COLLABORATIVE PROJECT PLAN – 6 Projects 2 Days Each

RAMPED – *Robotics, Applied Mathematics, Physics, and Engineering Design*

Note that Week 2 is described before Week 1 in this document

Week 2: 2-Day workshops

Note – Teachers will chose 2 of the 3 proposals per week to explore
With 25 teachers, each proposal will have approximately 8 teachers in the 2-day sessions

Proposal #1 – Space Modeling - Week 1 choice
(Space)

1. Keywords and content of your activities for the teachers during the MSP

Python programming/SQL queries/large data sets and databases/statistical analysis/fitting a model to data/outlier significance/quasars/galaxies/black holes

2. Materials you (and the teachers) would need for your activities

We would need one computer running linux or unix for every 2 teachers and each of the teachers to have undergone tutorials in UNIX, Python and SQL.

3. Half page write-up on your proposed 2-day project with the teachers (during the summer)

The dominant component of a galaxy is starlight. As stars shine mostly at optical wavelengths, distant galaxies typically appear red and dim. Besides being composed of stars and gas, every galaxy in the Universe contains an extremely massive black hole at its center. When material falls into these black holes, the centers of the galaxies become bright and emit energetic light, far outshining everything else in the galaxy. During this phase, which is known as a "quasar," galaxies become bright and blue. Recently—in fact, only in the last year—the first quasars have been discovered that "turn off". Such quasars, known as "changing look quasars" are examples of the material that is falling into the black hole at the center of a galaxy somehow being disrupted. These new objects are of immense astronomical importance as they can be used to learn about the black hole and the stars in the same galaxy for the first time.

Over a 20-year period, the Sloan Digital Sky Survey (SDSS) took digital images at various wavelengths over the same 200 square degree area of the sky. Effectively, the SDSS built a color movie of this region of the sky. Such movies will become increasingly important in the next 10 years as many telescopes are starting to produce them. The teachers will use SQL queries to create a database of the colors of quasars as a function of time in this SDSS movie. They will use Python queries to analyze brightness and color as a function of time to attempt to identify quasars that have turned off. The end product will be a list of potential changing-look quasars in the SDSS. The teachers will also research and analyze the main uses of such quasars in understanding black holes and galaxies and will present a short discussion of these uses to their peers. This discussion will serve as a jumping-off point for a discussion of quasars, galaxies and black holes that the teachers can have with their students.

4. Paragraph write-up on your proposed follow-up day during the academic year with the teachers

Teachers will work together to produce Python tutorials, examples, and lesson plans appropriate to how students might conduct the Changing Look Quasar project in their own classroom. These materials will be submitted to a github repository and organized such that the teachers could use them in their own classroom as a student project.

5. Timeline for the 2 days during the summer and 1 day during the academic year

SUMMER:

Day 1

Morning:

1 hour - Meet and greet. Icebreaker Python and UNIX examples. Pre-testing.

2 hours - Brush up on your Python. Python tutorial to refresh teachers' preparatory work.

1 hour - Brush up on your SQL. SQL tutorial to refresh teachers' preparatory work.

Over Lunch:

30 mins - Introductory lecture on quasars, galaxies, black holes and why changing look quasars are important.

30 mins - Breakout discussion with teachers deciding what aspect of changing look quasars they might wish to present on.

Afternoon:

3 hours - construction of Python and SQL code to query the SDSS and recover a database of color versus time for quasars

1 hour/Homework: Finish code and/or create a few slides for presentation.

Day 2

Morning:

1 hour - discussion of possible statistical approaches for separating quasar look quasars using color versus time information and how they might be implemented in Python.

3 hours - Python coding to read database and attempt to find changing look quasars.

Afternoon:

1 hour - Further coding, if needed

1 hour - finalizing slides and presentation of results. What aspect of Changing Look Quasars did you research. Did you manage to find any in the SDSS database?

1.5 hours - presentation of results to peers

30 mins - post-test and debrief.

ACADEMIC YEAR:

Morning:

30 mins - meet and greet. Pre-testing.

1 hour - github tutorial and examples.

1 hour - reminder of project, discussion of what aspects worked and were memorable, discussion of what elements of code and documentation would be critical for the project to work in classrooms.

1.5 hours - documentation of code, writing of tutorials and lesson plans

Afternoon:

3 hours - documentation of code, writing of tutorials and lesson plans, submission to a github repository available to all of the teachers

1 hour - debrief and post-testing.

6. What connections you see between your activity and STEM and/or other disciplines

The Changing Look Quasar activity combines aspects of physics, astronomy, chemistry (a basic understanding of spectroscopy) with aspects of computer science as applied to data analysis, or as I've started to call it "data engineering" (coding, databases, networking, shared repositories) and aspects of math (statistics for identifying outliers in a simple 2-D space). It thus runs the gamut on STEM. The project can be quite reasonably simplified or reduced in scope. For instance the github (shared repository) element could be replaced with simply uploading work to a central website that all of the teachers could access.

Proposal #2 – 3D User Interaction & Virtual Reality Systems - Week 2 choice (Virtual Reality)

Specific Activity Topics: Creating objects in virtual or augmented worlds using smart phones (need enough smart phones). This is ideal for both elementary and high schools.

***Materials Needed**:* Smartphone(s), Unity or Google cardboard API, Vuforia or OpenCV,

Connections: almost anything "physical-world" can be simulated in the vr environment. Very related to psychology, sociology, kinesiology, physics, engineering, math, cause-effect, literature, history, etc.. Also with augmented reality, teachers can set up more "physical play" type things to connect virtual-to-physical.

Keywords and Content: virtual reality, augmented reality, computing, computer science, immersion, mobile-based technology, interaction, stereoscopic displays, tracking, virtual worlds.

Description of Activities:
Why should we care about educating our young students about virtual reality? Virtual reality has been defined as providing an experience where users are immersed in a responsive and interactive computer generated environment or virtual world (Brooks, 1999). Virtual reality technology has been used to enhance training especially for unsafe conditions, treat medical conditions (such as post-traumatic stress disorder), enrich education, lower costs in design and construction, and experience past historical worlds and cultures. While the benefits have been shown for years in research, only recently has the display (how you can gain the 3-D view of the environment or world) and tracking (how the world knows where the user is and what the user is looking at to provide that view into the world) technology gotten inexpensive enough that it has exploded in the mainstream. This means that in the next few years we will hope to see an explosion of these benefits in healthcare, education, design, etc.
What is missing? The number and diversity of professionals with the appropriate knowledge and expertise in this specialized computing and engineering field. There are so many aspects that virtual reality technology can be improved upon. In addition, virtual reality is a 'visual' field that grabs students' attention and can get them excited about STEM fields! Since the components of virtual reality have gotten fairly inexpensive, one can teach the concepts and basic components of virtual reality in many different ways and of varying cost points. Additionally, virtual reality environments can be used as platforms to explore concepts in other sciences such as physics, sociology, kinesiology, physics, engineering, math, cause-effect, literature, history, etc.

What will teachers learn? The activities will focus on learning the basic concepts of virtual reality, a range of low-cost hardware options, and a range of low-cost software options. Virtual reality can be defined as being fully immersed in a virtual world. Augmented reality is on the other end of that spectrum where virtual elements or objects are displayed in our real world. Mixed reality can be defined as any of the spectrum between virtual and augmented reality. Day one will focus purely on virtual reality technology, while day two will focus more on augmented and mixed reality technologies. The main focus is to provide the basics and the tools for teachers to get started, then providing enough tools that they can begin to explore specific solutions and design their own lesson plans that are tailored towards their classroom environment and level of students. The idea to convey in these two days is that these topics CAN BE accessible to younger students and that there are a variety of ways people can engage at all different levels.

Day 1, Virtual Reality: Day one's activities would include a combination of core knowledge and basic implementation activities related to virtual reality and immersive technology. Core knowledge would consist of basics of virtual reality, hardware and software to gain a foundation of understanding. Basic implementation activities would involve set programming samples that they could use to set up on their own, but step through guided tutorials of how to program and get basic capabilities to work. Tutorials would offer a range in experience levels. The basic components needed are: immersive display, tracking, virtual world, input device(s), and a controller for all those components to work together. There will be a sample set of basic tutorials for each component to get a very simple virtual environment system working all together. Potential tutorial options include: setting up a camera, manipulating a camera, making simple objects in the world, porting other objects (from online) into the world, adding animation, etc.

There could be a number of solutions at varying cost points and the following are two examples. One such example is converting a mobile device into a virtual reality system. Google cardboard is a set of lenses that enables the conversion of a smartphone into an immersive display. Tracking is already used from the phone's internal capabilities, such as an accelerometer. A simple button can provide some of basic input capabilities. Another example is that of the Oculus Rift and possible computing power of a Raspberry Pi, which is a solution that is bit more expensive (while still low-cost) but a great choice for dedicated display technology. For either examples Unity can be used as both the virtual world 'builder' and 'controller'. Unity is a great choice for a platform since a free version is offered and it is fairly easy for students to get started and make progress. I would expect similar results from the teachers even with little to know experience- it is designed as 'drag-and-drop' environment making it easy to not be a programming expert but still have success. One example of a tutorial would step them through basic set up of Unity program with a simple object and exporting that to work on the mobile device and an Oculus Rift.

Day 2, Augmented and Mixed Reality: Day two's activities would include a combination of core knowledge and basic implementation activities related to augmented and mixed reality. The focus would be again on both hardware and software familiarization. The focus would be less directed at creating the environment because this would be learned on day one. There would be more emphasis on how to connect the virtual world objects to the real world. A smartphone (one with a camera) can be used as the display. Printed patterns (called fiducials) can be used as the trackers to map to the virtual objects. Tutorials in this day would consist of showing how to set up the mapping between the fiducials and virtual objects, created from day one, and how to make the environments more interactive. Potential options for these tutorials consist of: OpenCV, Vuforia, or equivalent.

Proposed follow-up 1 day project with the teachers (during the academic year)

Follow-up activity:

At the end of day two, teachers will brainstorm more advance challenges that they would love to do with the students but would not be sure how to actually do them. From the total list of challenges, teachers will select one (or multiple) each or be grouped into partners or teams. These challenges will serve as advanced topics to engage in tools to find out how they can find the answers to what they would really like to do. Tools will be reviewed to how to find the answers. Teachers will then have "homework" over the summer and academic year to put these challenges together and get them working. Of course they can get assistance as they are working through email or phone exchanges. Once they are able to get those working, they will brainstorm how they will put together materials for the students to be able to incorporate this into their classroom and create lesson plans for their students. Prior to the academic year, they will provide input in advance as to what advanced topics they are struggling with and would like to learn more about.

Follow-Up Day During Academic Year: In the follow-up day during the academic year, they will share with each other their progress. Everyone will brainstorm together how to best incorporate these ideas in the classroom. This way, as each teacher may have pursued one challenge, they can all learn from each other challenges. In the second half of the day, tutorials will be provided in the more advanced topics in virtual reality and/or augmented reality as requested earlier. Teachers will work on those tutorials and again brainstorm how they can incorporate them into their classroom.

***Notes- alternative vr platform idea using online virtual worlds, less immersive but more connected*:** Scripting code in an online virtual world to explore objects, cause and effect, interfacing features, connect with others across the state (ie other schools or students), etc. Instead of art sculptures: could be combined with other disciplines like observing lighting in architectural features, physics activities, etc.

References:

Brooks Jr, F. P. (1999). What's real about virtual reality?. *Computer Graphics and Applications, IEEE*, *19*(6), 16-27.

Proposal #3 – STEM and Mathematics Inspiring Design and Solutions - Week 2 choice (Algorithms)

1. Keywords and content of your activities for the teachers during the MSP
   Mathematics, Biology, Genetics, Mutation, Physics, Metallurgy, Chemistry, Thermodynamics, Annealing, Computer Science

2. Materials you (and the teachers) would need for your activities
   Each teacher will need a computer with access to the Internet.

3. Half page write-up on your proposed 2 day project with the teachers (during the summer)

   Teachers will investigate the relationship between common science and manufacturing processes and the design of algorithms to solve optimization and design problems that have no apparent brute-force solution. Of specific focus during the two sessions will be investigations of: 1) the bio-mimicry in genetic algorithms (biological concepts within genetics of population diversity, selection, mutations, termination) and 2) the relationship between the physical properties of systems (such as the heating and cooling of metals and the balancing of interconnected spring-networks) to the creation of megalithic and nanoscopic structures.

   The foundations of genetics rely on the intersection of biology, math and chemistry. During the first part of the teacher-centric investigation on how genetics influences the design of mathematical algorithms this session will build up enough baseline knowledge for the teachers – relying first on the knowledge of the teachers in the programs and then scaffolded and extended by domain content experts. Teachers will then have a hands-on, active learning session with a genetic algorithm that creates valid mathematical and chemical equations. After the hands on approach, teachers will develop their skill set in either the Python or Sketch programming languages (based on their student's age / skill sets and personal self-selection). Finally, teacher will have the opportunity to modify of a genetic algorithm template (in Python or Sketch) to solve simple "game of life" that requires setting parameters of birth rate, death rate, and food densities for multiple populations to achieve maximal survival of a targeted species.

   After exposure to the use of genetic-based algorithms the teachers will investigate algorithms rooted in physics and chemistry – a similar pattern of using the groups prior knowledge will enable a more realistic starting point for the domain experts to scaffold off of. The primary focus of discussion will be on hooks law (springs) and annealing (forming/breaking crystal lattice structures). Again, the group of teachers will choose/investigate two separate algorithms that solve the same problem of where to a set of settlements in a geographic area. The session will continue by supplementing the prior day's experiences in Python or Sketch and will culminate in the teacher's modification of the "settlement code" to include more realistic constraints and then comparing the results to actual geological settlements.

4. Paragraph write-up on your proposed follow-up day during the academic year with the teachers
   During the follow-up day lesson teachers will be exposed to applications and models of systems that are derived from naturally existing phenomenon –an area of research generally encapsulated by "biomorphic systems" or "bio-inspired systems" or "biologically derived systems." This one-day session will focus more on the physical structures of elements (wings, nests, animal skin coloration) and as well as how organisms' form collectives based on their fundamental characteristics and interactions with their environment (e.g. flocking birds, schooling fish, ant-food gathering, etc.). The ideas of population genetics, survival and cost, will be explored in conjunction with these observable phenomenon.

5. Timeline for the 2 days during the summer and 1 day during the academic year
   Day 1:
   - Scaffolding the basics of genetics: the biology, math and chemistry
   - Investigating a genetic algorithm that builds valid mathematical/chemical equations
   - Primer of Python/Sketch
   - Teacher modification of a genetic algorithm template (in Python or Sketch) to solve simple game

   Day 2:
   - Scaffolding the basics of Annealing & Hooks Law: the math, physics and chemistry
   - Investigating a Force Directed Placement Algorithm (Spring Network) and an Annealing Algorithm that could effectively place towns in habitable zones [biology/anthropology with applications to astro-biology/astro-anthropology]
   - Advanced materials on Python/Sketch
   - Teacher modification of either algorithm to include additional/modified scenario constraints

6. What connections you see between your activity and STEM and/or other disciplines
   Applications of mathematics in physics, chemistry, and biology will be explored. Specifically, probabilities, permutations, and general algebraic skills will serve as the basis for solving each problem.

Week 1: 2-Day workshops

Proposal #4 – Parallel Computing Using a Raspberry Pi based Computer Cluster - Week 1 choice (Raspberry Pi)

Parallel computing is increasingly becoming a topic that is taught as a part of computer engineering, electrical engineering and computer science education because of the advancement in the traditional microprocessors and graphic processor unit (GPU) technology. This rapid change in technology is forcing the educators and students to adapt to stay current. Currently, a large portion of consumer computer markets consists of machines with multi-core processor architectures like Intel i-series and NVIDIA GPUs resulting in a need of software that can take advantage of these multi-core designs.

This paradigm shift poses a significant challenge first to the educators who wish to teach about multi-core processors and large-scale parallel computing. In order for a teacher to teach topics on parallel computing, both the teachers and the students would have to have access to cluster computers. However, access is severely limited and restricted due to the cost, time restrictions due to demand and large physical space requirement of a commercial computer cluster.

The recent development of small computer systems like the Raspberry Pi and NVIDIA Jetson has paved way for both teachers and students to have unlimited access to cluster computers. In addition to Raspberry Pi and NVIDIA Jetson, a number of flavors of inexpensive small computer systems are available. Hence, the goal of this workshop is to give the teachers the expertise required to setup a small cluster computer of Raspberry Pi's and teach multi-core processors and parallel computing.

In the workshop, a flow of topics, with each topic building on the previous topic will be presented. The topics are 1) Hardware and software setup of the Raspberry Pi based cluster computer 2) Basic understanding of the Rasbian Operating System (OS) a Linux variant optimized for Raspberry Pi computer (3) Introduction to basic programming on Raspberry Pi using Python over C language 4) Communication among the nodes of the cluster using Message Passing Interface (MPI) and Python and 5) Parallel Implementation of linear algebra algorithms.

Materials:

Each teacher will develop a cluster computer of five Raspberry Pi's during the workshop, which they will take back to their schools for classroom use. Furthermore, they will also have remote access to a number of cluster computers of Raspberry Pi, hosted by University of Wyoming and NCAR, Boulder.

Keywords:

Parallel Computing, Cluster, Raspberry Pi, Python and Algorithms

Time Line:

Day 1:

Morning Session: Hardware and Software setup of Raspberry Pi Cluster Computer

- Physical assembly of multiple Raspberry Pi to form a cluster.
- Setting up basic network infrastructure to interconnect the cluster nodes.
- Installation of Rasbian OS on a single Raspberry Pi.
- Installation of MPICH a high performance and portable implementation of MPI for Raspberry Pi, required for exchanging messages between the nodes of a cluster.
- Installation of the array based language Python over C language for parallel programming.
- Automatic replication of the software installed on the single Raspberry Pi across all the nodes in the cluster.

Afternoon Session: Rasbian OS and Simple Python Programming

- Perform basic operations on the Rasbian OS.
- Develop simple programs using Python.

Day 2:

Morning Session: MPICH and Parallel Algorithms

- Introduction to basic knowledge of MPI in particular the MPICH.
- Developing simple programs to understand the static approach of sending and receiving data and messages between individual nodes in the cluster.
- Developing advanced programs to understand the concept of dynamic exchange of data and messages among the nodes of the cluster.
- Introduction of linear algebra algorithms suitable for parallel implementation like matrix addition, matrix multiplication and solution of a system of linear equations.

Afternoon Session: Parallel Programming using Python over C language

- Implement matrix addition program to execute first on a single node and as a parallel program to execute across the nodes of the cluster.
- Implement different approaches of distributing the job across the cluster nodes.
- Introduce MPI synchronization concepts like barrier, critical sections, etc.
- Demonstrate the synchronization concepts by developing a parallel program to perform matrix multiplication.
- Introduce performance profiling.

Day 3 (During Academic Year):

The teaches having participated in the two day workshop would have a clear idea of the potential of using Raspberry Pi based computer cluster to teach parallel computing concepts to students.

This would allow the teachers to explore algorithms that would demonstrate STEM and parallel computing concepts to students. Some of the possible topics with practical applications are

- Processing high resolution images for health applications in near real-time.
- Simple Pattern and Object recognition algorithm implementation in parallel computing environment.
- Big Data problems.

Morning Session:

- Teachers will work in groups to implement two topics out of the list above and any additional topics of interest.

Afternoon Session:

- Discussion of issues experienced by the teachers and their students in parallel computation.
- Introduce teachers to commercial and practical clusters based on GPUs and Intel processors.

Proposal #5 – Scientific Investigations Using Arduino - Week 1 choice (Arduino)

The goal of this workshop is to give teachers the skills needed to incorporate basic electronics and the Arduino microcontroller into classroom science experiments.

When teachers make instrument-based measurements for classroom science experiments, they often rely on devices from vendors such as Vernier, which offers a wide variety of devices such as temperature probes, light sensors, and others. Although this approach offers easy "plug and play" operation, disadvantages include high price, single purpose use, and little opportunity to modify or experiment.

This workshop will develop skills for teachers to create their own microcontroller-based science experiments in which they and their students participate in the design and construction of the measurement equipment. Advantages include: low cost; hands-on design with deeper understanding of underlying concepts; great flexibility in the experiment design and sensor selection; and increased student involvement and excitement.

In this extensively hands-on workshop, a sequence of topics will be presented, each building on previous information: 1) essential electronic concepts of current, voltage, resistance, etc.; 2) electronic components such as resistors, switches, and LEDs; 3) the Arduino microcontroller and basic C programming; 3) sensors and how to use them; and 4) logging data to an SD memory card and analyzing on a PC.

Materials

Each teacher will receive a complete stand-alone Arduino learning kit including Arduino, sensors, and necessary electronic components.

Key Words

Arduino, hands-on learning, microcontroller, sensors, data logging, and high school science experiments

Time line

Day 1

- Teachers learn essential electronics ideas of voltage, current, and resistance. Fundamental circuit analysis concepts of Ohm's law, Kirchoff's current and voltage laws, and related concepts are discussed. Students study basic components including resistors, batteries, switches, and LEDs by building simple circuits.
- Teachers are introduced to the Arduino microcontroller and it's peripherals including analog-to-digital converters, serial I/O, and memory. The C++ programming language is introduced, and teachers learn how to use the Arduino programming environment to develop, download, run, and debug programs.

- Teachers learn how to use the Arduino to control outputs such as LEDs, sound devices, and motors.

Day 2

- Teachers learn about sensors including temperature and light sensors, and build Arduino circuits to measure, process, and display sensor data. For example, they will build an Arduino system to measure photo diode resistance and convert that value into light intensity in units of Lux.
- Students will be introduced to advanced but easy to use devices such as LCD displays, SD card devices, and real-time clocks. A capstone project to integrate skills they've learned will include: (1) build a system that measures environmental conditions such as light and temperature, (2) add data-logging capability to store data to a PC or to an Arduino-mounted SD card, and (3) analyze the data using a readily available PC application such as Excel.

Day 3 (during Academic year)

Focus: After having a chance to use Arduinos in the classroom they would have much clearer idea of what topics would be most useful to them. Some possible topics:

- Enhanced sensors that make use of I2C or SPI busses.
- Other inputs and outputs such as keyboards, IR TV remotes, touch screens, radio modules, GPS, Wi-Fi, Bluetooth, etc
- Other Arduino-compatible microcontrollers such as Galileo, Edison, Arduino Due, and non-compatibles such as Raspberry Pi
- Wearable technologies and biologically motivated sensors such as pulse rate, blood pressure sensors.

The format for the day would be to spend 1 hour on each of the selected topics for one half day. The second half of the day would be devoted to individual student-selected projects.

Proposal #6 – Understanding the Robot Operating System (ROS) Using Simulators and Baxter the Research Robot - Week 1 choice (Baxter)

Due to the growing number of robots, the academic, research, and industrial worlds have recognized the need to standardize a programming framework for controlling robots. While this framework (ROS) has not been universally adopted, the future of robotics is headed in this direction as exemplified by the increasing number of robots that are currently compatible with or using ROS. The goal of this workshop is to introduce educators to technology, which will allow them to in turn introduce the basic concepts of ROS to their students and allow them to control simulated robots.

In this hands-on workshop, the teachers will be presented a series of progressive skills. They will learn how to install a virtual machine within a Windows based operating system, install a Linux based operating system within the virtual machine, and then subsequently, the Robot Operating System. From this point, the teachers will learn the basic concepts of ROS and be provided step by step instructions with proposed lesson plans for students on how to control and acquire data from a simulated robot using ROS.

Advantages include exposing teachers to a virtual machine which can be used as a "sandbox" to introduce not only a Linux based operating system to their students, but other types of software without permanently affecting the underlying operating system. Although Linux is used on less than 5% of personal computers, it is by far the leading operating system used in scientific research and sites, which require complex computations. Educators will be able to expose their students to an operating system used in companies such as Google, Twitter, Facebook, IBM, the U.S. Department of Defense, and Postal Services.

Additional advantages include: 1) Using a simulated environment to learn the necessary skills needed to control robots makes the transition to an actual robot easier, and 2) The virtual machine, Linux based operating system, and ROS are open source and thus free.

A future consideration for the follow up workshop would be to provide the teachers with a relatively inexpensive robot such as the iRobot Create 2 Programmable Robot http://www.irobot.com/About-iRobot/STEM/Create-2.aspx which is currently being used in STEM projects. The educators would take the robot back to their schools and provide their students the opportunity to work with a real robot.

Materials:

Depending on class size, we will use a lab at the University of Wyoming with adequate desktops available so that each teacher has a workstation.

Software is open source and thus free.

A very detailed PDF with material and instructions will be provided for the attendees to take with them for future use.

Key Words:

Baxter the Research Robot, Robot Operating System (ROS), hands on learning, Robot Simulator, Virtual Machine, Ubuntu (Linux based operating system), Programming Languages.

Time Line

Day 1

- Demonstrate the capabilities of a high level robot (Baxter the Research Robot) and what is achievable via control and communication with ROS.
- Overview of the increase in utilization of robots, why a standardized form of communication/control of the robot is needed, and the basics of ROS including Master Node, Nodes, Publisher, Subscribers, and Topics. Teachers will gain an understanding of how these key components are used to access data from the robot as well as control its movements.
- Teachers will be introduced to virtual machines, Ubuntu (a Linux based operating system), ROS, and a robot simulator through a series of labs. They will be shown Python, a programming language used; however, no prior experience will be required. Necessary code will be provided for them.

Day 2

- Teachers will utilize the concepts gained in Day 1 to view graphic tools available through ROS to view the data from internal communications in the robot.
- Lab sessions will be devoted to customizing templated code that allows teachers to change the robot's actions based on changes to variables such as angular or linear velocity. We will also explore how to control the robot via a keyboard.
- The concept of transform and frame of reference will be introduced in a lab. The demonstration will show how one robot follows another because its frame of reference is the first robot. We will then offset the frame of reference and see how this changes the second robots movements.
- A lab will be devoted to "Putting It Altogether" for the teachers. We will review a proposed template/introduction on how teachers can present the information to their students.

Day 3 (during Academic year)

Focus: Based upon the teachers' experience with using the simulator in the classroom, possible topics may include the following:

- Create objects in the simulated environment that the robot will need to manuever around.
- Use rViz to see and/or evaluate sensory data coming from the robot.
- Interface with Baxter via the tool MoveIt. Gain exposure with how to use the tool and then plan a simple movement that can be executed by Baxter
- Teleoperating or controlling the robot using a joystick.

Day 3 Alternative if robots are purchased in future for educators (during Academic year)

- After time to gain experience and confidence using ROS and the Robot Simulator, the teachers would return to spend the entire day in a lab dedicated to orienting them to the iRobot Create 2 Programmable Robot.
- Teachers would learn how to set up the robot and run through one or two simple projects that could be accomplished with the robot.