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Adaptive Learning Platform for Engineering Dynamics

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Engineering Dynamics is a core junior-level course that covers the fundamentals of modeling engineering systems through differential equations. In this presentation, we outline how we used the Realizit Adaptive Learning platform at UNC Charlotte to develop an adaptive Approach and how we leveraged data-driven insights to support student success in Mechanical Engineering's System Dynamics curriculum.

Organization

– Key differences and benefits of AL
– How the adaptive approach was designed for Dynamics 2
– Tracking student progress and providing targeted support
– Conclusions and next steps

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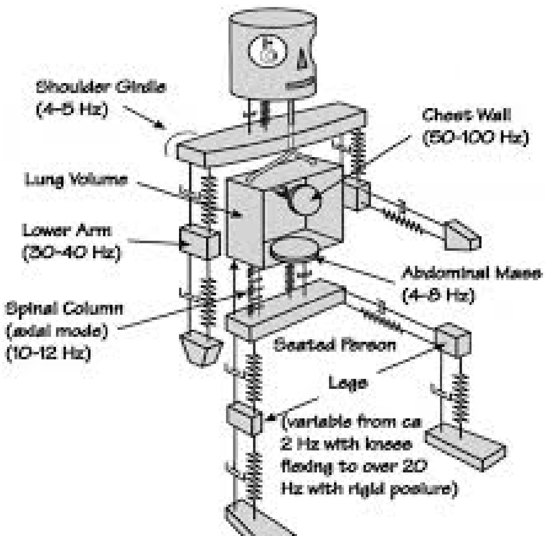
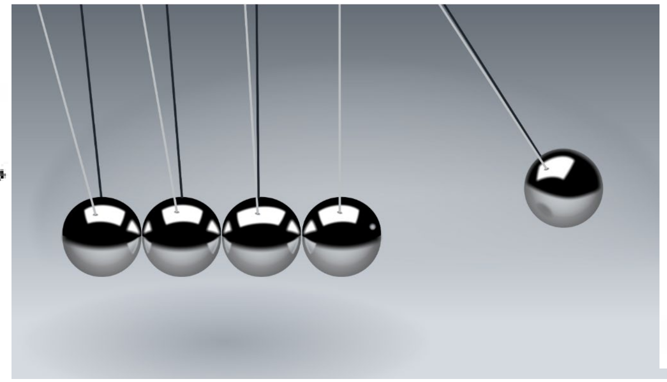
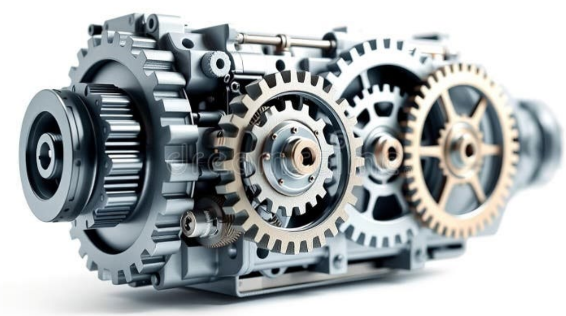
Engineering Dynamics is a core junior level course in engineering curricula that teaches the fundamentals of dynamic modeling of engineering systems with differential equations.



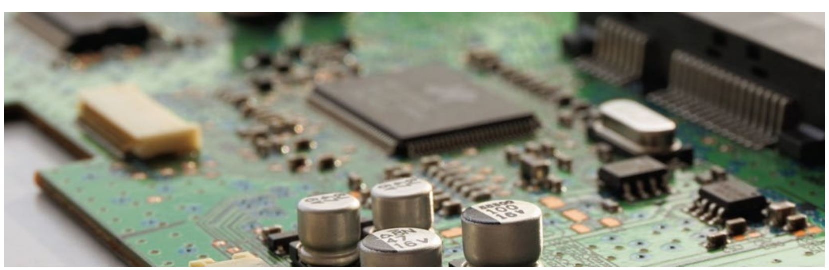
Rectilinear Motion Systems



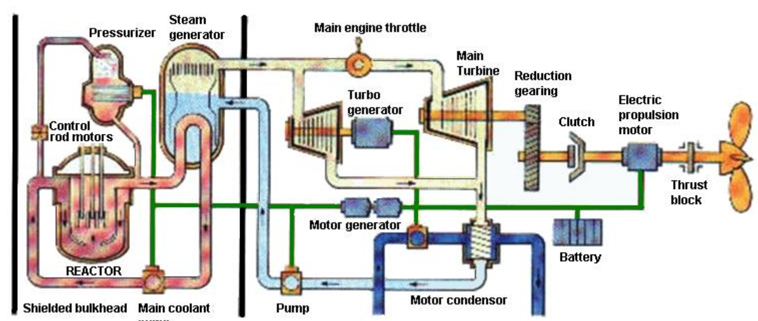
Rotational Motion System



Systems with Transmission Elements



Electrical Systems



Thermal Systems

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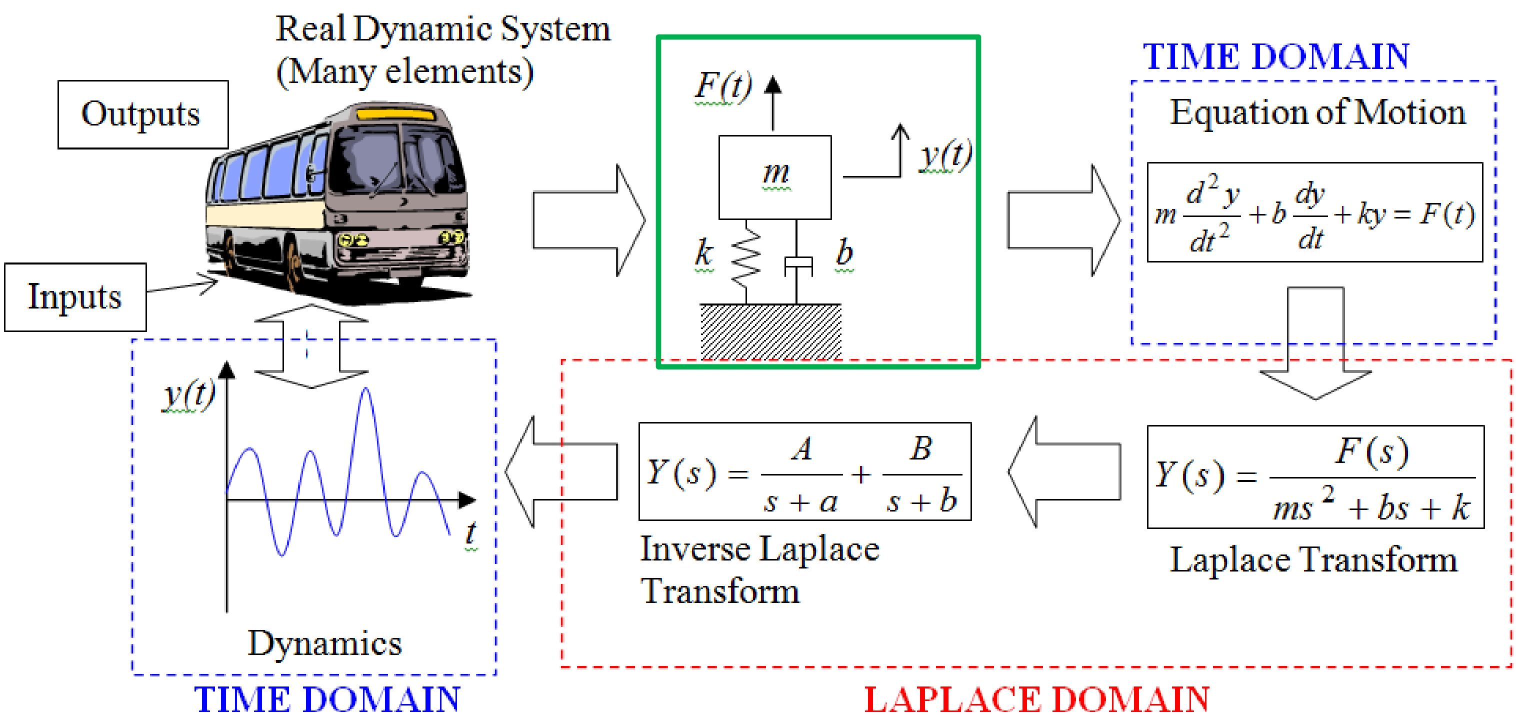
Course Objectives

1. Understanding how physical systems translate into mathematical models
2. Applying differential equations, Laplace transforms, and transfer functions to describe the behavior of the system
3. Use MATLAB to simulate, analyze, and visualize system dynamics



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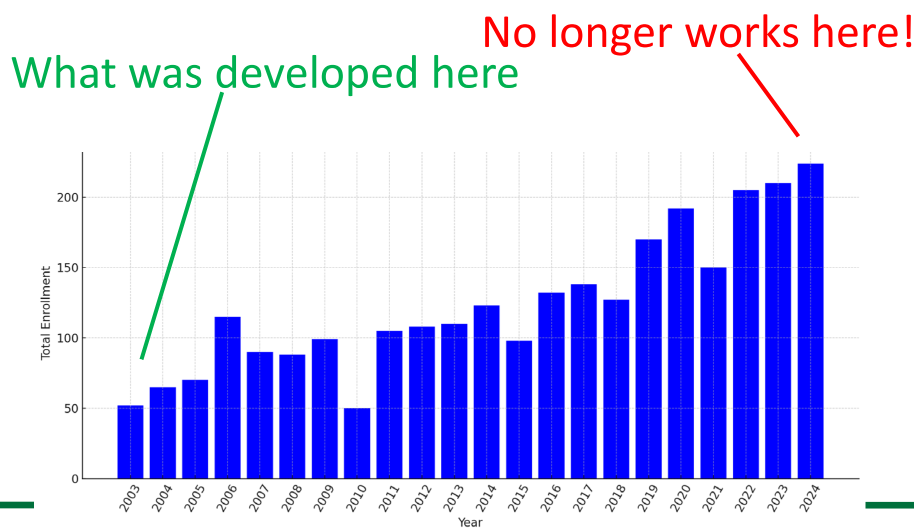
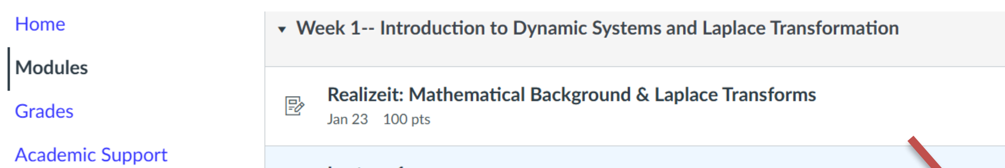
Why Adopt Adaptive Learning for a course Like Dynamics 2

Key Aspects	**Traditional Approach**	**Adaptive Learning Approach (Realizeit)**
Complex & Math-Intensive Content	Limited repetitive exercises;	Near-infinite practice via randomized problems or parameters
Large, Diverse Classrooms	One-size-fits-all lectures Varied math backgrounds ignored.	Personalized pacing Students advance based on mastery.
Feedback & Grading	Slow manual grading; misunderstandings linger too long.	Instant feedback on each question Suggest what topics might need additional review
Student Support & Intervention$ fees	End-of-term evaluations minimal data on individual progress. $100-ish textbook	Ongoing performance tracking Timely instructor interventions. $35 registration fee

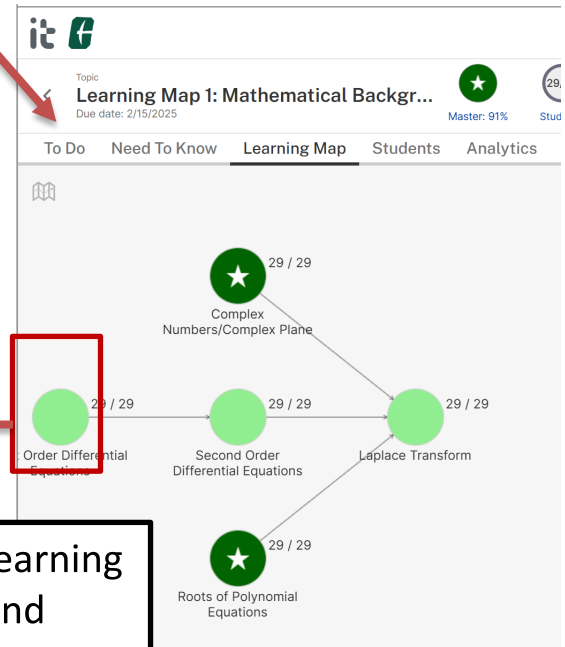


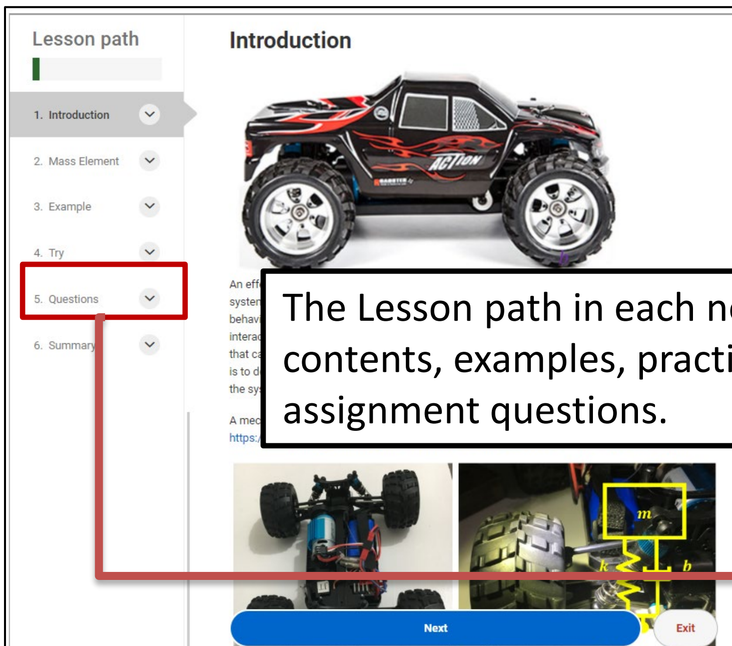
Realizeit is an adaptive learning platform that can be integrated into Canvas via its assignment tools.



Clicking a Realizeit assignment link in Canvas takes students straight to the corresponding unit in Realizeit. Each link can be set for a specific assignment or exam

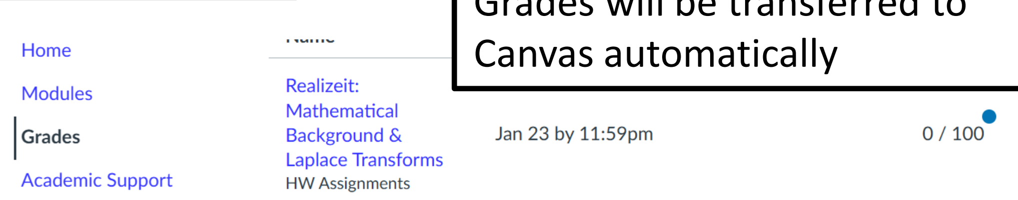
Each assignment module is built as a graph of connected nodes addressing prerequisites. As soon as one node is completed, the next unlocks, ensuring mastery at every step.





The Lesson path in each node contains learning contents, examples, practice problems and assignment questions.

Grades will be transferred to Canvas automatically



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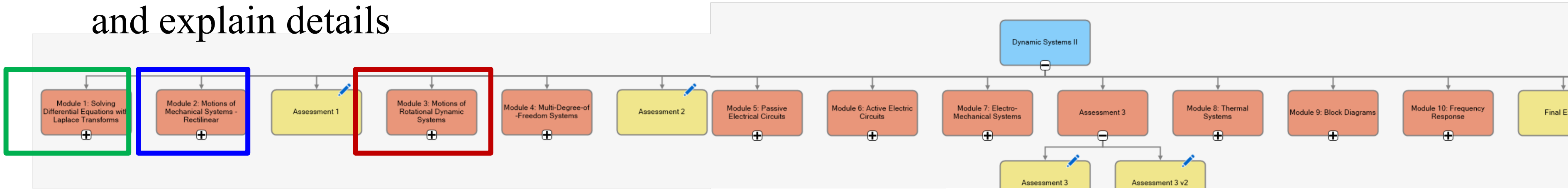
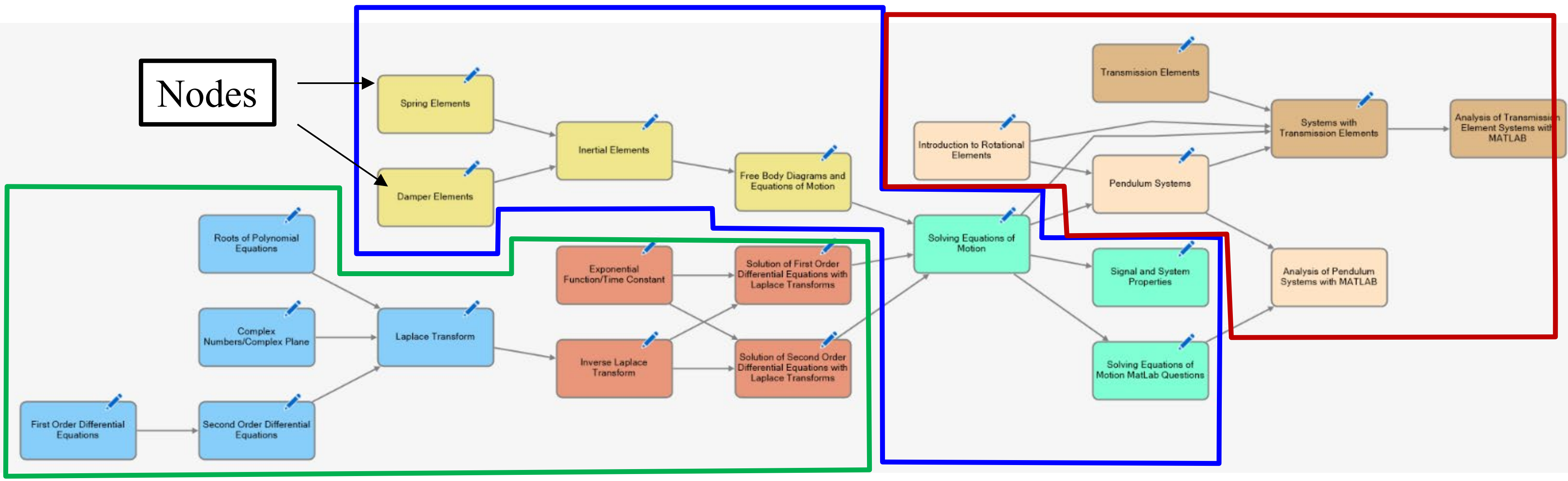
The entire course was reimagined.

- Mapped key concepts into a hierarchical curriculum
- Aligned lessons and objectives through a prerequisite network. The network contains modules which are focused on key concepts. Multiple nodes per module to break down and explain details



Module 2 – Motion of Mechanical Systems: Rectilinear

Module 3 – Motion of Mechanical Systems: Rotational



Module 1 – Solving Differential Equations with Laplace Transforms

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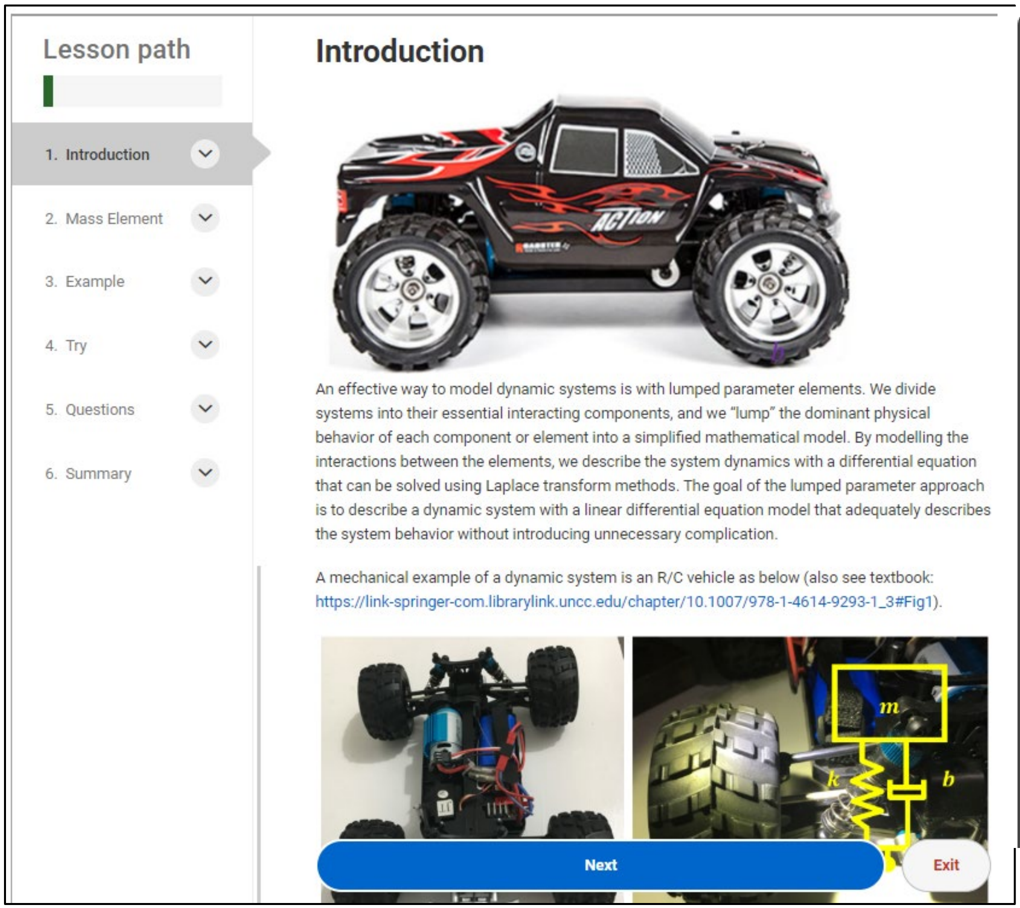
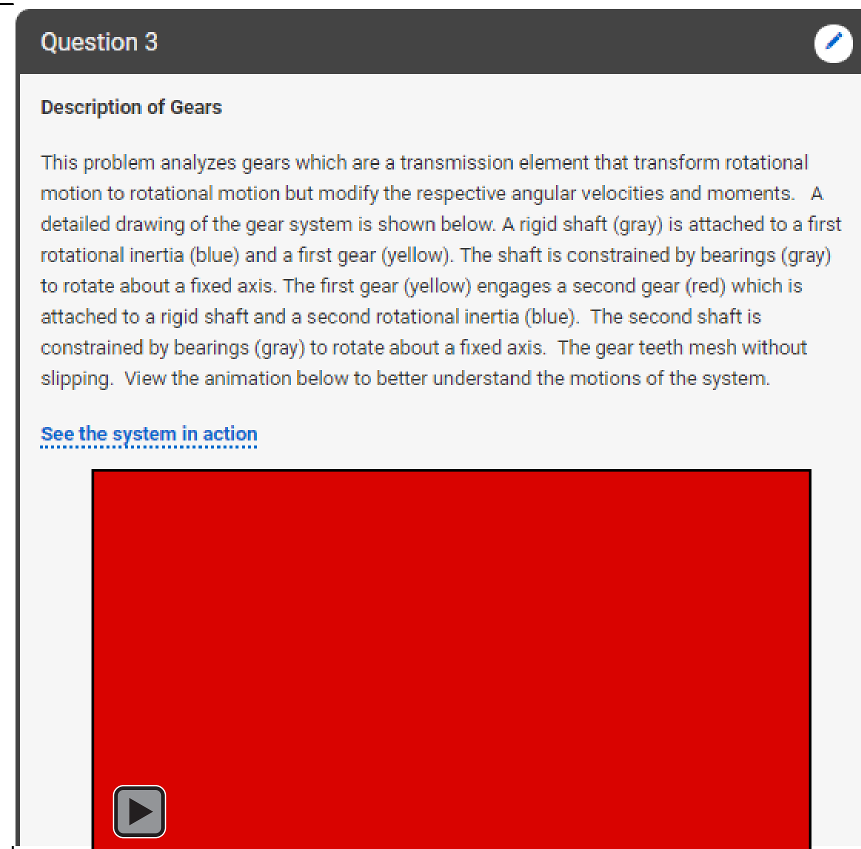
Instructional Content in Realizeit

- Instructional content was created using our own and open-source materials.
- Content is delivered in multiple formats—videos, files, and questions—embedded in a single page so students stay within the systems.
- Today, with platforms like ChatGPT, this part of the work can be done much faster and more efficiently.





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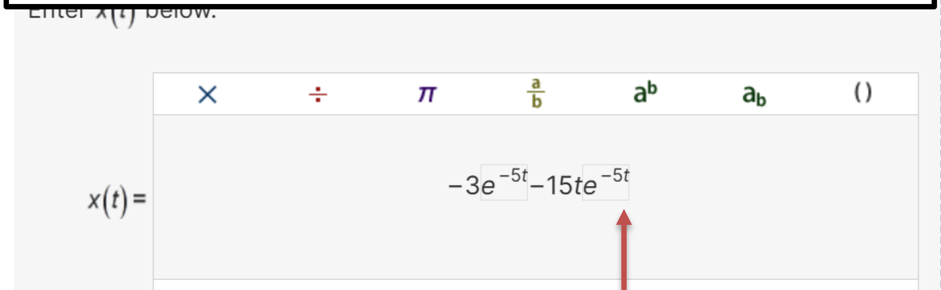
Questions in Realizeit

Student View

We express the equation in this form because each variable—$c_2, \sigma, \omega,$ —has a distinct physical interpretation, which is a key focus in Dynamics 2.



We define the range of variable to ensure the answer will have the form of

$$\boxed{x(t) = A_1 e^{-p_1 t} + A_1 t e^{-p_1 t}}$$

We call these systems critically-damped where the system does not oscillate.

Other possible form $x(t)$

$x(t) = A_1 e^{-p_1 t} + A_2 e^{-p_2 t}$ (over damped)

$x(t) = A_1 e^{-p_1 t}(\cos \psi t + \sin \psi t)$ (under damped)

Behind-the-scene

Step 1: Problem Definition

Use Laplace transform to solve the differential equation $c_2 \ddot{x} + 2c_2 \sigma \dot{x} + c_2(\sigma^2 + \omega^2) = 0$

With the initial conditions of $x(0) = x_0$ and $\dot{x}(0) = v_0$ for $x(t)$

Step 2: Variable Selection

Variables are defined as

- c_2 is a random integer number from $c_{2,\min}$ to $c_{2,max}$
- σ is a random integer number from $\sigma_{\min}$ to σ_{max} but $\sigma \neq 0$
- ω is a random integer number from $\omega_{\min}$ to ω_{max} but $\omega \neq 0$
- x_0 and v_0 are random integer numbers from $x_{0,\min}$, $v_{0,\min}$ to $x_{0,max}$, $v_{0,max}$ but $v_0 \neq 0$

Behind the Scene

```
% Clear environment
clear; clc;
syms s t X x0 v0 c2 sigma omega

% Define the roots of the characteristic equation
a = 1;
b = 2*sigma;
c = sigma^2 + omega^2;
p = solve(a*s^2 + b*s + c == 0, s);
p1 = simplify(p(1));
p2 = simplify(p(2));

% Laplace domain solution
X = ((s + 2*sigma)*x0 + v0) / ((s + p1)*(s + p2));
x_t = ilaplace(X, s, t);
x_t = simplify(x_t);

% Match to form a1*exp(-p1*t) + a2*exp(-p2*t)
syms A1 A2 real
expr = A1*exp(-p1*t) + A2*exp(-p2*t);
eqns = [subs(expr, t, 0) == x0, ...
        subs(diff(expr, t), t, 0) == v0];
sol = solve(eqns, [A1 A2]);
```

A	B	C	D	E	F	G	H	I
c2	sigma	omega	x0	v0	p1	p2	a1	a2
6	4	3	-1	1	-4	-4	-1	-1
3	2	1	1	-1	-2	-2	0.5	0.5
3	4	1	1	0	-4	-4	0.5	0.5
1	5	1	-1	-1	-5	-5	-1	-1
4	5	1	-2	-2	-5	-5	-1	-1
4	5	2	1	1	-5	-5	0.5	0.5
3	4	1	2	-2	-4	-4	1	1
2	5	2	1	-1	-5	-5	0.5	0.5
2	4	1	0	0	-4	-4	0	0
2	5	3	-2	-2	-5	-5	-1	-1
2	5	0	-3	0	-5	-5	-3	-1

Step 1: Problem Definition

Use Laplace transform to solve the differential equation $c_2\ddot{x} + 2c_2\sigma\dot{x} + c_2(\sigma^2 + \omega^2) = 0$
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- ω is a random integer number from ω_{min} to ω_{max} but $\omega \neq 0$
- x_0 and v_0 are random integer numbers from $x_{0,min}$, $v_{0,min}$ to $x_{0,max}$, $v_{0,max}$ but $v_0 \neq 0$

Such that the results have a form of

$$x(t) = A_1 e^{-p_1 t} + A_2 t e^{-p_1 t}$$

Step 3: Solution Generation

A Matlab code is written and the values of A_1, p_1, A_2, p_2 for a given $c_2, \sigma, \omega, x_0, v_0$ and an excel sheet is generated as source to Realizeit

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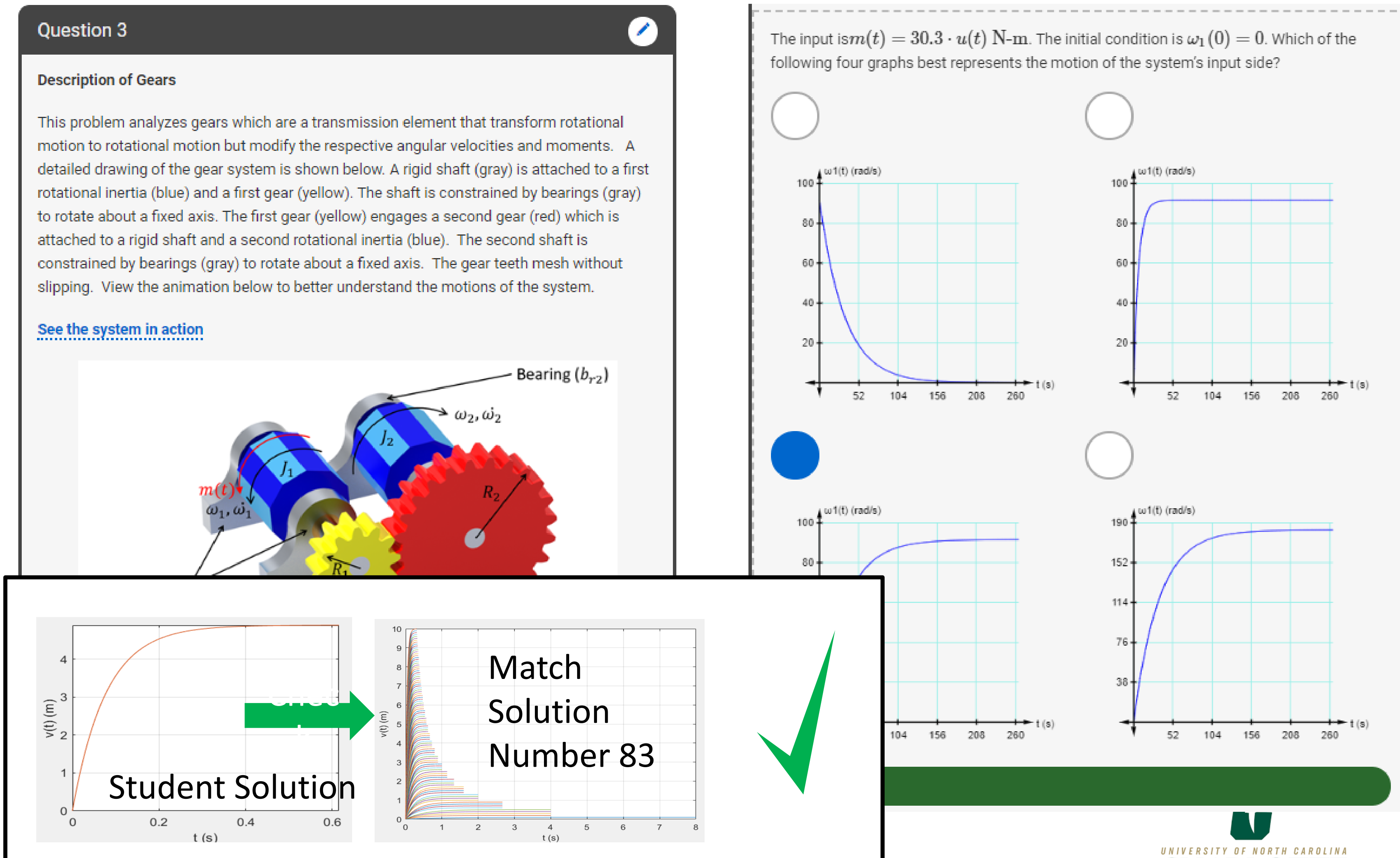
For graph-based problems, we generated several meaningful parameter sets, and behind the scenes, Realizeit checks each student's solution against all valid answers!



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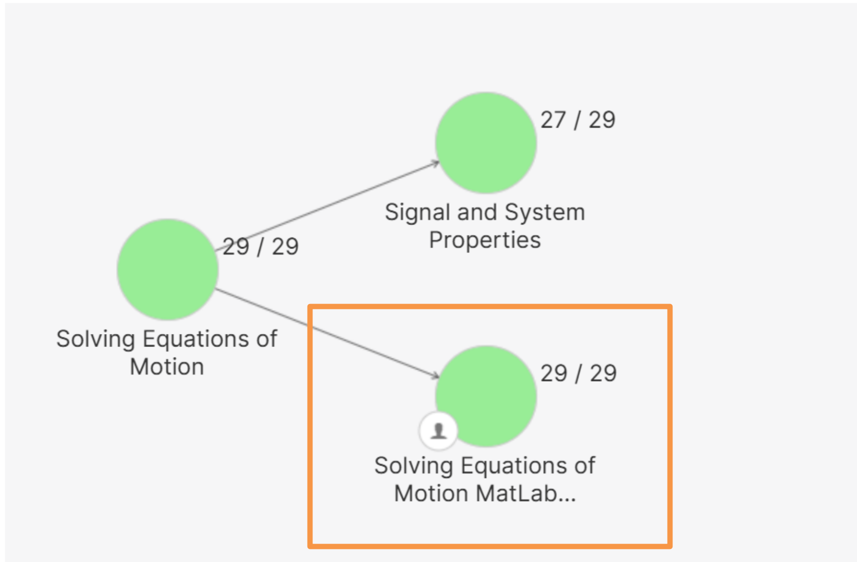
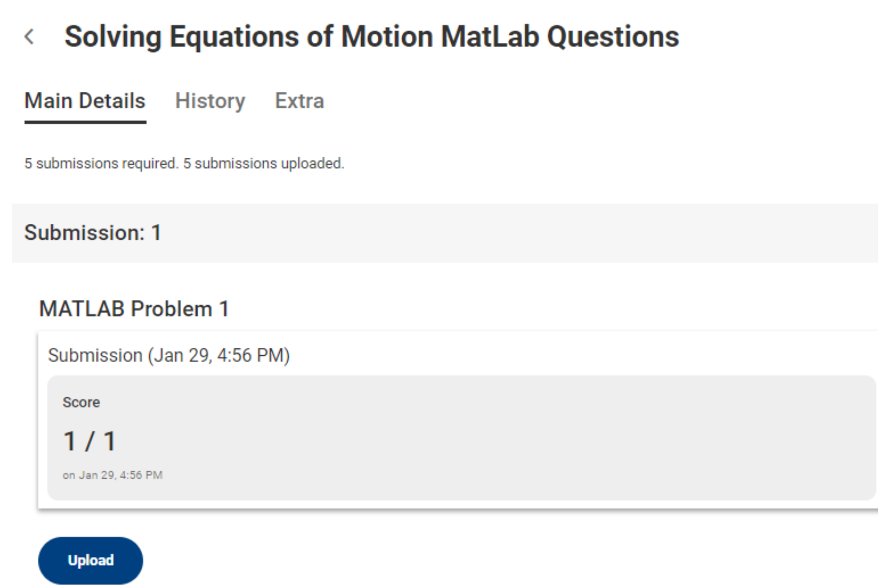
MATLAB Integration in Realizeit



- **MATLAB Grader** – for simple, auto-graded code within the platform.
- **Uploading Matlab Files** – for complex scripts that instructors review manually.



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5 submissions required. No submissions uploaded yet.

Submission: 1

MATLAB Problem 1

Upload

Students select the upload button to see the question

Problem 1: Simple Harmonic Oscillator

My Solutions >

In the previous node, Problem 1, you solved the problem below for x(t). Retrieve your answer now. In order to better
the following in MATLAB Grader: (1) generate a time vector "ts" with a maximum value of $4T$, a minimum value of 0, a
corresponding to the time vector "ts"; (4) plot "xs" versus "ts". Follow the instructions carefully.

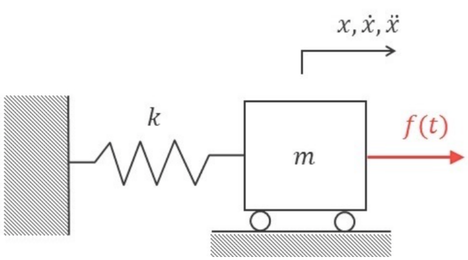
Click "Run Script" and ask yourself the following questions.

Can I see the period of the oscillation in my plot and does it make sense?

Do I see that my solution is not damped?

When you are confident your code is correct, click "Submit" and MATLAB Grader will check your solution. When you a

The Matlab questions are the same questions in the previous nodes. Therefore, students already know the parameters and answers, but they are asked to code it up for better understanding.



Script

Save Reset MATLAB Documentation Open Item in MATLAB Online

```
% READ THE FOLLOWING INSTRUCTIONS BEFORE CODING
% Do not define the statements "clear all" and "clc"
% Assign your time values in a variable 'ts' and displacement values in variable 'xs'.
% When using the plot command assign the the command to a variable f (i.e.) use f = plot(ts,xs);
% The evaluation algorithm will search for the variables ts, xs and f to evaluate your code.

```

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MATLAB Integration in Realizeit

Your Script

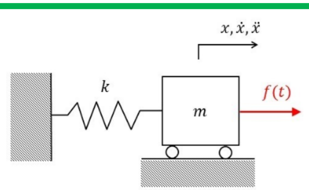
Save | Reset | MATLAB Documentation

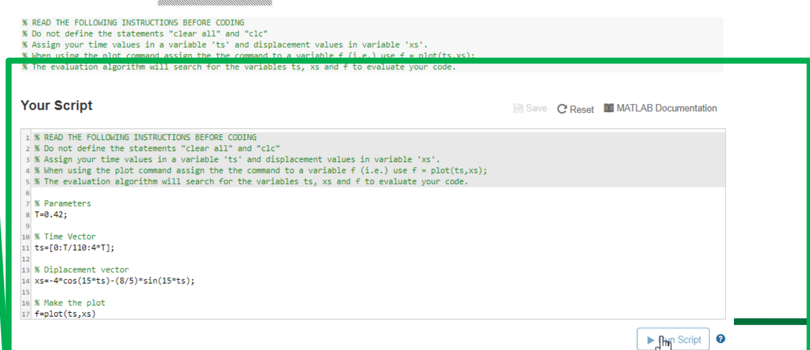
```
% READ THE FOLLOWING INSTRUCTIONS BEFORE CODING
% Do not define the statements "clear all" and "clc"
% Assign your time values in a variable 'ts' and displacement values in variable 'xs'.
% When using the plot command assign the the command to a variable f (i.e.) use f = pl
% The evaluation algorithm will search for the variables ts, xs and f to evaluate your

% Parameters
T=0.42;

% Time Vector
ts=[0:T/110:4*T];

% Diplacement vector
xs=-4*cos(15*ts)-(8/5)*sin(15*ts);

% Make the plot
f=plot(ts,xs);
xlabel('t (s)')
ylabel('x(t) (m)')
axis([0 max(ts) min(xs) max(xs)])
grid
```

Run Script

The scripts have some instructions to make it implementable in Malab graders

Known parameters from problems that the student have already solved in other nodes





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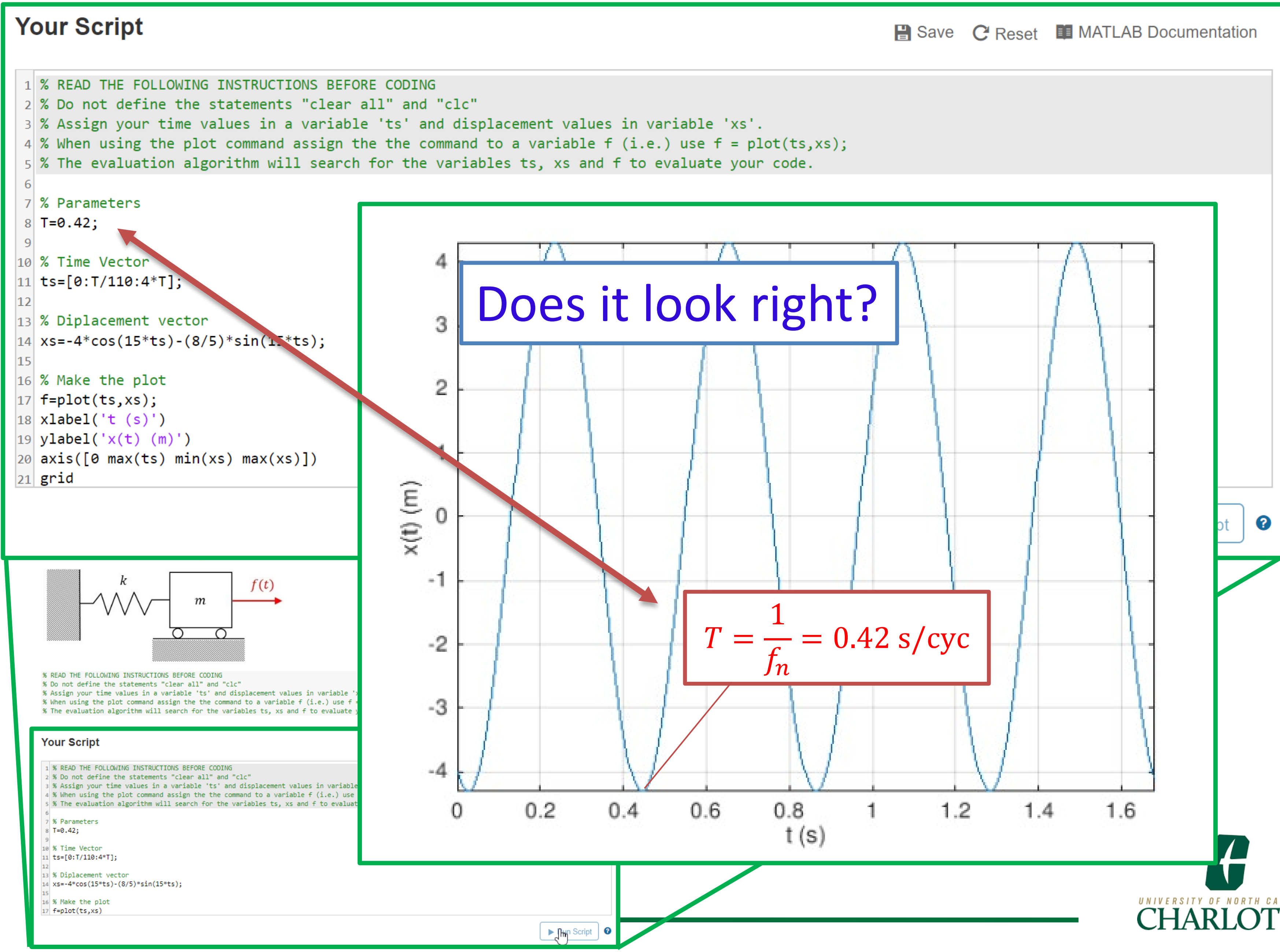
Plot the solution in MATLAB Grader.



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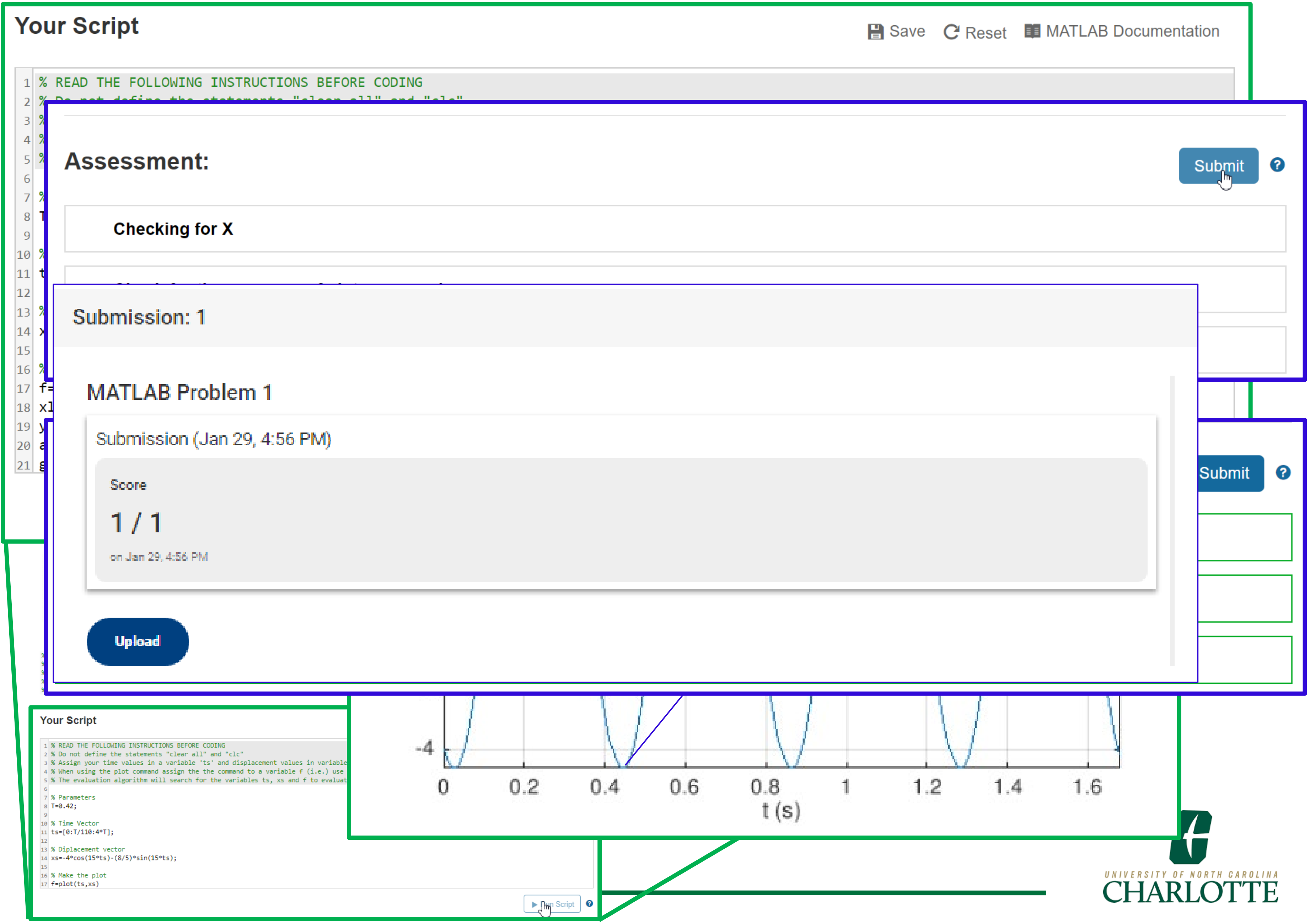
Example 1: Plot the solution in MATLAB Grader.



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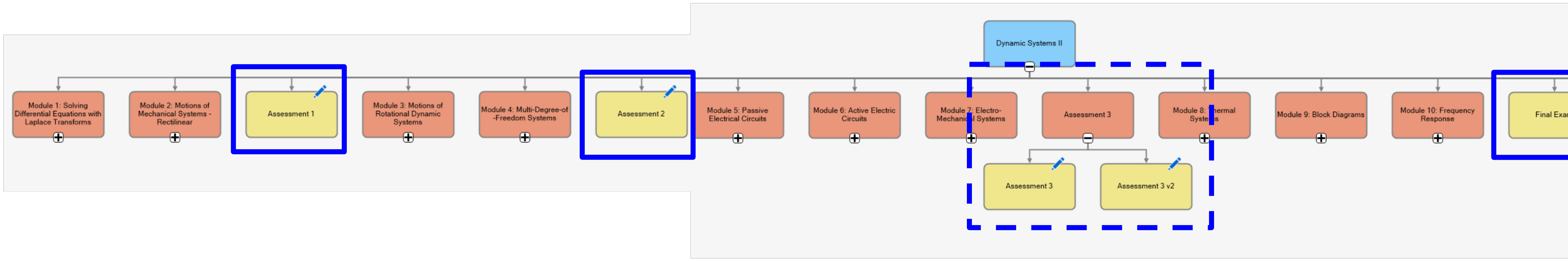
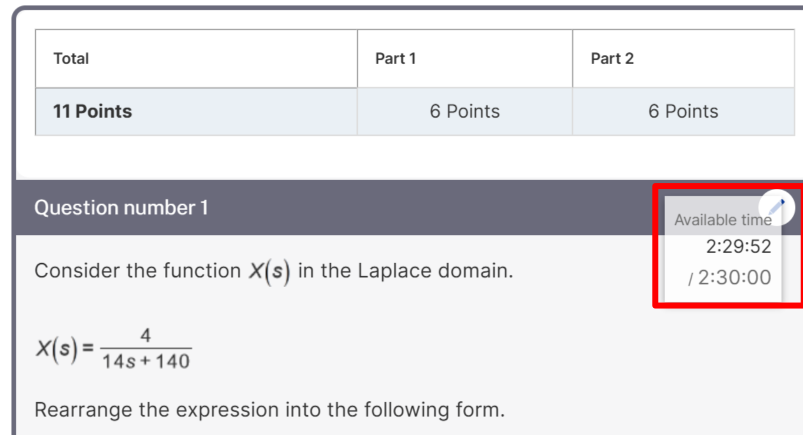
Exams in Realizeit

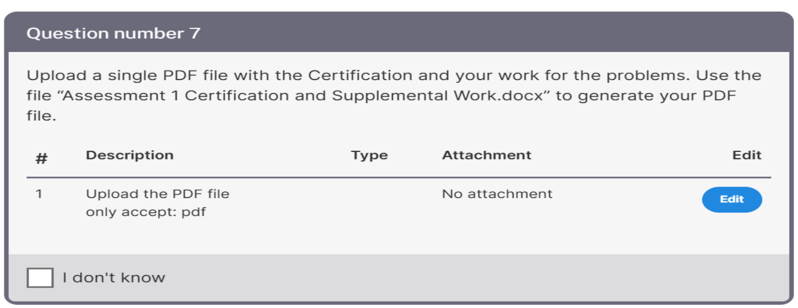
We created exam modules as standalone modules outside the adaptive path to assess mastery independently of practice progress. The exam modules only consist of several questions.



Different students get different values—same structure, same difficulty.

Exams can be set with a **strict timer, single attempt**, and **optional lockdown browser** if needed.





The exams are auto-graded but we ask students to submit their work for partial credits.

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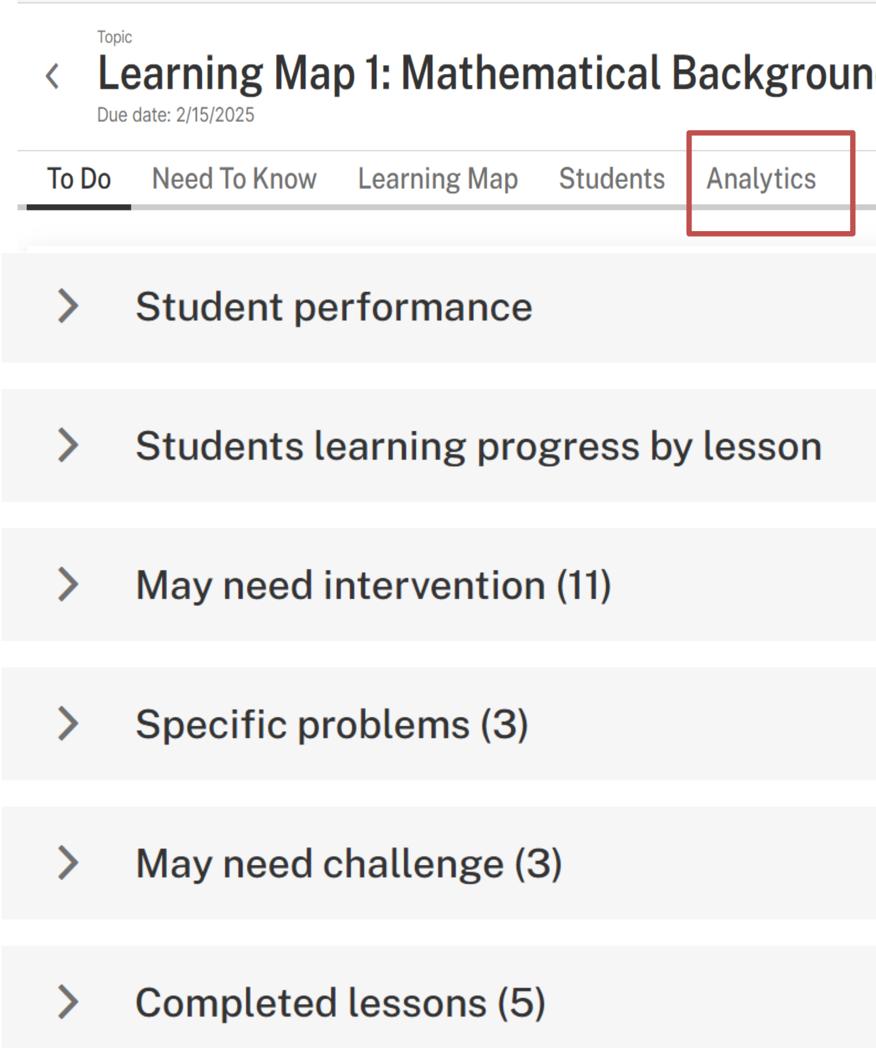
Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool



Objective: Investigate the use of targeted interventions to improve student performance and engagement.

Student Groups:
- **High Achievers**: Strong performers with consistent progress.
- **Struggling Learners:** Students significantly behind in coursework.
- **Inconsistent Performers:** Began work but struggled to complete it.
- **Whole Class:** General interventions sent to all students.

Interventions: Personalized messages offering assistance, motivational support, and sample problem solutions, tailored to each group's needs.

Evaluation Metrics: Submission rates, grades, engagement levels, and overall student satisfaction.

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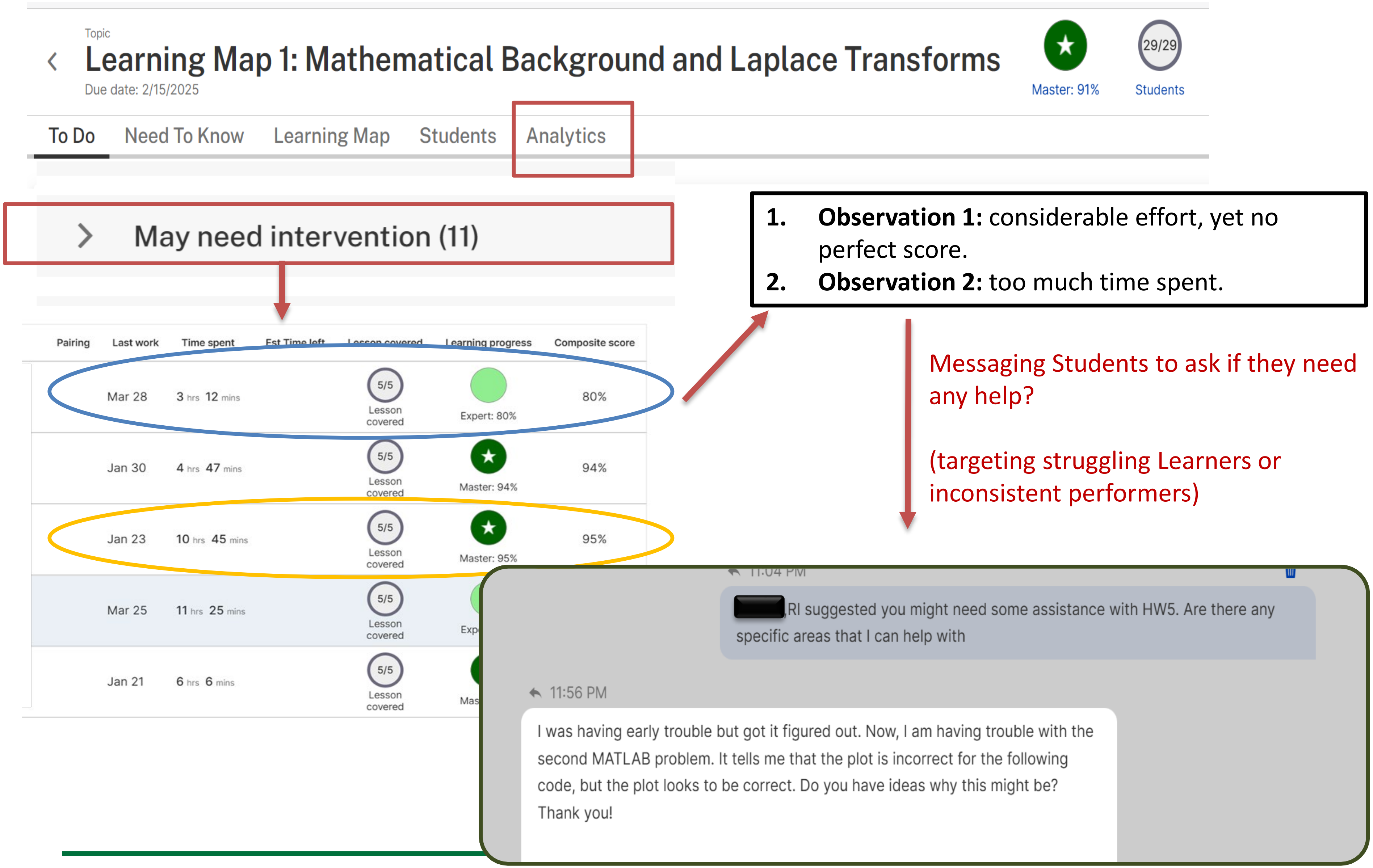

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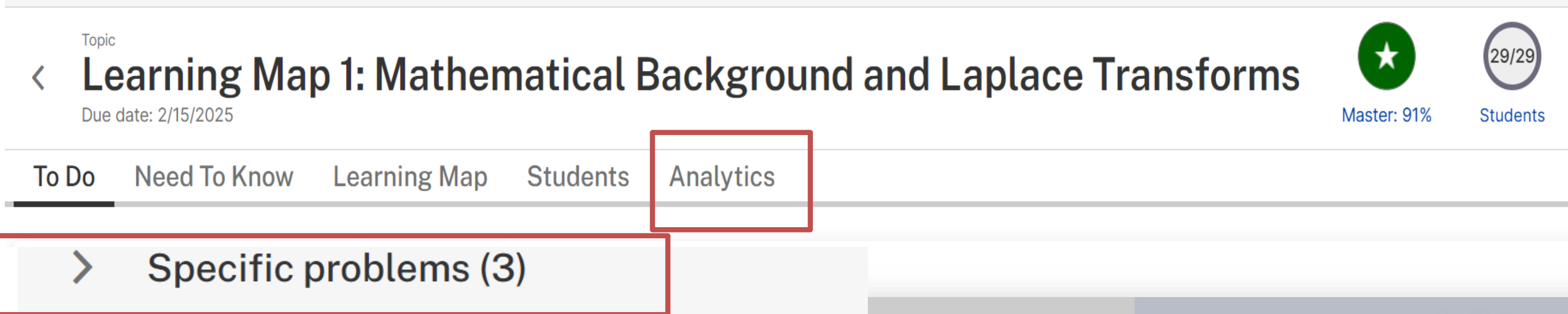
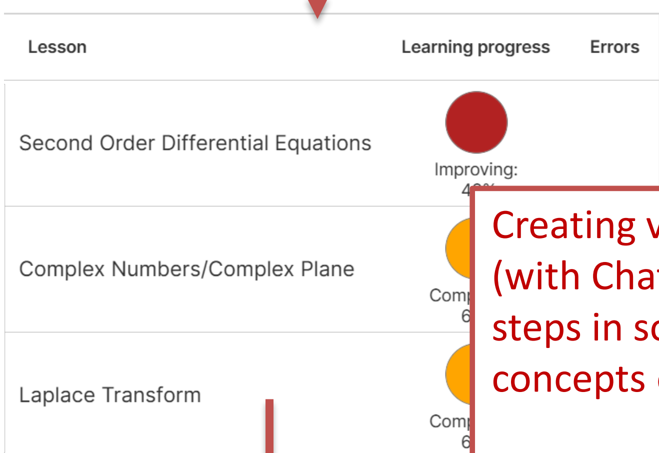
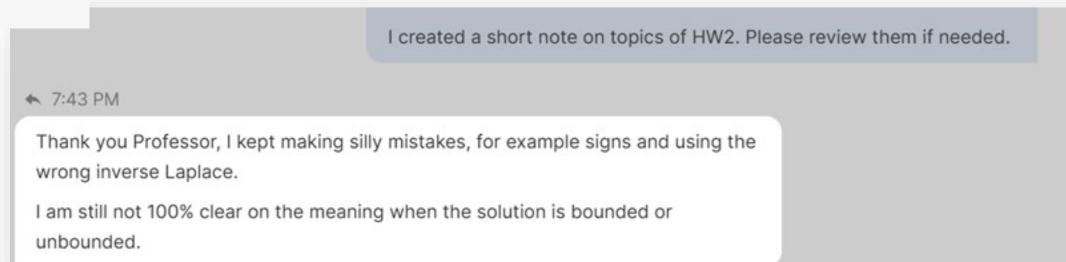


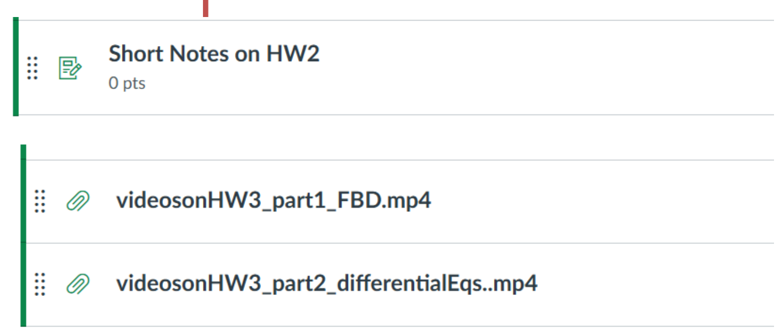




Creating videos or concise lecture notes (with ChatGPT) that highlight the primary steps in solving problems and the core concepts of the material.

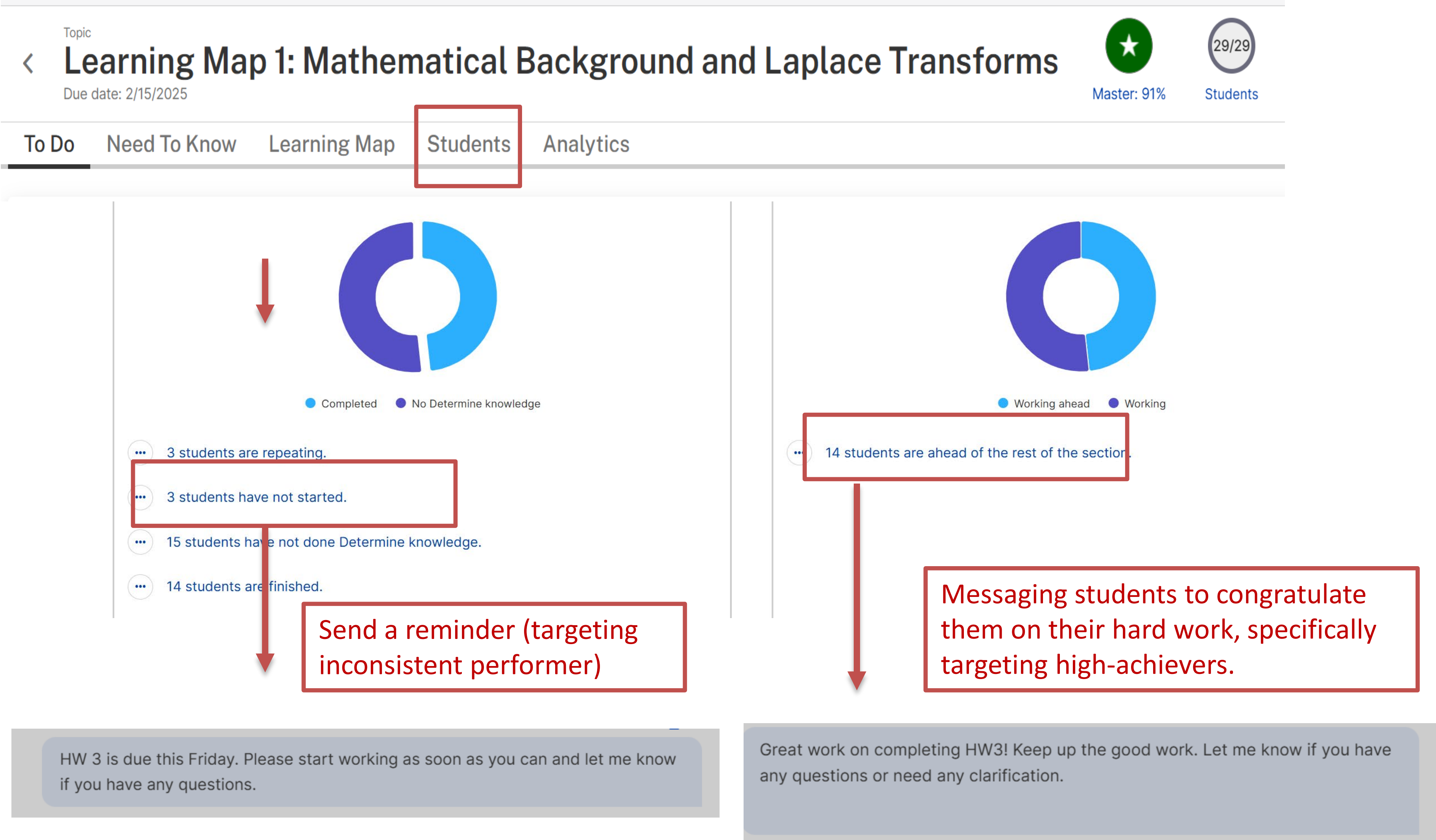
(targeting whole class and struggling learners)

Messaging students and let them know about additional resources



Observation Quickly spot the specific nodes and content areas where students struggle

Realizeit allows student support by tracking their performance and providing timely interventions via its analytic tool



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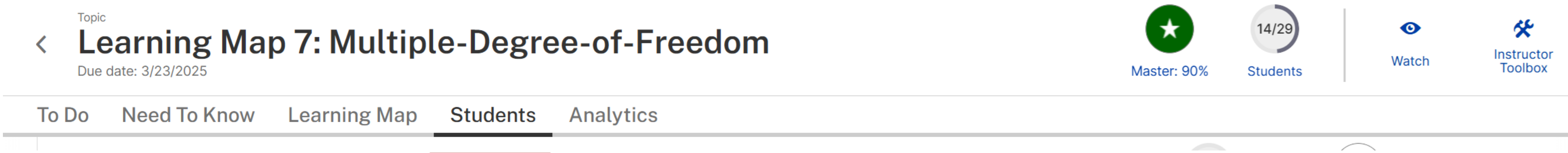

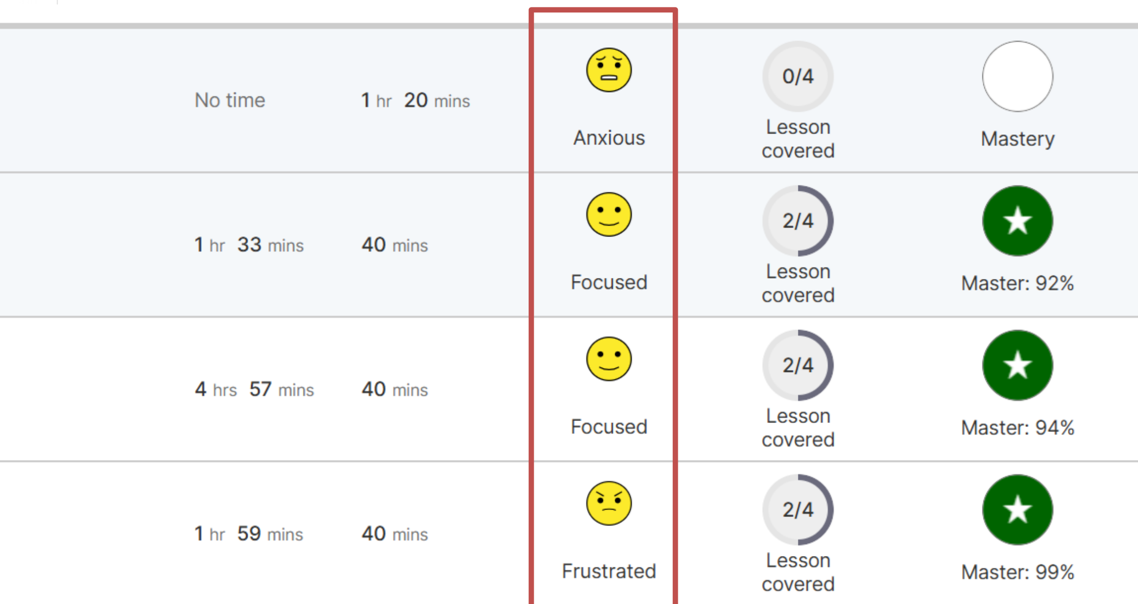

Observation: Although students can use emojis as an indicator on their emotions for achieving their goals, they rarely update their responses or engage with emails regarding their emoji status. After completing HW1, there is **minimal** change in the emoji patterns.

> I noticed that you selected the "frustrated" emoji. Please let me know if there's anything I can do to help. I encourage you to review the short notes I posted on Canvas related to HW1, as well as the video on complex numbers.
>
> Let me know if you have any questions—I'm happy to assist!

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Personal Connections with Students Matters: Adaptive Learning Makes It Scalable

My Reviews in Spring 2024

- My biggest issue was less with the course and more with the realizeit course. I just feel it took way too much time out of my week to complete in comparison equivalent homework assignments.
- I really enjoyed the content and lectures in this course, but felt like the Realizeits were buggy and kind of confusing at times.

My Reviews in Spring 2025

- Online resources were excellent.
- The professor related the problems to real life so it was easier to understand the concepts. Going over problems during class helped a lot too. RealizeIt is great because it reinforces what was learned in class.

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Conclusions

- Students value personalized messaging and targeted interventions.
- Realizeit's analytics help instructors quickly identify student challenges.
- While the initial setup may be resource-intensive, the system is highly sustainable—and often requires minimal resources to maintain.

New Challenges when AL is implemented

1. Some students attend class less, relying on online resources.
2. Need deeper real-world context and application to maintain student's interest and attendance.

Future Plans

- Promote attendance with bonus/challenge problems.
- Continuously refine interventions (or even automate some of them), sharing best practices.
- Expand adaptive learning to other engineering and STEM areas.

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Thank you very much!

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