Arabian High Schools

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SELP 695 – 01 System Engineering Integrated Project
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Systems Engineering Methodologies & Project Overview

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Saudi Arabian Public Education System

**Education Expenditure**

- 6.8% of Saudi Arabia's Gross Domestic Product (GDP)
- 25% of Saudi Arabia's Government Budget

*(World Bank, 2004)*

**Ministry of Education**

- Primary (Elementary)
- Middle School (Intermediate)
- High School (Secondary)

**Ministry of Higher Education**

- College and Universities
- College-level education is publicly provided (free)
- Available to citizens after graduation from High School
KSA Government Education Investment

"Human Capital Development is a national priority."

– Saudi Arabia General Investment Authority (SAGIA)

• Huge investments made in Public Education
  
  • In 2012, total investment was $39.5 billion.
  
  • In 2014, total investment was $35.2 billion. However, King Abdullah invested additional $21 billion in education system, to reach $56.2 billion
  
  • Total investment in education in 2015: $57.9 billion

HUMAN CAPITAL

Human Capital Development (HCD) is a national priority as it is the core of creating knowledge based society.

Figure: SAGIA Website (2015)
Issues and Criticisms of KSA Education

- Criticisms of KSA Education
  - “Struggle between moral tradition and teaching”
  - Conservative moral tradition
  - Conflicts with Western globalized educational perspectives and ideologies
  - Discouraging freedom of thought
  - The system, teachers and education officials are resistant to change
  - Lacking focus on technical skills and adapting to employer and economic needs
  - English is not viewed favorably, “view English as vessel for Western ideologies”
**Prior Attempts to Change KSA Education**

- Major criticism of KSA education is textbook content
- Textbooks contain excessive ideological and subjective content
  
  — News Article from Boston Globe in 2005

- Ministry of Education pushed to address criticisms - 2006

- "**Comprehensive Curricula Development Project**"
  
  - Project managed by KSA Ministry of Education to update textbooks used for instruction.
  
  - Expected to only take a few years to complete. However, it is still in-progress (2015).

- Reason for delay in Project Implementation and Completion:
  
  - Disagreement among Ministry of Education Officials.
  
  - Resistance to reform and change. As late as 2009, “refusal to acknowledge the need for change.”
Literature Review

- **Education and Technology**
  - Technology use in education is a popular topic in the academic literature.
  - Use of technology in education to influence outcomes has been growing.
  - Wide variety of technology used to improve and facilitate delivery of education and student outcomes.
    - Hardware
    - Electronic Textbooks
    - Multimedia
    - Software Programs
    - Websites
    - Network Infrastructure (Wi-Fi)
Literature Review

- **Education in Saudi Arabia**

- Literature heavily focused on criticisms of KSA Education System.

- Cultural and societal challenges to implement changes to education.

- Implementing change requires teacher involvement to adopt changes and prevent issues and to avoid confusion. *(Wedell & Alshumaimeri, 2014)*

- Tradition is very important in education culture. *(Nafjan, 2014)*

- Prior attempts to make changes to education content or teaching faced strong pushback. *(Nafjan, 2014)*

- Use of internet in education conflicts with traditional approach of teaching.

- Preference of teachers for physical classroom environment, which allows teachers to maintain “power”, which is lost using online education. *(Elyas & Basalamah, 2012)*
Problem Definition

- Identified Problem with High School Education in KSA
  - Graduates of high school not prepared with skills desired by employers
  - Graduates are having difficulty finding good jobs
  - High school graduates not exposed to technology

"At present, there is a significant gap between the needs of business and industry, and the skills and knowledge being provided by the country's education system. Young Saudis are finishing their education at higher levels than ever before, but are finding it increasingly difficult to find meaningful employment."

- Gulf Cooperation Council (GCC, 2014)
Key Objectives

Key Objectives Provide confidence that the business case is sound and the proposed solutions are achievable.

Key Objectives

- Improve educational outcomes of High School Students
- Modernize education system infrastructure
- Expand educational resources available to students and teachers
- Facilitate and improve delivery of education and instruction
- After graduation, students are better prepared to compete for:
  - Educational Opportunities
  - Employment Opportunities

Reference: INCOSE
Systems Engineering Plan (SEP)

- Systems Engineering Plan defines the processes and principles of developing and implementing system solution to the defined problem.

**Systems Engineering Plan**

- Identify and document customer and user requirements.
- Propose and evaluate alternatives using MoEs.
- Identify and justify optimal system concept to proceed to SE development stage.
- Define system architecture, including key elements and sub-system level architectures
- Define the Integration, Verification and Validation (IV&V) Plan
- Use project management/risk management to mitigate risks to implementation
- Identify ethical issues throughout the systems engineering process
- Use lean thinking to minimize waste and maximize value

Reference: INCOSE
Identify Key Stakeholders

- Customer/User: KSA Government
  - Ministry of Education (Systems Integrator – establishing system requirements)

- Users
  - High School Students
  - High School Teachers
  - High School Administration

- Contractors
  - Hardware/Device Manufacturer
  - Education Technology/Software Development Companies
  - Infrastructure Development

- Other Key Stakeholders
  - Parents, Families and Relatives of High School Students
  - Private Employers
  - Colleges & Universities
  - KSA Citizens
Top Level Stakeholder / User Requirements

1. The system shall provide ease of access to all users.
2. The system shall provide all users with hardware required to interface with system.
3. The system shall integrate sub-systems and elements to ensure proper system functions and capabilities.
4. The system shall include infrastructure to support multiple simultaneous users and content delivered in teaching and instruction.
5. The system shall be reliable and online 90% of time (during instruction).
6. The system shall include security to prevent external or unauthorized access.
7. The system shall facilitate communication and delivery of important announcements.
8. The system shall be monitored and controlled for appropriate use.
9. The system shall provide open access to academic and educational resources.
10. The system shall provide users with equal access to learning opportunities.
11. The system shall provide on-going support from vendors or contractors.
12. The system shall provide training for all users.
Alternatives

- Based on the needs of stakeholders and their requirements, alternative system architectures were considered:

1. **Technical Programs in High Schools and Establish Vocational/Trade Schools**

2. **Online Education and Virtual Classrooms**

3. **Educational Technology in High Schools**
Alternative Solution 1:
High School Technical Programs and Vocational Schools

- Technical programs and job specific training in high schools.

- Establishing vocational/trade schools.

Advantages & Disadvantages:

- Meet the needs of employers and national economy.

- Technically train graduates to develop skills needed by industry.

- Designed for students who desire to join workforce directly after graduation.

- Due to benefit to employers, may be possible to attract investment and endorsement by companies highly demanding technically trained graduates.

- Requires physical infrastructure including buildings and classrooms.
Alternative Solution 2: Online Education and Virtual Learning

- Online education and virtual classrooms:

  **Advantages & Disadvantages**

  - Students overcome distance and transportation barriers to education.
  
  - Efficient use of specialized teachers.
  
  - Expand opportunities for students enrolled in disadvantaged schools.
  
  - Requires students and teachers to have access to internet and computers to interface in virtual classrooms.
  
  - Requires hiring educational software developer to create software infrastructure.
  
  - Requires hardware infrastructure, such as servers and other network equipment.
Alternative Solution 3: Education Technology in High Schools

- Comprehensive system of education technology including:
  - Hardware and operating system user interface
  - Educational software user interface
  - Network infrastructure.

Advantages:

- Enhance learning experience.
- Expand access to academic resources.
- Student development of skills in utilizing technology.
- Facilitates communication and interaction.
- Modernize technology infrastructure.
## Analysis of Alternatives (AoA) - Measures of Effectiveness (MoEs)

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1: Tech Programs &amp; Vocational Schools</th>
<th>Alternative 2: Online/Virtual Classrooms</th>
<th>Alternative 3: Education Technology in High Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Accessibility</strong></td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Number of Users (Participation)</strong></td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Optimal System is Alternative 3: Education Technology in High Schools
Defining System Architecture

System-Level Technical Requirements (elements/sub-systems of the system-of-interest):

1. Mobile Devices
   (Hardware User Interface)

2. Education Software
   (Software User Interface)

3. Fiber-Optic Backbone Network
   (Network Infrastructure)
Overview (OV-1): System-of-Interest Hierarchy

**SYSTEM**
- Mobile Devices (Hardware User Interface)
- Education Software (Software User Interface)
- Network Infrastructure

**SUB-SYSTEMS**
- Operating System
- Apps
- Upload & Document Storage
- Grades & Records Database
- Academic Databases
- Multimedia Content
- Internet Resources
- Fiber-Optic Cable
- Wi-Fi Hotspot Equipment
- Network Switches
- Hard-Disk Storage
- Processor

**SUB-ASSEMBLIES**
- Laptop (Processing Power)
- Tablet (Portability)
- Communications
- Administration
- Educational Resources
- Hardware & Cables
- Server

**COMPONENTS**
Requirements for Sub-System 1: Mobile Devices (Hardware User Interface)

1. All system users (high school students, teachers and administrators) shall receive one of two defined mobile devices:
   (1) laptop for processing power need.
   (2) tablet device for portability need.

2. Mobile devices with installed operating system, shall be the technology platform to interface with education software (Sub-system #2) software user interface) and internet browser.

3. Mobile devices shall include adequate security and virus protection to protect from unauthorized access and software viruses.

4. Mobile devices shall include technology enforcement software to protect devices from installation of unauthorized software and to ensure appropriate use.

5. Procurement and acquisition of devices shall utilize RFP (Request for Proposals) to receive contractor/vendor proposals to supply devices, training and tech support at fixed cost.

6. Mobile technology devices shall meet minimum computing requirements to be updated every 3 years by Ministry of Education.
Overview (OV-1): System Architecture for Mobile Devices (Hardware)
Requirements for Sub-System 2:
Educational Software (Software User Interface)

1. Education software shall enhance delivery of education and supplement teaching and instruction.

2. User interface of education software shall be designed for ease of use.

3. User interface shall facilitate collaboration between users and provide capability to deliver school wide announcements from administration.

4. Education software shall be integrated with high school enterprise architecture and records/grading system.

5. Educational software shall provide capability for teachers to maintain records and issue grades and feedback to students.

6. Educational software shall provide capability for students to submit assignments, take exams and check grades and teacher feedback.

7. Software shall facilitate prompt delivery of grades and teacher feedback to students for course grades and grading/comments for graded assignments.

8. Software shall be developed by a reputable software developer based on proposals/bids submitted under an RFP (Request for Proposals).
Educational Software Development Process

- Learn past SE programs and from more advanced systems.
- US Department of Education advanced system methods.
- Education Technology Development Process.
- Contracting educational software developer based on RFP selection of contractor.
- Contractor development of educational software UI based on user/customer requirements.
- Alignment of user requirements with contractor technology development process.

Requirements for Sub-System 3: Network Infrastructure

1. **Network Infrastructure shall have capability of supporting:**
   i. High number of simultaneous users
   ii. Uploading and downloading of “data-intensive” educational content.

2. **Network shall include fiber optic backbone.**
   i. In the long run, will require less upgrades as technology advances.
   ii. Supports high volume of simultaneous users.
   iii. High-bandwidth for data will maintain high-speed access.

3. **Network shall include Wi-Fi routers for wireless internet connectivity.**

4. **Network shall have adequate security.**
   i. Secured access through user login.
   ii. Firewall security to prevent external access.
   iii. System monitoring for security.

5. **Network shall be reliable and online not less than 90% of school operating hours.**

<table>
<thead>
<tr>
<th>Optical fiber vs. copper: the choice is clear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Capex Cost (2,000-user optical LAN)</strong></td>
</tr>
<tr>
<td>$&lt;$300,000</td>
</tr>
<tr>
<td><strong>Lifecycle</strong></td>
</tr>
<tr>
<td><strong>Distance</strong></td>
</tr>
<tr>
<td><strong>Weight (per 1,000 ft.)</strong></td>
</tr>
<tr>
<td><strong>Energy Consumed</strong></td>
</tr>
<tr>
<td><strong>Maximum Bandwidth</strong></td>
</tr>
<tr>
<td><strong>Security</strong></td>
</tr>
</tbody>
</table>
Overview (OV-1): Network Infrastructure System Architecture
Integration, Verification & Validation (IV&V) – "V Model"

- **LEFT**: System Design and Development is completed from **"top-down"**.
- **RIGHT**: Integration, Verification & Validation completed **"bottom-up"**.
Integration, Verification & Validation (IV&V)

IV&V Plan for Implementation

1. **Integration:** Analysis Method
   - **Analysis:** N-Squared Diagram analyzes subsystem interfaces of mobile devices, network and software. Supports proper integration of developed subsystems that will provide a system with functions and capabilities that will satisfy customer/user requirements.

2. **Verification:** Certification Method
   (Visual inspection and light testing can also supplement)
   - **Certification:** Contractor must certify that delivered product meets specifications.
   - Contractor is liable for any rework or reproduction. Certification greatly reduces risk to customer, is efficient by saving time and money compared to other verification methods.

3. **Validation:** Testing Method
   - **Testing:** Overall validation test will test overall system operation, therefore validating the system. This involves installation of educational software on mobile devices and use of educational software on mobile devices while using campus wireless network for internet connectivity.
   - Analysis was used to validate system during the design and development of system architecture. Before implementation, traceability matrix is used to show validation.
Integration Plan: N-Squared Interface Diagram (INCOSE)
## System Verification & Validation: Traceability Matrix

### System Functions to Customer/User Requirements and Activities

<table>
<thead>
<tr>
<th>System-of-Interest Elements</th>
<th>User/Customer Requirements and Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Internet Connectivity</td>
</tr>
<tr>
<td><strong>Subsystem 1:</strong> Mobile Devices/Operating System (Hardware)</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Subsystem 2:</strong> Education Software</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>Subsystem 3:</strong> Network Infrastructure</td>
<td>✔️</td>
</tr>
</tbody>
</table>
System-of-Interest: Measurements of Effectiveness (MoEs)

1. Cost Performance
2. Ease of Access
3. Reliability
4. Security
5. Speed & System Capacity
## Summary: Measurements of Effectiveness (MoEs)

<table>
<thead>
<tr>
<th></th>
<th>Subsystem 1: Mobile Technology Devices</th>
<th>Subsystem 2: Educational Software</th>
<th>Subsystem 3: Network Infrastructure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost Performance</strong></td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Ease of Access</strong></td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Speed and Capacity</strong></td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
Risk Management Strategy

A key activity of project management is Risk Management.

- Anticipated Risks Identified include:
  1. Cost Risk
  2. Contractor Unsatisfactory Performance Risk
  3. System Interface Integration Risk
  4. Cultural Risk
1. Cost Risk

- **Risk of Exceeding Budgeted Cost of System**
  - Costs growth from changes in requirements.
  - Cost growth from inadequate requirements documentation and traceability.
  - Cost growth due lack of communication and flow down of system-requirements to component levels.

- **Consequences to System Implementation:**
  - Increase in final cost from reproduction of components or sub-systems.
  - System-level requirements may not be met due to insufficient budget to complete objectives and fulfill requirements of system.
  - Termination of project.

- **Strategy to Mitigate Risk:**
  - Close and consistent oversight and requirements documentation.
  - Ensure clear roles and responsibilities of contractor and customer.
  - Closely monitor implementation progress and control spending.
2. Contractor Performance Risk

- **Risk of Contractor Unsatisfactory Performance**
  - Contractor proposal may not be feasible/viable.
  - Contractor delivered system/sub-system may not satisfy all user requirements.
  - Contractor may not be able to deliver product to standards within constraints of budget and time.

- **Consequences to System Implementation:**
  - Inadequate sub-system capabilities and functions.
  - System-level and sub-system level technical requirements not met.
  - Excess costs.
  - Schedule delays.

- **Strategy to Mitigate Risk:**
  - Use RFP process to select private contractor based on competition and proposal merits, feasibility and proven track record of success/performance.
  - Close and consistent supervision and documentation.
  - Closely monitor implementation progress and control spending.
3. Interface Integration Risk

- Risk of system interface integration issues.
  - Original system requirements not be correctly flowed down to component level.
  - Changes to system-level technical requirements not well documented.

- Consequences to System Implementation:
  - Inadequate system capabilities and functions.
  - System-level requirements may not be met.
  - Cost growth due to reproduction of components and sub-systems.
  - Delay in project schedule.

- Strategy to Mitigate Risk:
  - Ensure communication of system requirements through hierarchy down to component level.
  - Establish strict requirements documentation.
  - Ensure clear roles and responsibilities of contractor and government.
4. Cultural Risk

- Cultural risk of user non-participation of system solution
  - Conservative and traditional cultural perspectives
  - Pushback from users and community
  - Prior changes display cultural risks to adopting change

- Consequences to System Implementation:
  - Non-use of implemented system.
  - Inability to achieve program objectives.

- Strategy to Mitigate Risk:
  - Build support among users and community stakeholders through public education of project goals and purpose
  - Involvement of all stakeholders, including users and community stakeholders, to motivate acceptance of change.
  - Mitigate negative attitudes through stakeholder engagement.
  - Disciplinary action for noncompliance of teachers/administrators.

Cultural Risk
Likelihood: (4) High
Consequence: (3) Significant

DoDAF RISK MATRIX

Mitigation of Risk
Likelihood: (2) Low
Consequence: (3) Significant
Lean Thinking

- Lean Systems aim to minimize waste and maximize value.

- *Womack* and *Jones* (Lean Thinking) consider: purpose, process and people.
  - **Purpose** – purpose of project is to enhance outcomes and delivery of education in KSA high school education.
  - **Process** – assess the value stream of each of the processes involved in the project to ensure flow, pull and leveling.
  - **People** – key to continuous improvement of system, through use of people to continually evaluate and assess the value stream.
Lean Thinking

Lean SE (LSE) is the area of synergy between Lean Thinking and SE, with the goal to deliver the best life-cycle value for technically complex systems with minimal waste.

Lean Principles used in Product Development:

- Request for proposal (RFP) is used as the method of sourcing the subsystems and implementing the education technology system. This involves publishing an announcement with customer requirements and using market competition by contract developers competing to win contract to provide services in developing system.
Lean Thinking

- RFP uses a competitive process, therefore it maximizes value to customers and efficiency of the value stream:

  - **Maximizes innovation and system value**: through competition, contract developer will offer most productive process with best and most innovative products and services to win contract. This maximizes the value that will be delivered to users of education technology system.

  - **Minimizes time**: in labor and paperwork intensive process. Without an RFP, the customer would need to search for a vendor and negotiate or directly source product from vendors, which would not only increase cost, but would be inefficient and wasteful.

  - **Minimizes cost**: competition minimizes overall cost, both from cost-saving from time efficiency, but also from cost, further adding value and improving efficiency

  - **Uses lean principle of “pull”**: customer is able to “pull” value from developers down the value stream, since developers are competing to win contract.

  - **Uses lean principle of “flow”**: processes in development, including receipt, review and selection of contract are efficiently ordered creating a “flow” of processes, which efficiently delivers value down the value stream in a more speedy way.
Ethical Issues

- Systems engineering is a comprehensive approach, which includes considering ethical issues and risks in all stages, in addition to program and technical requirements.

  "Moral values are embedded in even the simplest engineering projects" - Ethics in Engineering

1. Cultural values of traditionalism and conservatism that are embedded in the education system and may conflict with educational objectives.

2. Managing risk (i.e. cultural risk) which may conflict with objectives of the system.

3. In line with the goals of the system, it is important that the system best provide open access to educational content and academic resources for all students.

4. Respect for people and cultural differences is an important ethical consideration. Cultural mindsets may be difficult to change and should be addressed by engaging and involving stakeholders.

5. KSA education system needs to change in order to better integrate with global education ideologies, such as encouraging freedom of thought and allow students to explore different perspectives.
Conclusion

- The problem identified was ineffective delivery of education in producing student outcomes. The current system suffers from a variety of issues.
  - Lack of technology integrated into high school education
  - Inadequate preparation for students for the modern economy, where employers require technical skills in hiring and colleges use computers and internet in education
  - Current system suffers from lack of trust
  - Demotivated teachers and low student morale
- This system solution will enhance education in high schools and address the issues presented:
  - the lack of modern technology in high school education.
  - limited technical skills of high school graduates.
- Government (KSA Ministry of Education) recognized need for improvement, by making investments.
- KSA Government involvement is absolutely necessary since it requires changes in public education, privat schools can also benefit from this project.
- The optimal system is a comprehensive education technology system, composed of subsystems including mobile devices (hardware), education software, and network infrastructure.
Conclusion

- If the system is implemented with a deep understanding of the system environment and culture, it can be very effective in addressing the systemic issues of:
  - Lack of confidence in the performance of public schools by the general public
  - Lack of motivation and low morale among teachers

- Overall, effective implementation requires mitigating the risks of cultural resistance to change. System implementation should have a central focus on:

- The system solution has potential to both produce better prepared students and meet needs of industry.

- It might also be effective to:
  - Change the relationship between teachers and students.
  - Boost morale.
  - Change the reputation of not fostering change.
  - Reestablish trust and confidence in the public education system.
Lessons Learned – Learning Principles

- A comprehensive implementation of educational technology involves meeting user requirements through use of sub-systems and components in system hierarchy.
  - "The systems capabilities specified by the stakeholders will be met by the combination of system elements." INCOSE V. 3.2

- Understanding cultural perspectives and attitudes are very important for systems in societal institutions, in order to mitigate risks to implementation.

- Early stage exploratory research is important to develop feasible and viable concept alternatives to meet user requirements.

- Higher costs from initial investment will lower long term cost, especially in technology which evolves and becomes cheaper at a very fast pace.

- Lean system principles of minimizing waste and maximizing efficiency are effective in evolving the system to better provide value to system users.
References


References (Continued)


17. http://saudiarabia.angloinfo.com/family/schooling-education/

