Modeling and Simulation Technology

8460/36 weeks

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Acknowledgments

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B.J. Scott, State Advisor, Virginia Technology Student Association, reviewed and updated the TSA correlations.
Course Description

Suggested Grade Level: 10 or 11 or 12 Students will explore the use of modeling and simulation (M&S), as well as game development concepts and software, to solve real-world problems in multiple domain areas. Activities will include developing, evaluating, and testing engineering designs, employing geospatial data, observing and analyzing physics simulations, designing games for educational purposes, and designing and creating visualization systems with three-dimensional (3D) models. Students will develop an understanding of the concepts, systems, processes, tools, and implications of the field of M&S and associated design and visualization technologies.

Task Essentials Table

- Tasks/competencies designated by plus icons (+) in the left-hand column(s) are essential
- Tasks/competencies designated by empty-circle icons (○) are optional
- Tasks/competencies designated by minus icons (−) are omitted
- Tasks marked with an asterisk (*) are sensitive.

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<td>+</td>
<td>Describe models and simulations and the relationship between the two.</td>
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<td>Describe application domains for M&amp;S activity.</td>
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<td>41</td>
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<td>Explain the history of M&amp;S.</td>
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<td>Explain the M&amp;S process and life cycle.</td>
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<td>43</td>
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<td>Identify types of modeling and modeling tools.</td>
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<td>Differentiate the uses of various modeling methods.</td>
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<td>Identify types of simulation.</td>
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<td>Examine career opportunities in M&amp;S.</td>
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<td>Learning Technical Skills for M&amp;S</td>
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<td>Create a functional simulation.</td>
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### Visualizing Data

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<td>Create a visual representation of data using student-collected data or a simulation model.</td>
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### Evaluating Complex Systems

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<td>Produce a physical model based on requirements from a 3D design.</td>
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**Curriculum Framework**

**Exploring Modeling and Simulation (M&S)**

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**Task Number 39**

**Describe models and simulations and the relationship between the two.**

**Definition**

Description should include

- the definition of model—represents something that exists in reality; an abstraction and simplification of reality; provides something to think with, build on (e.g., model trains, traffic models, hurricane tracking, infectious disease modeling, urban planning, economic modeling)

- the definition of simulation—the execution of a model on a computer; algorithms using data (e.g., city simulation games, real-time simulation, military simulation,)
• the process of modeling and simulating, as well as the concept that models are used as the basis for simulation
• the presence of models and simulations within homes and society (e.g., board gaming, chess, checkers, climate models, electoral models)
• experimental design methodologies, such as
  o pre-assessment/post-assessment
  o randomization
  o control
  o A/B testing (i.e., split testing).

Process/Skill Questions

• What are the similarities and differences between models and simulations?
• How are models and simulations related?
• How do M&S apply to everyday life?
• What is the role of randomization and distribution of data in modeling?

ITEEA National Standards

STEL 2, 3

Board Game Design

Video Game Design

Task Number 40

Describe application domains for M&S activity.

Definition

Description should include examples for

• training and education (e.g., maritime, construction)
• production and delivery
• research and testing
• decision making
• digital twin (i.e., the replication of physical systems)
• environmental monitoring
• entertainment
• planning
• analysis
• healthcare education, policy, and treatment
• therapeutic purposes
• machine learning.

Process/Skill Questions

• How is it possible to determine the best simulation tool for a given problem?
• How are simulations and electronic games related?
• How are M&S applicable to research in the social sciences, music, sports, and academics?
• What makes a simulation effective? Are all simulations equally effective? What are the applications of M&S?

ITEEA National Standards

STEL 3
Task Number 41

Explain the history of M&S.

Definition

Explanation should focus on how and why M&S have evolved, tracing M&S history from ancient times through the present to include successes and failures.

Teacher resource:
A Primer on Modeling and Simulation

Process/Skill Questions

- How have M&S developed? What factors have driven this development?
- How has technology influenced the development of M&S over time?
- How has M&S influenced modern society?

ITEEA National Standards

STEL6

Technology Bowl

Task Number 42

Explain the M&S process and life cycle.

Definition

Explanation should include the following steps of the M&S design process:

- Initial analysis
  - Identify the need or opportunity for a simulation model.
  - Define a problem.
  - Identify requirements and constraints.
- Conceptual modeling
  - Research potential solutions for a design problem.
  - Generate multiple solutions (brainstorming) for a design problem.
  - Sketch solutions for a design problem.
  - Evaluate potential solutions to a design problem.
  - Choose the best solution to a design problem.
- Model development
  - Implement the solution to the design problem.
- Verification and validation
  - Verify correctness of the implementation (i.e., Did we build it correctly?).
  - Validate the solution against requirements then communicate the solution to stakeholders to ensure the simulation model does what it is supposed to do (i.e., Did we build the right thing?).
- Plan and execute
Plan activity: experiments (design of experiment) or training.
- Conduct experiments or training.
- Evaluate results.
- Evaluate the results and map the insights back to the original problem.

Process/Skill Questions

- What is the most crucial step in the engineering M&S design process?
- Why do the M&S engineering design steps need to be completed in order?
- What can happen if the M&S engineering design process is not used when solving a problem?
- What is the result when changes occur in the requirements and scope of the design?
- What is the relationship among time, cost, and quality in the M&S engineering design process?
- What steps require reevaluation of the initial design request?
- How is M&S an iterative process?
- How do accessibility, diversity, and inclusion factor into the design of ethical simulation models?
- Why is it important to implement conceptual modeling before starting the development process?
- What is the difference between verification and validation?
- How can the information gathered be used in development?
- What is the role of reference architecture and reference models in supporting these processes?
- How should one use insights gained by simulation to address the original problem?

ITEEA National Standards

Architectural Design
Board Game Design
CAD Architecture
CAD Engineering
Dragster Design
Engineering Design
Promotional Design
Video Game Design

Task Number 43

Identify types of modeling and modeling tools.

Definition

Identification should include

- types of modeling (e.g., physical, virtual, mathematical, process, conceptual)
- modeling tools, including engineering sketches and drawings, specialized modeling hardware and software
  - three-dimensional (3D) modeling software
    - Maya/Stingray
    - 3D Studio Max
    - Blender
  - geographical information systems (GIS)
    - Google Earth
    - QGIS
    - ArcGIS
Process/Skill Questions

- Why are models used?
- How accurate do models need to be? What happens if models are incomplete or inaccurate?
- How is it possible to determine the best modeling tool for a given problem?
- Why is interpreting engineering sketches and drawings critical during the design phase of a project?

ITEEA National Standards

STEL 8

Board Game Design

CAD Architecture

CAD Engineering

Date Science and Analytics

Geospatial Technology

Video Game Design

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Task Number 44

Differentiate the uses of various modeling methods.

Definition

Differentiation should include

- discrete event simulation (DES)
- agent-based modeling (ABM)
- system dynamic modeling
- physical models.

Process/Skill Questions

- Why is it important to identify the modeling method before starting the design?
- How are the different modeling methods applied?
• How does one determine the best modeling method for a given problem (e.g., strengths, limitations)?
• When is it appropriate to use real time vs. virtual time?

ITEEA National Standards

STEL 8

Technology Bowl

Task Number 45

Identify types of simulation.

Definition

Identification should include

• the definition of live—real humans with real systems in a simulated environment
• the definition of virtual—real humans with simulated systems in a simulated environment
• the definition of constructive—simulated humans with simulated systems in a simulated environment.

Process/Skill Questions

• What roles do simulations play?
• When are live simulations appropriate?
• What are the benefits and challenges of applying simulations?

ITEEA National Standards

STEL 8

Technology Bowl

Task Number 46

Examine ethical and legal issues in M&S.

Definition

Examination should include

• an analysis of ethical concerns (e.g., conflict of interest, misrepresentation of data)
• legal issues (e.g., intellectual property, incorporating copyrights, patents, trademarks, trade secrets) related to M&S
• data ethics and privacy (e.g., The Health Insurance Portability and Accountability Act of 1996 [HIPAA], The Family Educational Rights and Privacy Act [FERPA]).

Process/Skill Questions

• Why are ethical issues important in M&S? What are some current examples?
• How do intellectual property laws apply to M&S? What are some current examples?
• How can it be ethical to simulate a successful bank robbery or a successful terrorist act?
• What is the concept of open source, and how does it relate to M&S?
Task Number 47

Examine career opportunities in M&S.

Definition

Examination should include researching and evaluating current employment opportunities related to M&S in a wide range of fields, such as

- defense and security
- aerospace
- robotics
- cyber-based systems
- software development
- medicine and healthcare
- manufacturing and material handling
- logistics and supply chain
- transportation
- computer and communications systems
- cloud computing
- data science
- environment and ecology
- business
- social science
- maritime industry.

Teacher resources:

AWS Educate

AWS provides self-paced content, interactive challenges and hands-on activities designed to introduce cloud computing skills which drive innovation in fields such as artificial intelligence, voice and facial recognition, gaming, medical advancements, and more. Students could earn AWS Educate cloud badges.

IBMDeveloperSkillsNetwork: CC0101EN Introduction to Cloud

Introduction to Cloud is an introductory course on Cloud Computing on Open P-Tech.

Process/Skill Questions

- Where can a student locate resources for M&S careers and job openings in a given geographical area?
- What are the educational requirements for various occupations in M&S?
- What is the salary ranges for employees in M&S occupations?

ITEEA National Standards

STEL 3

Cybersecurity
Learning Technical Skills for M&S

Task Number 48

Describe computer programming tools that can be used to develop models and simulations.

Definition

Description should include

- major programming languages (e.g., C++, C#, Java, R, Python)
- general application packages (e.g., matrix laboratory [MATLAB])
- major simulation software packages (e.g., Arena, AnyLogic, Cloudes, NetLogo, Simio, Simulink)
- typical electronic games (e.g., Unity, GameMaker, Code.org, Game Lab)
- visualization software (e.g., Maya/Stingray, Unreal Development Kit [UDK])
- similar software development tools.

Teacher resource:

Unity – Create with Code

Students use Unity to learn the fundamentals of programming in the context of creating several game prototypes, managing a larger personal project more independently, and completing challenges and quizzes along the way.

Process/Skill Questions

- How does one determine the best software tool for a particular project?
- What are the benefits and limitations of each software product for a particular project?
- What programming skills are required for each software product?
- What are the advantages of program libraries?

ITEEA National Standards

STEL 8

Technology Bowl

Video Game Design

Task Number 49

Explain the principles of an object-oriented approach to the design of models and simulations.
Definition

Explanation should include

- the decomposition of the simulation model into functional components
- application of the object-oriented programming (OOP) paradigm to the design of models and simulations
  - abstraction
  - encapsulation
  - inheritance
  - polymorphism
- advantages of applying the object-oriented paradigm in the design and implementation of a simulation
  - modularity
  - scalability
  - flexibility
  - reusability of the simulation environment.

Process/Skill Questions

- What are the advantages of abstraction?
- How are objects, classes, and variables used to represent more complex underlying code and data?
- What are the advantages of encapsulation?
- What are the benefits of inheritance?
- What are the benefits of polymorphism?

ITEEA National Standards

STEL 7, 8

Technology Bowl

Task Number 50

Reverse engineer an existing simulation or simulation game to its working components and systems.

Definition

Reverse engineering should include

- relationships and dependencies of
  - objects
  - events
  - actions
- data exchange (e.g., basis of data exchanges with databases, text files, comma-separated values [CSV] files, Microsoft [MS] Excel files)
- environment and the role of each in simulation game architecture
- components and scripting application programming interface (API)
  - systems (cameras and physics)
  - data (configurations, animations, and textures)
  - behaviors (game mechanics and scripted events)
- configuration of the simulation environment
  - parameters
  - initialization
  - user input
  - life cycle
Process/Skill Questions

- What is the difference between an event and an action in game architecture?
- How are objects, events, and actions related in game architecture?
- How can it be useful to analyze the architecture of an existing game?

ITEEA National Standards

STEL 8

Data Science and Analytics

Video Game Design

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Task Number 51

Architect a simulation, using an algorithm, pseudocode, flowchart, decision table, and/or a prototype.

Definition

Architecture should include

- diagrams (e.g., flowcharts, storyboards, other Unified Modeling Language [UML] diagrams)
- descriptive narrative describing the program, its purpose, and how it works
- examples of how abstraction is being used in the program
- use of common logic structures to control the execution of code that integrates into an existing system.

Process/Skill Questions

- How are abstractions used in M&S?
- How are data, physical phenomena (e.g., gravity, force, collision), and mathematical concepts represented on a computer?
- Why is it important to understand Boolean expressions?
- Why is documentation important during the design phase of a project?

ITEEA National Standards

STEL 8

CAD Architecture

Architecture Design

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Task Number 52

Create a functional simulation.

Definition

Simulation should
• provide equitable access for all users
• utilize multisensory frameworks
• enhance learning outcomes
• be created using physical materials or a two dimensional (2D), 3D, or console programming tool
• engage the user
• be aesthetically pleasing
• meet an educational goal (e.g., a STEM concept).

Teacher resource:

Crew Orbital Docking Simulation (CODing Sim)

Process/Skill Questions

• How can games lead to enhanced learning?
• What makes one game better than another?
• How can a game be used to simulate real-life behavior?
• What features might make a game more engaging?
• Why should one consider the audience before designing a game?

ITEEA National Standards

STEL 8, 3

CAD Architecture

CAD Engineering

Visualizing Data

Task Number 53

Explain data visualization.

Definition

Explanation should include the concept of data visualization and its purposes in a variety of fields, such as
• geospatial technologies
• physics environments
• satellite data
• magnetic resonance imaging (MRI)
• telemetry
• thermal imaging
• remote sensing.

Process/Skill Questions

• How can numeric data be presented?
• Why is it important to present data visually?
• What effects has data visualization had on society?
• How does data visualization affect your life?

ITEEA National Standards

STEL 3
Task Number 54

Explain techniques for presenting data in a visual format.

Definition

Explanation should include

- the process by which data are converted to visual representations (e.g., graphs, 3D models, charts, maps, vectors, rasters, coordinates)
- applications in a variety of fields (e.g., medicine, meteorology, topography)
- platforms
- interfaces.

Teacher resources:

Data Visualization and Analysis with Python courses on Open P-Tech:

https://yl-p-tech.skillsnetwork.site/courses/course-v1:CognitiveClass+DV0101EN+v2
https://yl-p-tech.skillsnetwork.site/courses/course-v1:CognitiveClass+DA0101EN+v1

Intro to VR on CodeHS

Introduction to VR Development in Unity

Process/Skill Questions

- What is the difference between vectors and rasters?
- How is this difference important in data visualization?
- What are the relative strengths of the different visualization tools?
- How can one determine the best way to present numeric data?
- How can data be misrepresented?
- How does interactivity change the impact of data visualization, negatively and/or positively?
- What are potential uses of virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR) in communicating complex information?
- What are some sources of bias that might occur in data visualization?
- How can sources of bias be mitigated?

ITEEA National Standards

STEL 3

CAD Engineering

Geospatial Technology

Coding

Task Number 55

Create a visual representation of data using student-collected data or a simulation model.
Definition

Creation should use the visualization process, which includes

- determining the data to be collected
- gathering the data (e.g., using GPS, using simulation results, surveying, identifying credible sources)
- interpreting the data
- creating a model to display the data, considering the purpose and audience
- describing the results represented by the model.

Process/Skill Questions

- What data are important to capture for a given representation?
- How much data is needed for an effective representation?
- What is the purpose of interpreting the data? Why is data interpretation critical?
- Who uses data to make decisions?
- What is the importance of an audience in building a model?
- How can animation help visualize data?
- How do animations enhance human understanding beyond static models?
- How can the sequence of data affect the animation?
- What psychological effects associated with color are important (e.g., the color red signals danger) when visualizing data?

ITEEA National Standards

STEL 8
Geospatial Technology

Evaluating Complex Systems

Task Number 56

Explain the nature of complex systems.

Definition

Explanation should include the concepts that

- a complex system cannot be divided into its subsystems and still function; it often produces adaptive behavior
- the complex system exhibits complex behavior as a result of the interconnectivity of its subsystems (e.g., queuing, biological, computer-integrated manufacturing, transportation systems)
- relations and interactions are often highly non-linear so that small changes in the input can produce large changes in the outcome.

Process/Skill Questions

- Why are different models needed for different systems?
- What is the purpose of feedback within a complex system?
- How can simple models accurately describe complex systems? Provide examples.
- Why is it difficult to repeatedly produce precise results in complex systems?

ITEEA National Standards

STEL 2
Task Number 57

Explain data variables that would be necessary to effectively model a complex system.

Definition

Explanation should include

- input variables (e.g., arrival time, volumes)
- process variables (e.g., customer service time, production time, transit time, inventory levels, error rate)
- output variables (e.g., profit, loss, total time in system, average time in queue, parts manufactured)
- simulation execution performance variables (e.g., events per second, frames per second, time scale, cost, weight).

Process/Skill Questions

- How does one decide which data to collect for modeling a complex system?
- What statistical tools can help ensure that data are valid?
- How confident can one be in the validity of a model?
- What is the importance of time studies?

ITEEA National Standards

STEL 8

Task Number 58

Propose models of complex systems.

Definition

Proposal should account for

- accurate reflection and description of a real or conceptual system (e.g., a predator-prey relationship using difference equations; a discrete event simulation for customer service in a salon; the operation of traffic lights using finite-state machines; the biological response of an ecosystem to a new species of fish using systems dynamics)
- model specifications, including
  - concept, input, and process variables
  - M&S methods (e.g., systems dynamics, discrete event simulation, agent-based modeling, multimethod)
  - M&S software
- strategies for validation and verification
- documentation of those systems in a standardized system, such as UML.

Process/Skill Questions

- What role(s) do complex systems play in improving society?
• How do models help humans make predictions?
• How can models help humans make responsible decisions?

ITEEA National Standards

Geospatial Technology

Task Number 59

Conduct experiments using developed simulation models.

Definition

Conducting should include

• multiple executions
• controlled-variable modifications
• calibration
• optimization
• sensitivity analysis
• design of experiment (e.g., what-if scenarios).

Process/Skill Questions

• Why is input data typically random?
• What is meant by relevant output data?
• How does one decide the best measures of a system’s performance?
• Why would one run an experiment multiple times?
• How can an experiment be refined?

ITEEA National Standards

STEL 8

Engineering Design

Task Number 60

Design a 3D working model, using 3D software.

Definition

Design should reflect the 3D design, and the design process should include

• a multiview and/or pictorial view
• dimensions of the object
• lighting effect of the object
• materials
• scenes
• rendering of an animation
• notes
• specifications
• a bill of materials.
Process/Skill Questions

- What are the advantages of using 3D software over 2D hand drawings?
- What are the benefits of geometric dimensioning and tolerancing (GD&T)?
- How are specifications established?
- What are the different methods of rendering?

ITEEA National Standards

STEL 7

CAD Engineering

Engineering Design

Task Number 61

Analyze the 3D model, using simulation software.

Definition

Analysis should include

- explaining the role of simulation as an analysis tool
- defining the analysis problem
- identifying sources of error in the simulation
- describing relationships among variables
- describing the effect of correlation on simulation results
- identifying use case for historical/empirical data
- describing the output distribution
- interpreting summary statistics
- interpreting confidence and prediction (certainty) intervals.

Teacher resource:

OnScale Solve Simulation Tutorials (works with Onshape)

Process/Skill Questions

- What types of analyses can be conducted on the model (e.g., flow, structural, stress)?
- What is the difference between destructive and nondestructive testing?
- Why is it important to know the design life cycle?
- How can an analysis using simulation software ensure the effectiveness of a design?

ITEEA National Standards

STEL 8

CAD Engineering

Task Number 62

Verify the model’s performance within a simulated environment or system.
Definition

Verification should

- identify remedies for deficiencies uncovered during the analysis
- include any necessary tradeoffs
- validate that the model was implemented correctly and works as required within the context of its purpose.

Process/Skill Questions

- Why are tradeoffs necessary when optimizing a design?
- How is it possible to optimize all aspects of a design?
- Which phase(s) of the design process could optimization affect? What effects might result?
- How is verification and validation accomplished?
- Why is it essential to verify and validate an object’s performance?
- What types of software could be useful for verification?

ITEEA National Standards

STEL 8

Engineering Design

Task Number 63

Produce a physical model based on requirements from a 3D design.

Definition

Production should accurately reflect determined requirements, such as

- proportion
- utility
- tolerances
- structural integrity.

Process/Skill Questions

- What is a scale model?
- What is the purpose of scale models, and what is the purpose of prototypes?
- What are the benefits of using a physical model?
- What steps are needed to finalize a physical model?

ITEEA National Standards

STEL 7, 8

CAD Engineering

Engineering Design
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<th>English</th>
<th>Science</th>
<th>Mathematics</th>
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<td>10.3, 10.5, 11.3, 11.5, 12.3, 12.5</td>
<td>PH.1</td>
<td>AII.6, AII.7, AII.9, AFDA.2, AFDA.3, AFDA.4, AFDA.5, AFDA.6, AFDA.8, COM.2, COM.3, COM.4, COM.7, COM.8, COM.9, OM.10, COM.11, COM.13, COM.14, COM.15, PS.8*, PS.10*, PS.11*, PS.12*, PS.15*, PS.16*, MA.1, MA.2, MA.3, MA.4, MA.5, MA.10</td>
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<tr>
<td>40</td>
<td>Describe application domains for M&amp;S activity.</td>
<td>10.1, 10.5, 11.1, 11.5, 12.1, 12.5</td>
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<tr>
<td>41</td>
<td>Explain the history of M&amp;S.</td>
<td>10.5, 11.5, 12.5</td>
<td>PH.1</td>
<td>PH.1, PH.2</td>
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<tr>
<td>42</td>
<td>Explain the M&amp;S process and life cycle.</td>
<td>10.1, 10.3, 10.5, 10.8, 11.1, 11.3, 11.5, 11.8, 12.1, 12.3, 12.5, 12.8</td>
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<td>AFDA.8, COM.3, COM.5, COM.17, PS.8*</td>
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<tr>
<td>43</td>
<td>Identify types of modeling and modeling tools.</td>
<td>10.2, 10.5, 11.2, 11.5, 12.2, 12.5</td>
<td>WG 17, WHI 1, WHII 14, VUS 14</td>
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<td>44</td>
<td>Differentiate the uses of various modeling methods.</td>
<td>10.3, 10.5, 11.3, 11.5, 12.3, 12.5</td>
<td>PH.1, PH.2</td>
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<td>45</td>
<td>Identify types of simulation.</td>
<td>10.3, 10.5, 11.3, 11.5, 12.3, 12.5</td>
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<td>46</td>
<td>Examine ethical and legal issues in M&amp;S.</td>
<td>10.5, 11.5, 12.5</td>
<td>Govt 7, 8, 9, 15</td>
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<td>47</td>
<td>Examine career opportunities in M&amp;S.</td>
<td>10.5, 10.8, 11.5, 11.8, 12.5, 12.8</td>
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<td>48</td>
<td>Describe computer programming tools that can be used to develop models and simulations.</td>
<td>10.5, 10.8, 11.5, 11.8, 12.5, 12.8</td>
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<td>49</td>
<td>Explain the principles of an object-oriented approach to the design of models and simulations.</td>
<td>10.5, 11.5, 12.5</td>
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<tr>
<td>50</td>
<td>Reverse engineer an existing simulation or simulation game to its working components and systems.</td>
<td>10.5, 10.8, 11.5, 11.8, 12.5, 12.8</td>
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<tr>
<td>51</td>
<td>Architect a simulation, using an algorithm, pseudocode, flowchart, decision table, and/or a prototype.</td>
<td>10.5, 11.5, 12.5</td>
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<tr>
<td>52</td>
<td>Create a functional simulation.</td>
<td>10.1, 11.1, 10.5, 11.5, 12.1, 12.5</td>
<td>PH.1</td>
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<td>53</td>
<td>Explain data visualization.</td>
<td>10.5, 11.5, 12.5</td>
<td>WG 17, WHI 1, WHII 14, VUS 14</td>
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<tr>
<td>Page</td>
<td>Task Description</td>
<td>English Standards:</td>
<td>Mathematics Standards:</td>
<td></td>
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<td>------</td>
<td>----------------------------------------------------------------------------------</td>
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<tr>
<td>54</td>
<td>Explain techniques for presenting data in a visual format.</td>
<td>10.5, 10.8, 11.5, 11.8, 12.5, 12.8</td>
<td>AII.9, COM.14, PS.1*</td>
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<tr>
<td>55</td>
<td>Create a visual representation of data using student-collected data or a simulation model.</td>
<td>10.5, 11.5, 12.5</td>
<td>AII.9, AFDA.3, AFDA.4, AFDA.8, COM.14, PS.1*, PS.2*, PS.3*, PS.4*, PS.10*, MA.7</td>
<td></td>
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<tr>
<td>56</td>
<td>Explain the nature of complex systems.</td>
<td>10.5, 11.5, 12.5</td>
<td></td>
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<tr>
<td>57</td>
<td>Explain data variables that would be necessary to effectively model a complex system.</td>
<td>10.5, 11.5, 12.5</td>
<td>COM.15, COM.16</td>
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<td>58</td>
<td>Propose models of complex systems.</td>
<td>10.5, 10.6, 11.5, 11.6, 12.5, 12.6</td>
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<td>59</td>
<td>Conduct experiments using developed simulation models.</td>
<td>10.5, 11.5, 12.5</td>
<td>PH.1</td>
<td></td>
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<tr>
<td>60</td>
<td>Design a 3D working model, using 3D software.</td>
<td>10.1, 11.1, 12.1</td>
<td>PH.1</td>
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<td>61</td>
<td>Analyze the 3D model, using simulation software.</td>
<td>10.3, 10.5, 11.3, 11.5, 12.3, 12.5</td>
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<tr>
<td>62</td>
<td>Verify the model’s performance within a simulated environment or system.</td>
<td>10.5, 11.5, 12.5</td>
<td>PH.1</td>
<td></td>
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<tr>
<td>63</td>
<td>Produce a physical model based on requirements from a 3D design.</td>
<td>10.1, 10.5, 11.1, 11.5, 12.1, 12.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix: Credentials, Course Sequences, and Career Cluster Information

Industry Credentials (Only apply to 36-week courses)

- Autodesk Certified Professional Examinations
- Autodesk Certified User Examinations
- Certified SOLIDWORKS Associate (CSWA) Examination
- College and Work Readiness Assessment (CWRA+)
- Modeling & Simulation Certification Examination
- National Career Readiness Certificate Assessment
- Unity Certified User Examinations
- Workplace Readiness Skills for the Commonwealth Examination

Concentration sequences: A combination of this course and those below, equivalent to two 36-week courses, is a concentration sequence. Students wishing to complete a specialization may take additional courses based on their career pathways. A program completer is a student who has met the requirements for a CTE concentration sequence and all other requirements for high school graduation or an approved alternative education program.

- Digital Visualization (8459/36 weeks)
- Geospatial Technology I (8423/36 weeks)
- Graphic Communications Systems (8458/36 weeks)
  - Graphic Communications Systems (8494/18 weeks)
- Programming (6640/36 weeks)
- Programming, Advanced (6641/36 weeks)

Career Cluster: Education and Training

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Occupations</th>
</tr>
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<tbody>
<tr>
<td>Teaching and Training</td>
<td>Secondary School Teacher</td>
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<tr>
<td></td>
<td>Training Consultant/Training Specialist</td>
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</table>

Career Cluster: Information Technology

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Occupations</th>
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<tbody>
<tr>
<td>Information Support and Services</td>
<td>Applications Integrator</td>
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<tr>
<td></td>
<td>Computer Numerical Control Programmer (CNC Programmer)</td>
</tr>
<tr>
<td></td>
<td>Data Modeler</td>
</tr>
<tr>
<td></td>
<td>Database Analyst</td>
</tr>
<tr>
<td></td>
<td>Geographic Information Systems (GIS) Technician</td>
</tr>
<tr>
<td></td>
<td>Multimedia Artist, Animator</td>
</tr>
<tr>
<td></td>
<td>Systems Analyst</td>
</tr>
<tr>
<td>Network Systems</td>
<td>Computer Software Engineer</td>
</tr>
<tr>
<td></td>
<td>Database Analyst</td>
</tr>
<tr>
<td></td>
<td>Systems Analyst</td>
</tr>
<tr>
<td>Programming and Software Development</td>
<td>Computer Software Engineer</td>
</tr>
<tr>
<td></td>
<td>Game Designer, Programmer</td>
</tr>
<tr>
<td></td>
<td>Multimedia Artist, Animator</td>
</tr>
<tr>
<td></td>
<td>Systems Analyst</td>
</tr>
<tr>
<td>Web and Digital Communications</td>
<td>Game Designer, Programmer</td>
</tr>
<tr>
<td></td>
<td>Multimedia Artist, Animator</td>
</tr>
<tr>
<td></td>
<td>Systems Analyst</td>
</tr>
<tr>
<td>Pathway</td>
<td>Occupations</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Engineering and Technology | Aerospace Engineer  
                      Aerospace Engineering Technician  
                      Architect  
                      Biomedical Engineer  
                      Chemical Engineer  
                      Civil Engineer  
                      Civil Engineering Technician  
                      Commercial and Industrial Designer  
                      Computer Software Engineer  
                      Electrical Engineer  
                      Electrical Engineering Technician  
                      Electro-Mechanical Technician  
                      Electronics Engineering Technician  
                      Engineer  
                      Engineering Technician  
                      Environmental Engineer  
                      Industrial Engineer  
                      Industrial Engineering Technician  
                      Landscape Architect  
                      Manufacturing Systems Engineer  
                      Marine Engineer  
                      Materials Engineer  
                      Mechanical Engineer  
                      Mechanical Engineering Technician  
                      Nuclear Engineer  
                      Petroleum Engineer  
                      Power Systems Engineer  
                      Systems Analyst |
| Science and Mathematics  | Atmospheric Scientist  
                      Biologist  
                      Chemist  
                      Ecologist  
                      Economist  
                      Environmental Scientist  
                      Geoscientist  
                      Hydrologist  
                      Microbiologists  
                      Oceanographer  
                      Research Chemist |