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NOVICE DECISION MAKING DURING CREATION OF ELECTRIC GO-KART RACING EDUCATIONAL MATERIAL

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In 2017 Purdue evGrand Prix hired a K-12 Indiana public educator (the author) to write instructional material that could be implemented into participating teams' high school science and engineering classrooms. The goal was to create science-based integrated STEM learning experiences that complement the construction and racing of a 48-volt electric go-kart. Over the next four years, the instructional designer learned how to implement instructional design techniques and theories while navigating the changing dynamics of a fledgling educational program. Personal experience with woodworking, classroom instruction, and classroom curriculum development played a huge role in instructional design decisions. Early decision-making processes were rooted in making slight modifications to existing educational resources. Here, minor edits were made for application to motorsports generally, and go-kart racing specifically. When specific go-kart educational materials were not available, educational and classroom best practices became the raw material for creating new and innovative instructional material. Collaboration with peers, professionals, and subject matter experts became the norm, while feedback from participating schools helped develop a single-minded focus to meet both teacher and student needs. Formalized training within an instructional design and technology course provided much-needed organizational and methodological skills associated with the transition from a teacher designing classroom resources to an instructional design professional.

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INTRODUCTION

In 2009 Purdue University was awarded a $6M grant from the Department of Energy to expand electric vehicle (EV) education. As part of this grant, Purdue developed an EV educational program to provide college students with an increased understanding of EV capabilities and hands-on technical training for future EV-related careers. After five successful electric go-kart racing events at the college level, Purdue evGrand Prix developed a downsized version of the program for Indiana high schools.

The key difference between the collegiate go-kart program and the high school program is the electric powertrain and battery pack. Participants in the collegiate series are free to design or purchase necessary components for constructing battery packs using lithium-ion cells. The resulting 48V to 72V battery packs provide power to an AC motor by means of an AC motor controller (either purchased or designed specifically for constructed battery packs). Participants in the high school series power their go-karts using four 12V lead acid batteries (totaling 48V). This battery pack then supplies power to a DC motor by means of an off-the-shelf motor controller found in many electric golf carts.

It was this scaled-down version of EV education with which I was approached while teaching science in the Indianapolis Indiana (US) public school system. Initial conversations with program developers were dominated by their desire to provide learners with a one-of-a-kind learning experience where students would design, build, and race their go-karts on a temporary track at Indianapolis Motor Speedway (IMS).

Throughout this process, high school students would learn valuable engineering design skills and interact with professionals within the EV and motorsports industries. These conversations sold me on the program, and I became one of the five high school partners asked to pilot the program within my Integrated Chemistry Physics (ICP) course (see Figure 1).

Each pilot team was provided a complete chassis and electrical system after committing to obtain community

FIGURE 1. Myself and my classroom students as we learn how to operate our go-kart.

funding to offset the evGrand Prix program director's initial purchase of electronic components, batteries, and race day equipment. The "loaned" functioning go-kart was to be a tool for developing community outreach programs for obtaining sponsors and establishing student interest.

Teams would compete in the inaugural evGrand Prix High School World Championship event at IMS at the end of the school year (mid-May). The high school evGrand Prix would resemble the collegiate series, with teams earning points during an Academic Challenge (engineering and community outreach presentations). Additionally, points would be awarded based on race energy efficiency and final race placement. The team with the highest combined score would be crowned the High School evGrand Prix World Champion.

DESIGN CONTEXT

To facilitate a successful 2016 IMS race event, evGrand Prix leadership repurposed college program documentation into "educational" resources to bring high school teams up to speed with "running a motorsport" program. Teams were provided a sample PowerPoint used by college teams to obtain sponsors and financial support. However, we had to figure out the best way to approach this based on previous experience with funding projects.

Next, teams were given manuals detailing the collegiate go-kart assembly process, sans battery build and AC motor wiring. This modified collegiate manual included images of select processes, components, and necessary sprinter chassis modifications to account for added battery weight. This resulted in a trial-and-error approach when working with students in maintaining go-kart functionality.

An engineer from the Purdue University Electrical Engineering Department provided a component wiring diagram detailing electrical connections necessary for a functional 48V DC electric powertrain. This wiring diagram was drawn on a stripped-down image of a sprinter chassis to illustrate the recommended placement of interconnected components. This was helpful when tracing electrical faults and replacing faulty components, but little else.

During the piloting stage of the high school evGrand Prix program, the motorsports educational outreach subject matter expert (motorsport SME) and evGrand Prix director continually touted the educational value associated with this unique STEM career readiness program. The motorsports SME suggested learning aspects would occur naturally as students were introduced to the competitive world of motorsports racing. On the other hand, the evGrand Prix director insisted the program was built on educational experiences culminating in a real-world competition of acquired skills and knowledge. Still, no associated curricular material was provided.

A compromise between the motorsport SME's focus on putting on a good show for spectators and the evGrand Prix director's insistence on explicit educational learning activities resulted in the high school teams being provided the collegiate series scoring rubrics for each of the Academic Competition presentations two weeks prior to the IMS event. Teams were thus able to throw together draft versions of what each had done related to managing a go-kart team, obtaining sponsors, and maintaining a race-ready go-kart.

Finally, just prior to the IMS event, teams were provided a single-page document detailing race day procedures and safe practices at the track. Teams were also provided documentation regarding needed equipment and a list of other "critical" aspects related to the High School evGrand Prix World Championship.

Feedback provided by pilot teachers (myself included) regarding the 2016 and 2017 IMS events indicated the need for classroom resources and educational strategies to teach students how to safely operate the go-kart, maintain functionality, and implement mechanical and electrical adjustments to improve performance. Impetus within initial documentation made available to pilot teachers. In addition, pilot teachers expressed interest in ways to relate coursework in science and career technology education (CTE) classes to their go-kart programs.

At this point, the evGrand Prix program director recognized the need to hire someone with experience creating hands-on learning activities within high school classrooms to develop resources using go-karts as a learning tool both inside and outside the classroom. I was subsequently hired as an instructional designer and assigned the task of developing envisioned educational resources for evGrand Prix high school participants. This article describes my journey designing these instructional resources and my efforts to meet teacher and student needs associated with this truly unique learning experience. I will focus on my decision-making as a novice instructional designer while developing classroom resources and track-side educational go-karting events.

INITIAL FRAME OF MIND

After teaching high school inquiry-based science for 17 years, the transition to a full-time instructional designer was a new experience, requiring me to learn and develop new skills. As part of a STEM curriculum development project outside my own classroom, I was tasked with creating STEM-based learning experiences all high school teachers could integrate into their classrooms. In addition, I was to assist evGrand Prix program staff in meeting program goals directly related to an ongoing multi-million-dollar research project. Finally, I was also tasked with acting as a liaison between evGrand Prix program staff and high schools.

While I had guided my high school teams through the initial two years of the program (2016 and 2017 IMS events), I was by no means a go-kart expert or an instructional design professional. However, my experience within the K-12 educational system, my connections to potential participants, and my success leading my pilot team in both 2016 and 2017 made me uniquely qualified to grow into this position. As I settled into my new role, I realized I had other expertise that might prove valuable. It was from this frame of mind I first drew on my extensive woodworking knowledge to prioritize my workload.

There are two fundamental types of woodworkers: (a) those who repair and improve existing woodworking projects; and (b) those who create items from scratch using a pattern or template. Each type has their own set of constraints and associated required knowledge and skills.

Imagine a typical kitchen or dining room chair with the spindle between two legs having been chewed by the family dog and mold/water damage from sitting in the basement for years (see Figure 2, left image). While technically still usable, this neglected chair just needs repair and refinishing to bring it back into full function for the owner.

Now, imagine being asked to create a one-of-a-kind bathroom vanity that looks like a table with a stone bowl sitting on top (see Figure 2, right image).Thought must be put into the table's structure and creative elements (i.e., shape, placement of legs, laminating various types of wood together, etc.). This is especially challenging when the client indicates the "sink basin" must be equipped for plumbing and inconspicuously functional.

In both cases, key decisions along the way impact the final product. When working on a repair, restoration, or refurbishment project, one takes something that already exists and makes much-needed repairs and improvements without modifying the original design. One is just bringing the item back into working order and returning it to a lost quality and usefulness.

 

FIGURE 2. The left image shows a chair with visible spindle damage I was asked to repair. The right image shows a bathroom vanity the author was commissioned to create from scratch; the half-moon shape was specifically requested by the client.

On the other hand, when designing a new piece, one begins with a set of raw materials and brings them together to form the final piece. When starting from scratch, one cannot anticipate every detail or slight design modification necessitated by inherent features of the chosen wood, processing methods, and client stylistic add-ons and modifications. All unanticipated edits and add-ons force the woodworker to make required modifications to both the original design conception and the raw materials used during construction.

Sitting at my office computer and designing classroom-ready science content was very different from hiding out in my shop and working on a woodworking project. In my workshop, I am an expert surrounded by trusted tools, familiar sights and sounds, and I am the sole decision maker. Sitting in an office at Purdue surrounded by so many highly educated individuals, unfamiliar sights, and sounds, and pressure to effectively merge teacher wants and needs with program administrator wants and desires was an intimidating experience for me.

Feelings of inadequacy as an instructional designer were compounded when evGrand Prix's motorsport SME forwarded me a document discussing the evGrad Prix mission, vision statement, and more details about the project accompanied by the note "Here is the working document for the curriculum project".

Repurposing vs Creating From Scratch

The last section of the evGrand Prix vision statement stated the need "to create additional resources to improve course offerings and our program participants personal skills regarding 'employability' and/or 'college preparedness'. Skills that were researched and recommended by our industry partners as well as our other institutes of higher education." Additionally, the program documentation included a comprehensive list of identified relevant skills.

My familiarity with Indiana Academic Standards helped me understand that most of the stated topics could be accomplished using the Indiana Department of Education (IDOE) suggested high school science, mathematics, and career technology education (CTE) curriculum. Repurposing these resources would be akin to repairing and refinishing a piece of furniture. While the fundamental aspects of each course's resources could be retained, I anticipated slight modifications while adapting resources unique to specific educational contexts and programs.

In addition, many of my thoughts were influenced by STEM and maker education articles I was familiar with referring to this integration of scientific inquiry with principles of technological design from CTE courses as purposeful design and inquiry (Sanders, 2008). Repurposeable science content included motion and forces activities, DC circuits, and friction. Mathematics activities included data analysis and statistics; linear equations; inequalities; and number systems and expressions.

During this time, I came across two thought-provoking articles. Hallström & Schönborn (2019) and Ornek (2008) identify modeling as a methodological link between science and CTE education. I, therefore, envisioned using various modeling activities as starting points for connecting the evGrand Prix track-based program with classroom-based activities. Fortunately, pairing existing Indiana Science, Mathematics, and CTE standards with most of the identified skills appeared straightforward.

At the end of the evGrand Prix documentation of identified skills came a section entitled "Using the kart as a platform of relevance in the classroom." Here, program administrators indicated lights-on-moments coming from opportunities for students to utilize the go-kart in math, physics, engineering, and technology problems. Teachers were told they would be able to find the right scenario to demonstrate any course content issue and apply that problem to the team's go-kart.

I interpreted this as a call for classroom content that teachers could use when working with students prior to hands-on go-kart specific activities. In the process, I envisioned the go-kart becoming a discussion point in multiple science, engineering, and math activities. To this end, I actively began looking for classroom content from automotive courses that could be repurposed, informal go-kart learning options, and go-kart maintenance how-to content. Identified automotive and motorsports content that could be repurposed including understanding race lines, tire contact patch, steering alignment, and go-kart seat positioning to name just a few.

In the end, I was able to whittle down the list of topics I had to develop from scratch to a manageable number. This included motor controller programming; tuning the go-kart for the race; preparing the go-kart for technical inspection (tech-inspection); and roles and responsibilities of team members (driver, crew chief, pit crew)

Creation of STEM Investigation Template

I assumed the best place to begin was by evaluating my own experience participating in the Go-kart program. I started asking myself how I teach my students to understand such things as go-kart handling and performance, the science and engineering behind chassis design, and how to manage and maintain battery charge. Evaluating my existing classroom/track side content would assist me during both the repurposing of existing activities and the design, fabrication, and assembly of new educational content into a finished product.

I decided to focus on activities relating specifically to operating the 48V high school go-kart itself. It was then I recognized that associated topics could be grouped into broader SME categories. I reached out to experts at Purdue, and peers within Indiana high school classrooms to learn current practices within STEM subjects being taught in rural, urban, and suburban classrooms. For the topics relating to go-kart handling and performance, I reached out to the owner of a local go-kart shop (Fox Valley Kart Shop) in downtown Lafayette Indiana (US).

Having spent much of my teaching career creating classroom activities targeting student-driven problem-based inquiry activities for science classes, I felt completely at ease with creating the exploratory science content. Within my classroom, we blended science content with engineering content to increase student understanding of motion and forces. In one example project students designed, fabricated, and raced pneumatic dragsters. Connecting specific go-kart related content to this existing classroom content would be relatively straightforward. I imagined I could apply the same thinking and design techniques used when developing connections between relevant science topics and the design, construction, and racing of the electric go-kart.

I then began the leg work associated with developing drafts of several resources. This included looking into what has been written about formalized integrated STEM education. Most of this centered around balancing the need to assimilate science content and mathematical reasoning within an engineering context and strategic use of technological resources (Kelley & Knowles, 2016; Stohlmann et al, 2012; Thibaut et al., 2018). These readings also indicated a gap in research on integrated STEM frameworks.

As a novice instructional designer with no formal training outside of an undergraduate science teaching methods course, I was never introduced to instructional design models nor was I aware of research-proven strategies with which to appropriately design and implement all four STEM subjects as an integrated whole. Ejiwale (2013) indicated failing to approach STEM integration effectively would decrease "the curiosity and self-guided inquiries on the part of learners" (p. 66) and will limit any long-term learning goals a STEM program may envision.

My classroom experience told me less motivated learners would need assistance in transitioning away from teacher-centered instructional practices to more student-centered learning experiences. My interaction with science teaching colleagues led me to believe most classrooms' evGrand Prix curriculum would find its way into would not be facilitated by people with my skill set. I therefore returned to repurposing classroom projects, using them as models for designing go-kart specific classroom exploration activities (e.g., modeling acceleration, calculating speed from tire RPM, turning forces, steering alignment) that integrated all four STEM subjects into a single learning activity, examples of which can be found on hardwarestorescience.org.

Several unifying features between project-based learning and the envisioned exploratory activity include:

- Learners work in collaborative teams.
- Learners are provided with supporting information related to the project.
- Often requires learners to investigate a phenomenon by means of experimental testing apparatus.
- Requires some form of data collection.
- Asks learner to make connections between activity objectives and collected data.
- Teacher acts as faciliatory.

Combining CTE activities with traditional inquiry-based science classroom activities was the fundamental goal. Repurposing pre-existing science and CTE classroom resources resulted in a standardized high school science classroom investigation framework applicable when K-12 teachers and instructional designers are fabricating classroom content requiring learners to construct an experimental testing apparatus (White, In Press). What follows are just a few of the unique features found in the first iteration of the template developed to meet this objective, as illustrated within the Battery Operation Investigation.

> ***Build it Yourself***
>
> *In order to investigate battery runtime, you will need a model on which to experiment how the electric potential and current changes in relation to the number and arrangement of electrochemical cells in a battery or battery pack. Your model should consist of a sectioned ice cube tray with zinc coated sheet-metal screws and copper wire. One way to successfully do this would be to build a model that would allow the individual sections of the ice cube tray to be connected together with electrodes made from the zinc coated sheet-metal screws and copper. The electrodes can then be arranged so that the "cells" of the ice cube tray are connected in series and/or in parallel.*
>
> ***Investigation Objectives***
>
> *The overall objective of this experiment is to investigate battery runtime, and determine the electric potential and current as the number of electrochemical cells connected together increases and decreases. This is accomplished using the experimental test apparatus and the manipulating the placement of electrodes within the "cells" of the "battery," so that they are connected in series, parallel, or both series and parallel.*
>
> *Another key objective of this hands-on project is to build the experimental set-up from materials that are available from the local hardware store. This is the way that many, if not most, novel scientific discoveries are made – from an apparatus that is made by the scientist to test something that has never been accurately measured before. If the experimental apparatus comes from a kit, then it will probably just allow one to repeat a measurement that is already known. Thus, the making of your apparatus is an important learning experience in its own right.*
>
> *In principle, this experiment can be completed, with a reasonable amount of accuracy, using an ice cube tray, zinc coated sheet-metal screws, 6AWG copper wire, and water. However, by changing the electrolyte from water to vinegar, lemon juice, or saltwater one is able to increase the capacity of the battery in order to clearly refine the electric potential and current availability in order to determine how battery runtime increases or decreases.*
>
> ***Explorations***
>
> *Now that you have completed your first experiment, you have all the tools necessary to answer more questions concerning battery manufacturing. Here are some questions that would be interesting to explore:*
>
> 1. *What would happen if different metals were used in place of copper and zinc? Would the electric potential and available current still be the same? Does that have any effect on how the battery functions?*
> 2. *What if the number of cells changed was changed? Would the electric potential and available current still be the same? Does that have any effect on how the battery functions?*
> 3. *Batteries come in all shapes and sizes. What would happen if the "cells" were larger? What would happen if the "cells" were smaller? Does this change the electric potential and available current?*
> 4. *There are many types of batteries. Research the similarities and difference between three types and design and experiment that will allow you to compare all three types of batteries. Compare the electric potential and available current, then present your findings to the class.*
>
> *These are just a few of the what-if questions that you can ask. Use your imagination – there are many more questions. Any of these questions above (or the ones you have thought up) would be a good science fair project.*
>
> *Excerpts from Battery Operation Investigation found at https://www.purdue.edu/hardware-store-science/list-of-experiments/*

Creating an instructional planning resource familiar to K-12 education settings made implementing curricular resources connected with the evGrand Prix program straightforward. Additionally, classroom teachers would have a resource they could use when developing classroom material to move beyond proprietary evGrand Prix curricular content and create classroom-specific resources targeted at their specific students. These could then be shared with other evGrand Prix teams and expand the catalog of learning opportunities available to all evGrand Prix participants.

CONNECTING CLASSROOM CONTENT TO GO-KART RACING

Owing to my previous experience in creating similar content for my own classroom, I was able to crank out many of the required documents and learning material in a short amount of time. These in turn were shared with pilot schools to determine subject matter fit and obtain feedback from both teachers and students on rigor, implementation strategies, and validity of connections to electric go-karts.

Feedback from pilot schools indicated a need for more deliberate connections to go-kart racing, assistance in organizing data to identify patterns, and knowledge of how concepts and topics fit together so teachers can facilitate meaning-making and knowledge construction. I reasoned that high school teams might also benefit from companion on-track learning content using their go-karts. This would allow teams to take classroom-based instruction and apply it directly to specific go-kart related science content. This in turn would afford opportunities to work with complex mechanical and electrical go-kart setups, leading to student meaning-making, improved understanding, and event participant knowledge and safety.

With no prior experience developing auto racing or motorsport instructional materials, I sought assistance from the evGrand Prix motorsport SME to help develop these "learning activities". Unfortunately, not only was the motorsport SME unwilling to collaborate on these activities, but I was tasked with the additional responsibility of developing educational resources and event structures for two Test and Tune events during the coming spring.

As a K-12 teacher, there was a reason I did not take my students on field trips on a regular basis. Field trips require considerably more planning than classroom activities. Student attention to the task at hand is drastically decreased as they are inundated with distracters. Class management is more problematic as students perceive less educational rigor and decreased teacher supervision. All in all, field trips are extremely challenging to organize and execute, and I was not excited about accepting responsibility when my designed "field trip" to the track went miserably wrong. Additionally, my only experience with motorsports prior to this program was watching a few dirt-track races as a young adult. I had no clue how to organize a go-kart activity.

I therefore returned to Fox Valley Kart Shop and spent time at Top Kart USA (Indianapolis, Indiana, US) discussing go-kart mechanics and racing with the owners. During these conversations, I learned that a typical go-kart event is made up of three distinct activities: practice, qualification, and race. With no preexisting K-12 resources in these areas, I relied on real-world raw materials as an initial jumping-off point to develop anticipated track-side-specific learning activities.

One thing I was able to draw from was my experience working with my go-kart teams during previous race events. It was during my first go-kart practice session that I noticed all go-kart front wheels tend to point outwards. At subsequent practice sessions, I learned all go-karts tend to run the same gear ratio for motor and axle sprockets, and many teams put considerable time and effort into managing motor controller settings. After more research into running a go-kart event, and discussions with experts at Fox Valley Kart Shop and Top Kart USA, I identified six major themes associated with go-kart racing: Driver & Crew Orientation, Alignment & Steering, Gearing, Speed & Torque Curves, Energy Efficiency, and Race Day Activities.

Crash in Turn 1: Caution Flags Out

Based on the proposed practice, qualification, and race sequence of events at a go-kart track it was obvious to me that the only time formalized learning activities would be feasible was during the "practice" sessions. Additionally, limiting the schedule to a practice, qualification, and race sequence was supported by the motorsport SME championing track days consisting of "racing activities". I, therefore, envisioned each trackside learning activity could focus on one of the six previously identified themes. Teams could spend the morning collecting data regarding adjustments to a single go-kart system and the impact adjustments had on lap times and energy consumption.

After completing each targeted "practice" educational session, teams would complete data analysis and make final adjustments preparatory to qualifying for pole position during the main event "race". Ending the day with a mock race as an evaluation of their decision-making and learning would provide competitive real-world consequences to decisions and allow teachers (team coaches) to assess student content mastery. Mirroring the setup of the evGrand Prix World Championship event would provide the added benefit of preparing teams for the IMS event at the end of the school year.

I presented this instructional model to the motorsport SME but was quickly shot down. It turns out that while I had been discussing the topic with Top Kart USA, they had been negotiating a deal with the motorsport SME. Discussions about the feasibility of my educational ideas had been used to petition the motorsport SME for permission to develop resources relevant to activities and events as part of an EKSeries. This series would fall under the umbrella of the World Karting Association (WKA) and be marketed with WKA branding, appealing to motorsport SMEs' desire for a certified go-kart racing event.

At this same time, I was also informed high school teams would no longer "have to" engineer the chassis to handle battery weight. This would be solved by requiring all teams to run a purpose-built Top Kart chassis and powertrain "so no school had an advantage." These changes contradicted curriculum project documentation and effectively voided all go-kart specific curriculum development to this point.

Over the course of the meeting, the motorsport SME made every effort to convince me that schools did not want to do the engineering, "they only want to race". My bull-headed stubbornness concerning teacher feedback illustrating the value they placed on the piloted classroom resources did not help the situation. Additionally, I knew previously developed content aligned with stated project goals, meshed with state standards, and was backed by teacher-driven suggestions for future resource development. In the end, I was told this is how a racing program works, a spec chassis with a spec setup makes for a better race and there simply was not time at the track for my vision of educational activities.

After this, evGrand Prix staff and Top Kart USA began promoting "educational" events with high school teams. These would be events where teams could bring their go-kart(s) and gain "valuable driving experience" racing against other schools, the first of which would be at New Castle Raceway Park (New Castle, Indiana, US). The decision for only teams with a Top Kart chassis to be able to participate immediately alienated nearly half of existing high school teams.

A second unanticipated occurrence came in the form of schools not being provided with a schedule of events. Complaints from high school teachers who are used to

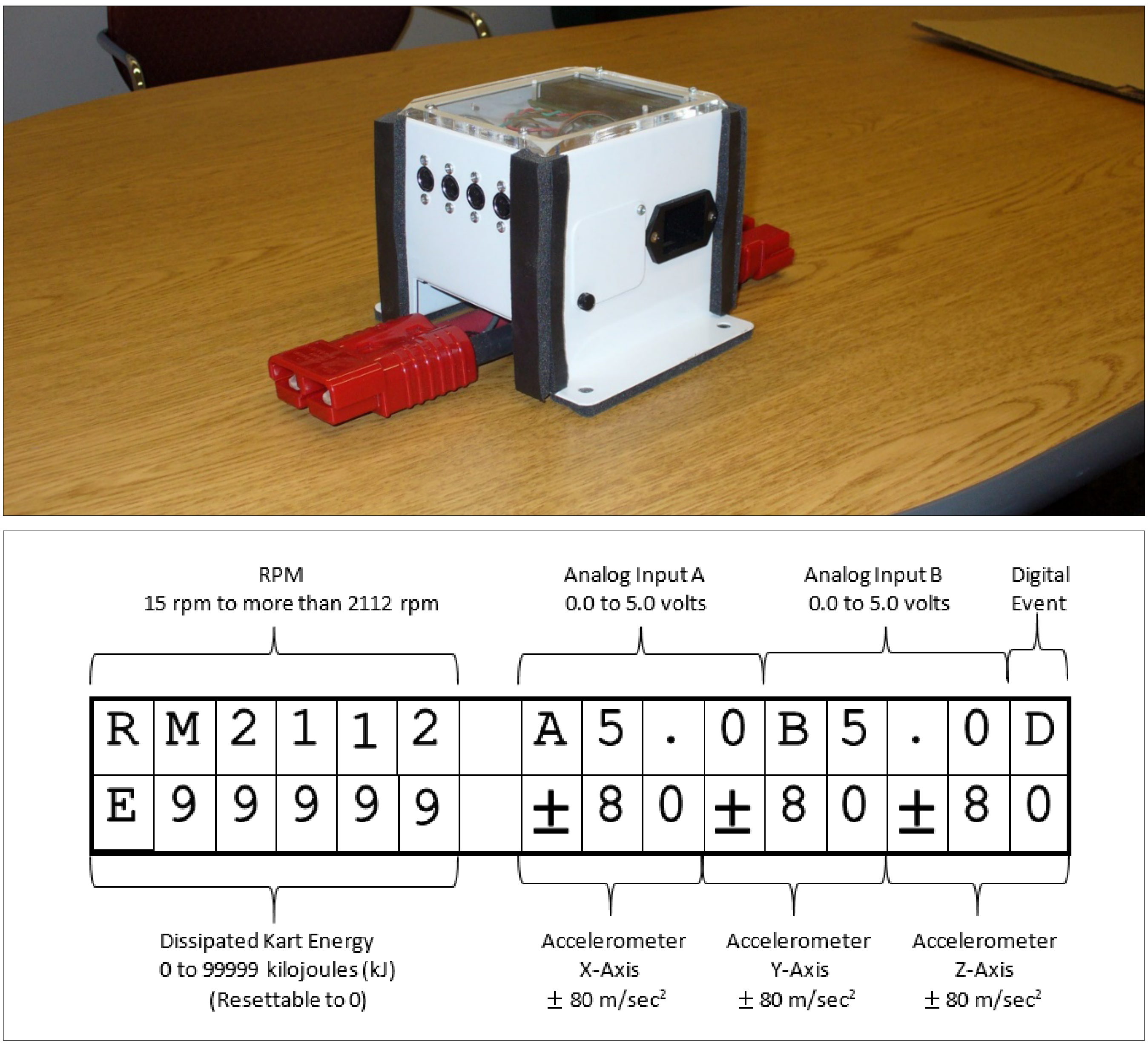

FIGURE 3. Physics Box with accompanying LED display breakdown.

FIGURE 4. Me and a group of students collecting data using Physics Box.

following an agenda/schedule pointed out that the lack of an event schedule made it difficult for teams to plan how best to prepare for each track session and leaving them at the mercy of last-minute changes.

A third compounding factor was the timing of the event within the school year. Happening at the beginning of the fall semester forced inexperienced drivers into new and challenging situations with little to no training prior to their first time driving the team's go-kart. As a result, there were multiple driving issues and breakdowns. Team "pit crews" had little more experience than loading the go-kart into a trailer and unloading it at the track. These issues required teachers to do most of the work on the go-karts, and success in this area was based on prior experience with the go-kart from the spring IMS event and the availability of Top Kart USA staff.

I decided then and there that I should have put more effort into meeting school needs and pushed back against non-education "professionals" dictating educational resources. Upon returning to Purdue from this event, I began putting together resources addressing the six identified track lesson areas and developing classroom resources teachers could implement prior to each track-side event.

Pitting Under Caution

I took the lessons learned from failed track practice sessions and my behind-the-scenes role at the spring evGrand Prix World Championship event at IMS and established a framework for developing track-side training sessions (see Figure 5). I began by breaking a day at the track down into timeslots for different activities. This would allow me to generate a schedule template that could be edited based on location and educational focus. Next, I focused on a previously developed device for collecting key sets of go-kart performance data.

The Physics Box (see Figure 3) was developed as part of the go-kart related science exploratory activities that changes to program focus made unusable. The Physics Box is mounted on the go-kart at the beginning to the day and allows teams to collect important data on battery voltage, instantaneous current and power, dissipated energy (E), 3-degree (X, Y, Z - ±80) acceleration, and four additional add-on sensors – accelerator pedal position (A), steering wheel position (B), axle RPM (RM), Lap completion (D).

Centering track-side curriculum on using the developed Physics Box allowed me to generate event-specific learning objectives that targeted data collection during each track-side educational activity (see Figure 4). I then collaborated with Top Kart USA to create a driver training certification program that would satisfy event organizers that participants had a rudimentary understanding of go-kart function and track safety prior to entering the track.

Issues related to event schedules would be remedied by making event officials responsible for notification of track-side educational event dates and schedules at the beginning of each academic semester, accompanied by educational resource access. This would provide teachers with the necessary time to obtain school board approval to attend and arrange the sequencing of classroom lesson plans and materials to prepare students for data collection and analysis requirements.

Rather than presenting these modifications to the motorsport SME, I went directly to the program director who adopted these changes for the remaining academic year events. Not all schools attended every event so a short information session was added at the beginning of each track event to orient teachers and teams to how the event would proceed. As this could be done during registration, the motorsport SME was tasked with providing a five-minute briefing prior to the first activity on the event schedule.

PURDUE UNIVERSITY

M-STEM HIGH SCHOOL CURRICULUM

[Event Title] – [Location]

Competition Rules and Objectives – Each team will compete [describe competition format]. Teams will be required to provide [event topic] settings of their go-kart prior to a qualifying run and not exceed an 10kW Power rating through each qualifying run; as determined by multiplying Alltrax current setting by nominal pack voltage (48v). The winner will be the team with the fastest average lap time through 3 different steering component configurations. All drivers are required to utilize a RACEceiver for track event official's communication needs. Frequency will be provided at competition location.

Check In 8:00am – All teams are required to "Check In" with Track Lab Officials prior to entering the track area. This will include verifying all paperwork is completed and turned in, appropriate passes are picked up and distributed, and event schedule is distributed.

All go-karts and equipment will need to be dropped off outside the Check-in area.

[arial image of track – Google Earth image]

Team Load-in 8:00am – 9:00am – All teams are required to maintain a neat and orderly Pit area during the educational event. Only authorized individuals will be allowed within the track area. The Pit is defined as the area immediately in front of the Grid/Pre-Grid area. Only individuals with a visible "Pit Pass" and officials will be allowed in this area. The Grid/Pre-Grid area is defined as the area where go-karts check in with event officials prior to practice and Heat sessions. Only crew members, drivers, and event officials will be allowed in this area. The Grid/Pre-Grid area is where go-karts and drivers receive final instructions prior to entering the track.

The garage is where teams, plus support group can work on the go-kart. Teams will be assigned a "garage" location for their go-kart, tools, and equipment. Teams will be allowed one canopy per go-kart. All charging must take place in the teams designated area.

Tech and Driver Meeting 9:00am – 10:30am – All go-karts and supporting equipment will be inspected by event personnel prior to participation in practice, qualifications, or heats. These inspections will include verifying Team Pre-Tech Inspection Form, completing Track Lab Tech Inspection Form – Pre-Race Checks the Installation of Transponder. School representative will draw group placement. Participating teams will be distributed between data collection groups equally, with no more than 6 go-karts in a single group. Each go-kart will be assigned a starting position for round 1 data collection.

- **Tech Inspection 9:00 -10:30 –** A minimum of 1 qualified Crew member and team coach must accompany the go-kart through Tech Inspection. Each go-kart must be accompanied by a completed Team Pre-Tech Inspection Form and Event Tech Inspection Form, this may be substituted by a Track Lab specific sticker applied to the go-kart by Competition official. Crew members will be made aware of the following expectations.
  a. [list out event expectations]
     - All go-karts will be required to mount a Physics Box data collection device to their go-kart for this educational activity. Teams may either utilize their own Physics Box or borrow/rent one from Track Lab Officials. Teams are encouraged to utilize an Aims Solo Data Logger for collecting track telemetry data.
- **Driver Meeting 9:30 – 10:30 –** Drivers attend mandatory driver meeting prior to entry onto track. Drivers will need a notebook and something to write with. Drivers will review course setup, cornering and driver etiquette. Drivers will be made aware of the following penalty assessments for this event.
  1. **Drivers will be instructed on** [identify driver specific material to cover].
  2. Push Back Bumper will result in a minimum scratch of fastest lap time from the effected qualifying round.
  3. Racer is allowed only 1 (one) instance of 3 or more tires leaving the track surface during a qualifying round. Subsequent "off track" instances will result in a minimum scratch of fastest lap time from the qualifying round.
  4. Drivers are required to follow all communications from track officials during each qualifying round. Failure to do so will result in the driver being required to return to the pit and forfeit the qualifying round.

Round 1 Event Practice & Ed-Comp [Time Period] **–** Round 1 qualifying laps. Each team will be allowed a minimum of 10 minutes of track time. Each team driver will have their course lap times recorded with the fastest 5 laps being used as official lap times. An official team score sheet must be submitted to competition officials at the end of the round. Drivers are required to follow all communications from track officials during this round. Failure to do so will result in the driver being required to return to the pit and forfeit the qualifying round.

- **[Group and Time] –** During this time slot, drivers from Group A will check in with event officials to verify alignment and steering settings. After check in, drivers will be allowed on the track to run laps. Lap times will be recorded and submitted to competition official at end of session.

[Subsequent Practice & Ed-Comp Rounds] – [repeat information above – ensuring go-karts rotate starting positions from previous round.]

[repeat process for each practice round]

Educational Competition Award Ceremony [Time] **–** All teams are required to clean up their areas and obtain the confirmation from the Track Lab staff in charge of that area. Pit areas must be free of race equipment, personal items, and trash. Award Ceremony will be held as soon as Competition scoring is complete and verified.

Educational Competition Check-Out [Time] **–** All teams must submit verification of Pit Clean-up prior to leaving the event.

Heat Races and Main Event [Time] **–** All teams wishing to participate in an EKS/evGrand Prix Point Race event will follow the Event Schedule provided by EKS and evGrand Prix Officials.

FIGURE 5. Track-Side Educational Competition Template – blending educational activities with competitive racing aspects wanted by motorsports SME and Top Kart USA.

An immediately identified fault was pointed out at the next track event. The proposed implementation of learning activities necessitated most teams to crowd 15 to 20 students around a single go-kart depending on team size. My personal experience with collaborative learning told me that this would make it more difficult for teachers to manage the horseplay associated with "immature" and distracted learners. Unfortunately, event officials retained a single-minded focus on the racing rather than the educational aspect of these events, and so concessions were made.

With renewed emphasis placed on educational activities, teacher and student satisfaction increased. Each team's improved knowledge of go-karts and understanding of motorsports, in general, led to more efficient use of time at the track. Restructuring of track-side events eliminated ambiguity of event schedule and last-minute changes. And, while website issues hindered the dissemination of developed classroom resources, this challenge did not significantly hamper the implementation of track-side learning activities.

OVERCOMING INSTRUCTIONAL DESIGNER LIMITATIONS

After these, and many other, successes and failures, I began looking for additional ways teachers could use inquiry-based learning activities that were directly transferable to the larger go-kart project. Returning to CTE subject matter experts provided several useful engineering activities being done within their classrooms. I believed the use of the previously developed STEM investigation template could be applied to these activities, making them a more science-focused experience. If I could figure out how to connect topics like braking and steering to science content such as motion and forces, I would have something completely new to existing science classroom curriculum packages.

Recognizing I didn't fully understand many aspects of instructional design was an impetus for me to enroll in an online Instructional Design & Technology (IDT) program offered through Purdue Global. Within the required degree courses, I learned about instructional models, educational technology/multimedia best practices, learning design environments, needs assessment and evaluation, design and development tools, and implementation of instructional strategies.

The coursework formed a much-needed foundation for developing my vision of high-quality instructional resources based on evGrand Prix participant feedback. These courses also reinvigorated me after a year of flying by the seat of his pants, and what appeared to me as minimal support in developing educationally sound resources.

Within this IDT program, I began to think teams would best be served by the development of targeted classroom learning activities that were directly transferable to the electric go-kart. My growing enthusiasm was tempered by the Purdue professor responsible for the development of the evGrand Prix program deciding to reduce his role, and the motorsports SME being advanced to evGrand Prix director of operations. Past interactions with this individual led me to believe he would be less enthusiastic about this curriculum than the prior program director.

I arranged to meet with my immediate supervisor (previous evGrand Prix director) to discuss this concern and was informed that the developed curriculum will continue as part of a supporting Hardware Store Science initiative and that all instructional material developed remained under his strict control. All work in implementing these resources with evGrand Prix schools would transition to the Hardware Store Science program.

Relieved by this news, I continued developing a curriculum to bridge the gap between classroom content and the six previously identified go-kart educational themes. The entire program would revolve around track-side educational events outlined using the on-track educational event template (see Figure 5).

An Implementation Strategy is Born

An example using the template (see Figure 5) with the Gearing Assessments learning focus follows. This topic's competition rules and objectives are:

Each team will compete to determine the overall fastest average lap time of 15 recorded laps. Teams will be required to provide the gearing ratio of their go-kart prior to a recorded run and not exceed a 10kW Power rating through each data collection run as determined by multiplying Alltrax current setting by nominal pack voltage (48v). The competition winner will be the team with the fastest average lap time through 3 different gearing ratios. All drivers are required to utilize a RACEceiver for track event official's communication needs. Frequency will be provided at competition location.

Contained within this track-side educational event template is the time allotment for participants to attend either a Tech or Driver meeting prior to running their go-kart on the track. The following is an outline of how the Tech meeting is set up so that crew members are made aware of educational activity goals and crew-specific instructional objectives:

"… *Crew members will be made aware of the following expectations.*

a. *Establishing a baseline setup of the team go-kart gearing ratio.*
b. *Monitoring and communication techniques for effective gearing adjustments to improve go-kart handling and performance.*
c. *Event documentation procedures for establishing historical records on driver, track, and set-up in order to improve team performance throughout season.*
d. *Instructional Time – Crew members will be familiarized with proper protocols for changing out sprockets and predicting appropriate track specific gear ratios.*
    - *Teams will be instructed on how to determine gearing ratios.*
    - *Teams will learn proper gear changing procedures."*

While crew members are attending the Tech Meeting, drivers are attending the Driver Meeting. During the driver meeting team drivers verify placement within competition groups and their ability to receive on-track communication from event officials. In addition, drivers receive training on how to communicate go-kart performance and handling to crew members to aid in analyzing go-kart performance. They then review course setup, cornering, and driver etiquette while being made aware of penalty assessments for the event.

Once participants have completed all necessary training, meetings, and safety inspections all participating go-karts are then organized into groups of six. Each group is then allowed a series of "practice sessions" with a minimum of 10 minutes of track time. Each team driver has their course lap times recorded with the fastest 5 laps being used as official lap times. An official team score sheet is then submitted to competition officials at the end of the round, indicating the mechanical/electrical setup of the go-kart based on the event theme. A minimum of three rounds of data collection take place, with go-kart modifications being made between each round. At the end of each round, the first two drivers rotate to the rear of the group such that all drivers experience "racing" from different "pole" positions.

Stohlmann et al (2012) point out that much of what is done within STEM education involves the process of designing,

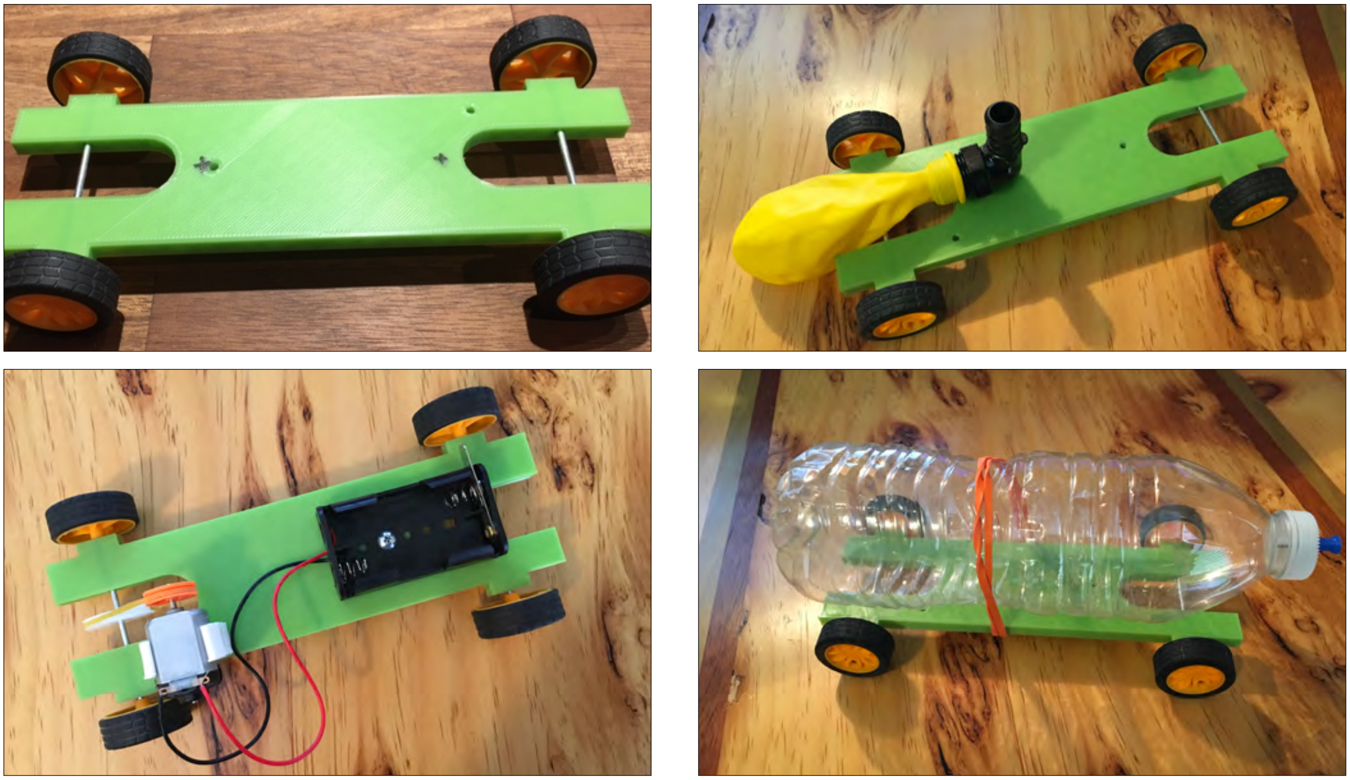

FIGURE 6. Example of weighted acceleration car chassis used within other contexts of the go-kart related classroom resources. Clockwise: i) propelled by gravity, ii) balloon powered, iii) chemical reaction powered, iv) battery powered.

prototyping, testing, and redesigning possible solutions to everyday problems. If one assumes the go-kart represents one such problem, then reconfiguring the go-kart setup within the areas of steering, gearing, motor controller, and driver experience would be ideal topics for problem-solving using integrated STEM knowledge from the classroom.

A Return to the STEM Investigation Template

While working through the track-side event schedule template, I began researching STEM related classroom practices that would be helpful in collecting data using the go-kart as the final stage of the learning process. Research has shown that teachers question learner engagement with STEM lessons if students are not required to actively do something in the engineering design process (Bevan et al., 2015). Here it was determined that, while the notion of tinkering challenges many teachers' idea of engagement, there was ample evidence of students "offering explanations, applying prior knowledge and using science vocabulary" (p. 114) as they try to process scientific investigations.

Thibaut et al. (2018) mention that the use of the engineering design process strengthens the learners' understanding of science and its connection with math and technology by eliminating gaps between knowledge and application. And, while it may be natural to suggest that teachers be willing to allow for the time to build, test, and redesign prototypes, it falls to the instructional designer to develop classroom material that minimizes this time commitment (Sims, 2006, 2015).

Eventually, I settled on returning to the STEM investigation template to facilitate the modeling process associated with integrating STEM disciplines. Making experimental devices played a major role in my high school science classroom. During these activities, students were provided with an experimental goal and a variety of materials from which to choose how best to meet this goal. I provided students guidance along the way as they explored solutions. The major challenge with incorporating this style of modeling into the developed educational content would be providing the evGrand Prix participating teachers with the tools necessary to implement this method of inquiry-based learning.

I decided to research whether this style of teaching had been tried elsewhere. I came across numerous articles addressing issues teachers face as they work towards implementing Making into their classrooms. This research also helped me better understand the methods, pedagogy, and technology needed to facilitate learning as students make experimental models (Godhe et al, 2019; Hallström & Schönborn, 2019; Hsu et al, 2017; Martin, 2015; Ornek, 2008) to represent functional electric go-karts.

Much of the subsequent development process was guided by this understanding and built upon the foundational classroom activity known as the Hardware Store Science

Weighted Acceleration Car chassis (see Figure 6) and the Mini EV Racer (resources available at purdue.edu/hardware-store-science).

Continued Program Issues

Changes in evGrand Prix leadership and program focus plagued educational events and track activities during the 2018-2019 season. Participating teams' use of curriculum and go-karts was prohibited outside events jointly sponsored by evGrand Prix and Top Kart USA. Past Participant's frustration also continued to mount over communication issues, overstated availability of educational material, and race focused mentality during Fall and Spring practice sessions.

By the time of the 2019 IMS event, a total of 29 go-karts teams registered to compete in the High School World Championship race. Only 11 of these go-kart teams participated in the community outreach portion of the Academic Competition while 14 go-kart teams participated in the engineering design portion. Event organizers voiced disappointment in not getting all 52 anticipated participating go-kart teams to IMS. In addition, the incurred cost of running the event at the IMS venue resulted in talks of moving the event to the Purdue Grand Prix track on the West Lafayette campus.

Participating teams' feedback centered on issues from evGrand Prix leadership changeover resulting in:

- Loss of interest due to elimination of engineering aspects
- Promised safety training videos not being developed as indicated
- Conflicts between IMS race date and AP testing
- Confusion over controlled use of track-side instructional material
- New marketing strategy promoting evGrand Prix as a racing series NOT an educational program

Student turnover is an overarching issue related to blending classroom curriculum needs and evGrand Prix racing aspects. The ingrained notion that go-kart, and motorsports in general, run their season based on a calendar year rather than a school year makes it hard for educators to evaluate the educational aspects of this learning project based on evGrand Prix season results. Teams end up with half of evGrand Prix scores resulting from one cohort of students and the other half resulting from a new cohort.

It was my contention that tracking driver and go-kart improvement over successive lap series for a given go-kart racing topic would provide the best method for evaluating the effectiveness of the educational material. Focusing on a much narrower subject – like how the race line taken around the course impacts lap times – makes it possible to determine how well participants are learning the target information and ties educational activities from classroom settings to the operation of the go-kart at the track.

The use of "practice" sessions as educational events provides immediate feedback to teachers as they evaluate student learning based on immediate data. Placing this learning within the context of participation in a 10-lap exhibition among other participants provides motivation to try and fail prior to "testing" teams on their knowledge under high-stakes racing conditions associated with the end of season evGrand Prix Championship event at IMS.

Mimicking practice and qualification prior to the race event established an authentic learning environment. Comparison among subsequent educational events related to a given topic would allow evGrand Prix program staff to determine how effective the training material was over time. It was anticipated that as evGrand Prix participants implemented the educational resources program safety, performance, engagement, and competitiveness would improve and be tracked.

By December of 2019, the world was beginning to discuss COVID 19, and by March 2020 schools across Indiana transitioned to remote learning and all in-person evGrand Prix activities came to a halt. By the time schools returned to "normal" classroom-based face-to-face learning in the 2020-2021 school year, large gatherings were still prohibited and the evGrand Prix management began asking for resources that could be used by evGrand Prix participants as a means of "keeping evGrand Prix relevant with schools".

My recommendation was that schools could maintain this relevancy by implementing the Hardware Store Science Acceleration Car and Mini EV Racer (these resources had been modified to meet the resulting online learning situations associated with the 2020-2021 school year). Based on this recommendation evGrand Prix personnel would be responsible for providing support for these activities.

In the fall of 2021, evGrand Prix staff decided to conduct a COVID postponed Championship race. This event began with significant fanfare and 12 participating go-karts, no academic competition, and no power or energy usage data collection. While participating teams were pleased to be back at the track, they were skeptical about how the program would move forward.

The Purdue high school evGrand Prix competition debuted in the spring of 2016 with seven go-karts racing on a makeshift track in a parking lot at IMS. Numbers climbed to a total of 52 high school go-kart teams from across the United States prior to COVID-19 event cancelations. By the time evGrand Prix returned in the fall of 2021 the race venue had changed and participation had dropped to seven high school programs (six from Indiana and one from Cincinnati, Ohio, US) and only 12 competing go-karts teams. This also marked the last evGrand Prix event for which I provided educational support.

DESIGNER REFLECTIONS

I began this instructional design (ID) journey as a complete novice to professional ID. I faced several challenges and setbacks as I learned to navigate my role within a more expansive educational context than my classroom. Balancing educational best practices with the wants and desires of program stakeholders was just one example of these challenges. This balancing act became a hallmark of the project and competing views

In the beginning, I relied heavily upon my experience within woodworking and high school science educational settings when thinking through the development of possible instructional resources. Each learning module included educational resources already in use within multiple science and CTE classrooms which I repurposed (some with slight modifications) to meet the needs of the target audience. This process allowed me to ease into the ID role in a manner that bolstered my confidence to create resources from scratch.

Being one of the first instructional design projects I worked on, the evGrand Prix program came with added challenges of having no prior formal instructional design training and working with program contributors who are not aware of the challenges facing K-12 educators. These issues were compounded by my ignorance of how best to address these issues. Additionally, unforeseen challenges came to light as I learned more about the ID process and attempted to incorporate such aspects as needs assessments, implementation strategies, and evaluation plans.

What started out (as I supposed) as a straightforward project of creating classroom resources directly related to my classroom experience as a former evGrand Prix participant, very soon evolved into the development of instructional resources outside my initial skillset. I eventually expanded my experience designing instructional resources for high school classrooms with formal ID training and knowledge concerning the dynamics, setup, and real-world functioning of competitive go-karts. I have attempted to use scenes illuminating my learning as an ID professional to share my experience developing educational track-side go-kart events during the timeframe from November 2017 to September 2021.

Part of that learning has included gaining a better understanding of how STEM resources can intentionally connect subject matter content in an authentic context. I have also attempted to illustrate how I made purposeful connections between STEM subjects to improve learning. During the initial stages of developing evGrand Prix curricular resources I recognized the need to create a working classroom lesson format that would specifically reference K-12 learning contexts. Due to this unique content, it was also important to make deliberate connections between subject matter content and application to real-world go-kart trouble shooting. Utilizing a design approach that combines scientific inquiry with the engineering process associated with CTE courses became a guiding theme.

Throughout the project, it became apparent that creating a seamless connection between classroom activities and on-track learning required the integration of multiple STEM subjects in a manner that promotes the application of content, in a setting where "knowledge and process[es] of the specific STEM disciplines are considered simultaneously… in context of a problem, project, or task" (Nadelson & Seifert, 2017, p. 221). Because teachers participating in evGrand Prix lack knowledge related to one or more STEM disciplines, it became my responsibility to provide all needed content specific knowledge within the developed instructional material.

Throughout my journey, I have come to understand how ID is an iterative process, and learning how to work within the iterative nature of the ID process is a crucial aspect of being an instructional designer. Finally, I have come to understand that as the instructional designer encounters, interprets, adapts, and applies various instructional design features, they will create better learning material. I have also come to appreciate that "the learner's internal state [and] the context within which the learner interacts with the learning technology" (Schmidt & Huang, 2021, p. 15) must be at the forefront of our thinking within every ID project.

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