From Sequential to Parallel

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Abstract

There is an urgent need for traditional programmers who write programs meant for a single processor to be able to modify or write new codes for multiple processor machines. Unfortunately, writing parallel programs has been esoteric, considered too complex and had been confined to a few developers. This paper presents Microsoft .NET framework versions and enhancements that provide modern approaches that are relatively easy for traditional programmers to learn rapidly and use. These new technologies provide support for both shared memory as well as distributed memory parallel programming models such as a decentralized software service model. However, the presentation of these technologies needs to build on the general background of the stored programmed memory model used by the traditional programmer. It needs to add structures that enable them to incrementally move from sequential model to the parallel model of computation. The goal of the paper is to present a comprehensive structure that integrates the parallel programming model with the sequential model and introduces the technologies in this context. The paper argues that a second level programming course should be based on such an approach. Such a course will be useful for students as well as professional programmers who need this new skill in the light of more and more multi-core, many-core and cluster based commodity multi-computing.

1. Problem statement

Parallel programming has traditionally been a highly specialized area of programming. Interestingly a very limited aspect of parallel processing is often known to traditional sequential programmer. This is multi-threading and is used to improve response time by off loading slow computations such as input/outputs to a thread different from the main thread. However, in parallel programming one is interested to distributed data/code to run concurrently as well as ensure proper coordination to ensure the sum total of these computations produce the result correctly. This requires a more sophisticated programming model and development approach suited for the purpose.

Due to diverse hardware architectures, environments and approaches the meaning of parallel programs incorporated features that ranged from instruction level, data array to higher level concurrency. This has resulted in different models such as data parallel, task parallel, asynchronous, dataflow, agent based as well as distributed parallel programming. All of this has added to the complexity of parallel programming. The good news however is that considerable experience in parallel programming has taken place over the last more than 4 decades and a rich body of knowledge is available. The bad news is parallel programming looks very complex to most sequential programmers.

There has been recognition of the fact that it is urgently needed to offer training in parallel programming to students in general and pro developers as well. Most of them however, have hardly looked at a bridging approach where a sequential programmer is gradually moved to the world of

parallel programming. For example, the course proposed in [1] includes all the aspects of parallel programming such as algorithm design, architectural constraints, programming approaches such as SPMD, mapping and scheduling as well as parallel databases. Students use parallel programming languages and tools such as OpenMP [2, 3, 4] for C/C++ with MS Visual Studio 2005 and Intel C/C++ compiler. Debugging tools include VTune, and threading tools include Intel Thread Profiler and Intel Thread Checker. However, it ignores two important issues –

1) Limitations to "think parallel" without support from a suitable environment
2) The scores of existing developers with developing programming skills for conventional sequentially executing computers.

Our contention is that the approach should be that a sequential (one processor) computation model, as exemplified via conventional sequential programs, is not being replaced by parallel computation model but simply being extended. The approach we need is to add parallel programming as an extension to existing courses on sequential programming and architecture.

We believe that point 1) will be address by building a connection to the common stored program model used in sequential programming from parallel programming models. Point 2) will be addressed by programming extensions (implemented possibly in multiple ways).

This paper presents a proposal for developing a second level course in this approach. Such a course may be part of the engineering curricula while being available to professionals desiring to upgrade their skill sets. This course is intended to demonstrate that using appropriate tools and environments sequential programming ideas can be broadened in order to progressively reduce the cognitive gap between sequential and parallel program development.

As a starting point, in section 2 we identify basic concepts all programmers seem to be aware of. We highlight aspects of computing model, languages and system as well as idea of multi-threading. In section 3 we present the concepts in parallel computing and discuss how they relate to concepts identified in the earlier section. In the next section we further explain the parallel computing concepts emphasizing the role of coordination. Finally in the following section we present the outline of a course designed in this approach.

2. Concepts programmers know

The most widely used model for sequential computation is the von-Neumann stored programming model. This model consists of a processor, a program, data and memory. The program is a sequence of instructions that the processor executes when directed by a program counter/instruction pointer. There are various forms of memory such as registers, random access memory, and secondary memory etc. There are external devices that can communicate to the processors.

An algorithm is a high level representation of a program. It consists of steps of statements that is unambiguous and may be interpreted by a computer. An algorithm must terminate. An algorithm is

used to reason about a specific recipe to solve a problem using a computer. It is implemented as a program using programming language.

A programming language is one that can express an algorithm and may be compiled into a low level program that may be directly executed by the computer hardware. The computer hardware recognizes programs stored in the memory and executes it instructions one by one as pointed to by the program counter. One instruction is executed at a time by the single processor.

2.1 High level language

Programmers write programs using a high level language such as C#, C++ etc. these languages allow various programming structures to help developing programs, reusing existing programs or its parts, composing programs using parts, ensuring semantic guarantee (delivers what it supposed to mean all the time), … The notion of assignment, condition checking, read/write, mathematical operations, data and types of data are very natural to human understanding of computational domain. Composite data such as collections, containers are common. Modern programming environment provide support for using multiple programming languages, using run time just in time compilation that optimizes use of the available infrastructure and various other development tools. Note that the underlying programming model provided is still the stored program model.

2.2 Operating Systems

Programmers understand the role of the operating system in managing computing resource among multiple users. They often use operating system services programmatically. For example, in dynamically allocating memory it uses the memory allocation services, in acquiring a network port it uses socket service of underlying network system.

2.3 Data and Database

Programmers recognize the value of associating a type with a data, composing data in databases for efficient storage and retrievals. They are aware of the mechanisms used for opening database, connecting to it, querying for information etc.

2.4 Network and distributed processing

Network is how computers connect to each other and other devices of various types. They know the different protocols used in such communications. They are aware of ports that are the interface to a computer and machine network addresses.

2.5 Multi-threading

One important understanding in this context is the role of a processor which is the key element of a computer. Mechanism for offloading processors computational load via threads is quite well known. This is to avoid long waiting time for an interactive user. This requires dividing into several pieces of

computations and maintaining their state. This type of support is provided by most operating systems today.

3. Parallel processing concepts

Parallel processing may be viewed as several computations taking place at the same time or concurrently. The notion of "same time" needs a bit of a clarification. If the state of computations is maintained in a computer with only one processor so that any of them may be started, halted before completion, another computation that might have been halted restarted then we are doing parallel processing. In case of multiple processors it is possible to have two or more computations actually running simultaneously.

Overall the notion is to be able to declare computational tasks that may be scheduled to available processors. Each computational task runs on a single processor when it is scheduled to it. Thinking in this way, a parallel process is the agglomeration of tasks. Each task corresponds to a program or a segment of a program that runs on a single processor in a sequential manner. However, such a task may be stopped and saved unfinished to allow another task to use the processor if necessary. The stopped task may resume in the future on this or another processor.

The overall conceptual approach is given by:

Parallel program = Sequential Program + coordination (communication)

Programs process data. The basic goal is to produce an output from input via steps of computations; some of which can take place concurrently in parallel programs. We can analyze the overall process and determine the input-output dependencies amongst the sequentially executing instances. The input of one instance may be generated as output of another. Similarly more than one instance may need the same input. Some of the computational operations on such data are safe if performed by one instance and not so, if performed by several at the same time. This is the limitations associated with the underlying hardware commonly available. In parallel programming we get around this issue by a coordination discipline. One common type is programming mechanisms such as locks and semaphores.

3.1 Coordination

The new concept learners need to understand is that of coordination because they are already aware of concepts in sequential program. One can think of multiple programs running at the same time where each may potentially impact behavior of the other directly (via altering common data) or indirectly (by blocking a resource resulting in the other programming not able to proceed or in deadlock) unless the input-output relations is ascertained to be correct from both a spatial as well as temporal point of view. The first is enforced easily in conventional memories (Random Access Model) but the later requires ordering discipline generally implemented via synchronization primitives [] similar to those used in operating system design.

3.2 Use of programming model

Parallel computer programming models incorporated the idea of coordination via memory or message passing operations. Often these are too low level and lack the high level structure and pattern that is commonly shared across parallel applications. The two corresponding models are the shared memory and the distributed memory models of parallel programming.

The shared memory model is also known as the symmetric multiprocessing or SMP where cost of data access by different sequential program instances of a parallel computation are the same. This assumption is not necessarily always valid, say when intermediate memory caches are used to cut down on memory access overhead.

With more and more such instances the contention for memory impacts this cost limiting scalability of the parallel program. This prompted distribution of the memory in the distributed memory model. However, this requires multi- staging of memory using caches and external networking. Additionally, data access from memory often requires explicit network communication. This model is also called the Multi-computer Parallel Processing or MPP. Language extensions and libraries to support these models are well known – Open MP [2-5] for shared memory while MPI [5, 6] and PVM [7] for distributed memory models. MPI has become very popular as it is easily available to run on commodity clusters of computers. With the advent of multi-core and multi-computers, hardware accelerators such as FPGA, graphic processor matrix a complete overhaul of software development to move to parallel processing is warranted today.

3.3 Languages and libraries:

Most programming languages support “threads” which is the unit of computation scheduled by operating systems. Windows provide API for using thread objects; UNIX pthreads library offers similar functionality. Developing and maintaining parallel programs at the thread level is low level. Language

structures suitable for parallel processing based on appropriate programming models are known. Parallel version of popular languages such as FORTRAN, C, C++ were developed and used. Unfortunately, these tended to be proprietary and expensive. Approaches based special compiler directives as in OpenMP, on libraries such as MPI and PVM were more popular and are currently widely used. The libraries are available from more than one programming languages.

Among other popular libraries are the TBL from Intel, AMD. Among compilers is the Cilk++ compiler which is an extension of industry standard compiler, the native extensions and optimization of the base compiler is fully supported. The underlying model is the shared memory model in all of these except for MPI and PVM which are based on distributed memory model.

4. Extending concepts to include parallel processing

Although considerable research and development has taken place in the area of parallel processing during the last several decades the idea of a novel parallel processing language never succeeded. The approach that worked has been that taken up by Open MP and MPI/PVM. One concern is though that both avoids calling out a concept of "computation" as a distributable object as a first class entity. This has been to avoid intruding into common language standards and concepts. In particular the languages did not provide appropriate options to build such an object.

Going back to the equations used above and reprinted here for convenience, we draw attention to the role of coordination/communication in design and development of parallel programs.

Parallel program = Sequential Program + coordination (communication)

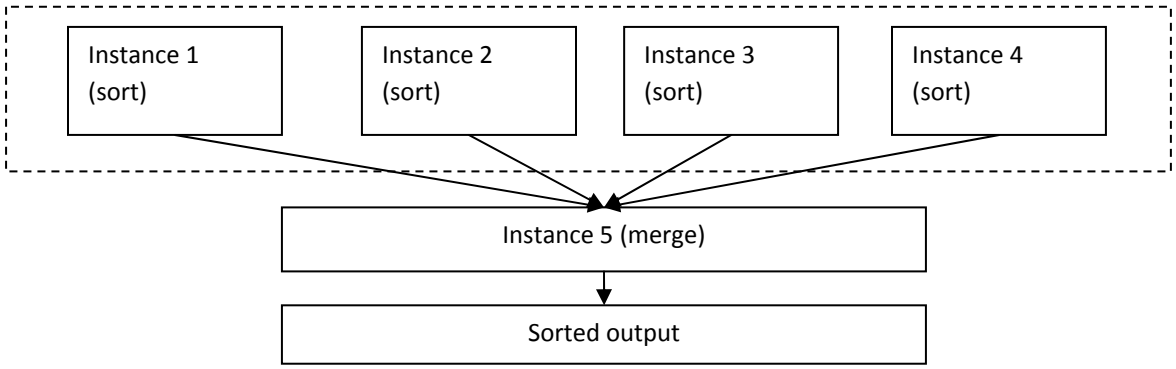
We need a first class representation of a sequential program as a computation in the language or its extension.

Looking at the topic of coordination observe that this depends upon the programming model to be used. For example in a shared memory model all coordination needs to happen by coordinating access to the shared memory. Alternately, if the model is a distributed memory model then such coordination is completely done via message passing often in an asynchronous manner.

This needs the new concept of coordination in shared memory and via message passing to be learnt. Considerable knowledge in both areas, albeit in different context, has been known to us. The goal is to identify them and present them in a unified and structured manner. This will be discussed in the next section.

At this point let us consider the simple example below of sorting a set of numbers:

Assuming parallel instances of several sequential sort programs we can visualize the enter operation as that of sort followed by merging of the sorted parts. This imposes input-output dependencies between the instance executions, shown with arrows.



Note that there is no need for direct coordination between the instances performing sort, while the merge instance may only execute after all sort operations are completed.

4. 1 Contrasting sequential and parallel algorithms

Sequential algorithms use three alternate models for algorithm analysis – RAM, RASP and the Turing machine. Parallel algorithms are essentially extension of a sequential algorithm model. The main ones for shared memory models are PRAM (Parallel RAM) and their variations such as EREW, CREW, and CRCW based on support for concurrent access to memory. Similar models are available for analysis of parallel algorithms targeted for distributed memory parallel computers. Excellent treaties on this is in [13]

In the above example, a PRAM model based algorithm is:

1. Do in parallel { Instance 1, Instance 2, Instance 3, Instance 4}
2. Merge sorted outputs from Instance 1, Instance 2, Instance 3, Instance 4 to create Instance 5
3. Print out the sorted output

Each instance in step 1 uses a sequential sorting algorithm that sorts one of four blocks of the total data to be sorted. The step 2 involves coordination of outputs produced by the four instances of step 1. It is evident that the characteristics of the algorithm depend on size of the blocks, speed of sequential computations, speed of coordination etc. For example, the time taken for step 1 is given by the maximum time spent by an instance of the four being executed. That of step 2 is given by the merging scheme etc.

Several coordination primitives and patterns are used in parallel programming. It is important to understand which should be used when. In the context of shared memory model most common primitives are those conventionally used for multi-threading and known in the OS context. This is quite known to traditional sequential developers as well as synchronization primitives.

Higher order synchronization and coordination primitives such as monitors, semaphores etc are built with lower ones such as locks. Principles and structures such as mutual exclusion, reader-writer paradigms are build from smaller primitives. Updating a variable in memory concurrently may lead to

unpredictable or non-deterministic value. This is due to race between concurrent operations that modify it. Locks are used to coordinate access to the variable by concurrent operations such that only one may deterministically modify it. This idea may be extended to larger data structures common in programming – such as stacks, queues, lists etc.

Patterns such as reduction … and generic schemes such as "map-reduce", "data-parallel", "task-parallel" are even higher level coordination schemes. These are actually the parallel algorithms we mentioned before. In the data parallel context sequential programs run on independent sets of data concurrently and there is no coordination necessary between them. Task parallel scheme defines independent computational blocks, known as tasks where having maximum fan-out in terms of maximum number of tasks to run concurrently lead to maximum speed up.

a) Task parallelism

   Tasks can execute concurrently when there are no dependencies among them. Examples include "ray-tracing" in image processing and Monte Carlo simulation programs. In some cases, it is possible to modify data and instructions to create independent tasks and engage task parallelism.

b) Divide and conquer

   This is similar to the parallel reduction scheme used for developing the maximum finding program. This general scheme is very popular in developing sequential as well as in parallel algorithms. In case of parallel algorithm the goal is to decompose to an extent that makes sense for the individual processors.

c) Geometric Decomposition

   In this approach the relationship of the data influences the pattern. For example, in computational fluid flow problem, operations on matrix element require only neighboring data. In such a case, the matrix geometry is used to formulate tasks. Also in matrix multiplication checker-board algorithms use geometric relationship.

d) Recursive data pattern

   Many sequential algorithms use recursive processing. In many cases these can be split into partitions. Processing recursively can occur in parallel across these partitions. Overall computation can be formulated as a sequence of parallel recursive operations followed by synchronization.

e) Pipelined

   A sequence of tasks can be executed in such a way that a processor is kept working all the time. For example, in case of executing a for-loop in a program, if there is no data dependency and

resource conflict, the first instruction (or task) of the n+1th loop can start executing immediately after the first instruction (or task) of the n-th loop has completed.

4.2 Task and data parallelism

When we partition the computation into tasks and execute them in parallel we get task parallelism. In this case data is not partitioned. Flynn's taxonomy gives four variations in task parallelism of which three are useful – Single Instruction Single Data (SISD), Single Instruction Multiple Data (SIMD), Multiple Instruction Multiple Data (MIMD).

When we partition data but not partition the tasks we have data parallelism. Data parallelism is a convenient way to introduce parallelism when operational dependency does not involve the entire data. This approach is very popular and gives rise to a specialized model of the distributed memory parallel computer called Single Program Multiple Data (SPMD).

4.3 Role of Synchronization

A key concept in coordination is synchronization. This process enforces a synchronous mode of computation in which (the time of) a set of computations are hidden by time period. The intent is to ensure all computations are completed when that period or "clock" cycle is complete. This is a way to impose deterministic state properties. This is very close to the shared memory model. A popular variation in array processing is the systolic architecture.

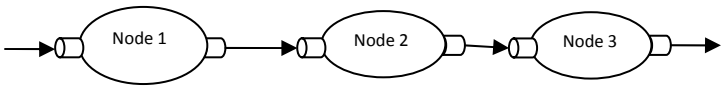
In a computation that does not use synchronization via clock; or in an asynchronous mode of computation, instructions may interact via generation of data or events. One common methodology known to conventional sequential programmers is to use events and call backs. Dataflow is a well known asynchronous parallel computing model. Other models include demand-flow or lazy-evaluation where a computation is performed only when its results are asked for or demanded.

Coordination algorithms may be implemented imperatively in code, in hardware network such as shuffle-exchange network, gate arrays, and distributed services and so on. Much of the coordination is embedded in the structure and topology of the network itself.

4.4 Network and arrays

Parallel coordination algorithms are implemented in arrays via simple messages or dataflow across them. In case of arrays of identical processors performing similar computations pipelined patterns are easily incorporated.

An algorithm for sorting on a linear array of three processors is given below. Note how the coordination scheme is somewhat embedded in the topology of the linear array. Note each node of the linear array sorts a block of data. Each node has an input and output port that establishes the linear relationship among them. We assume N data is being sorted, each node perform a sequential sort on N/3 using a simple insertion sort scheme.



Initially each node reads elements from its input and merges them into an internal sorted sequence of N/3 data.

1. Post N data at the input of node 1
2. Each node do in parallel {

   Read data from input and create sorted sequence locally;
   Pass data smaller than the smallest element in the sorted N/3 sequence to the output port

   }

3. Output sorted sequence

A systolic approach can clock the transmission of data across the network. A service oriented scheme based on CCR/DSS parallel technology supports this in an asynchronous parallel processing scheme.

4.6 Speedup and performance

A key point in parallel processing is performance. Speedup is given by the ratio of time taken by sequential program to the time taken by parallel program. Theoretical limits given by Amdahl's law or Boris-Gustafson's law are well known. It is important to understand concepts of speedup, and performance scalability.

This requires one to be able to understand the algorithmic issues governed by patterns, platform issues governed by the hardware and operating system that impact performance. One should be able to relate performance to code via tools such as profiler, which is rarely used in developing sequential programs.

Debugging parallel programs is difficult. This requires learning to reason about program behavior under multi-processing environment as well as knowing appropriate tools.

Aspects of availability, reliability and fault-tolerance are somewhat advanced topics. However, they should be related to the integrated approach we discuss here.

5. Foundation course

We present an high level outline of a course that help introduce parallel programming to students that have completed one or more traditional programming course. It is useful to professional programmers who have experience in programming single processor computers. The items below point to key topic areas that should be covered in such a course. It also gives relative hours to spend with a percent value for each topic.

- Executing code on a thread – understand the concept of computation in conventional programming environment.
- Developing algorithms – how a program has an underlying algorithm. How to look at an algorithm to reason about a program – correctness, performance and boundaries (max input size, type of input to process, any data ranges, accuracy of output etc.)
- Understanding parallel algorithms – sequential programs and coordination. Extending a sequential program into a parallel program. Identify sequential pieces, coordination process, any extension of boundary (improving performance – processing more data quicker, improving accuracy of data or range of data etc). Concepts of speed up and scale up. Ideal case of linear speed up, super-linear speed up etc. Compute to communication ratio limits speed up.
- Abstracting coordination – patterns. Consider other sequential programs and attempt to parallelize. Look at a good number of problems and identify patterns. At least 5 to 6 different types of patterns need to be discussed.
- Concurrency models – shared memory and distributed. Approach to developing parallel program. Type of model to choose and what type of programming languages etc.
- Scheduling and mapping – how does computational resource usage relate to parallel programming

We believe that the Microsoft .NET Framework and the latest Visual Studio 2010 (CTP available) includes rich set of parallel technology that can be used to develop such a course. This has been presented in Appendix I.

Appendix II illustrates features of the Microsoft .NET Framework parallel processing technology in providing a modern, rich approach to present the course in the above approach. It allows efficient delivery of the concept and approach of the course outlined. This is because we can quickly demonstrate how patterns such as data parallel, task parallel or service oriented design can be formulated in a modern programming environment around C# and Visual Studio. The availability of high quality development, debugging, profiling in the Visual Studio makes delivery of this course more efficient than other alternatives as understood by the authors. The goal is to provide the concepts and theories with complementary hands on experience. The balance can be only maintained with such a modern programming environment.

6. Conclusions

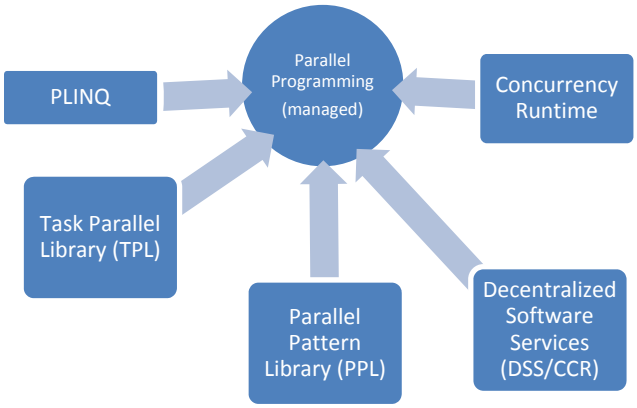
In summary the approach we propose is based on existing programming knowledge and practice of traditional sequential developers. The relationship between sequential and parallel programs/computations is a key underlying theme. The issue of parallel programming is viewed mainly as that of framing up the coordination patterns among sequential pieces. The area of sequential and parallel algorithm analysis and design is very well developed []. In most Computer Science and Engineering curricula the first is usually covered. Correctness, performance and issues such as reliability, availability need to get due coverage. Tools for debugging and profiling can be introduced as part of the curriculum in this context.

References

1) *Think Parallel: Teaching Parallel Programming Today,* Ami Marowka, Shenkar College of Engineering and Design, Israel, 2008 http://dsonline.computer.org/portal/site/dsonline/index.jsp
2) Quinn, M. J. (2003) *Parallel Programming in C with MPI and OpenMP*, McGraw Hill, 2003
3) *The OpenMP API specification for parallel programming*, http://openmp.org/wp/
4) Chapman, B. , Jost, G., & Van der Pas, R. (2007) *Using OpenMP: Portable Shared Memory Parallel Programming*, MIT Press, 2007.
5) Quinn, M.J. (2004) *Parallel Programming in C with MPI and OpenMP*, McGraw-Hill, 2004.
6) Karniadakis, G., Kirby II, R. M. (2003*) Parallel Scientific Computing in C++ and MPI: A Seamless Approach to Parallel Algorithms and their Implementation*, Cambridge University Press.
7) Geist, A., Beguelin, A., Dongarra, J., Jiang, W., Manchek, R., Sunderam, V. S. (1994) *PVM: Parallel Virtual Machine: A Users' Guide and Tutorial for Network Parallel Computing*, MIT Press, 1994.
8) M. Paprzycki, *"Integrating Parallel and Distributed Computing in Computer Science Curricula," IEEE Distributed Systems Online*, vol. 7, no. 2, 2006, http://doi.ieeecomputersociety.org/10.1109/MDSO.2006.9.
9) I. Foster, Designing and Building Parallel Programs, Addison-Wesley, 1995, www-unix.mcs.anl.gov/dbpp/text/book.html.
10) *Cilk Arts:* http://www.cilk.com/multicore-products/cilk-solution-overview
11) *The Manycore Shift: Microsoft Parallel Computing Initiative Ushers Computing into the Next Era (2007),* http://www.microsoft.com/downloads/details.aspx?FamilyId=633F9F08-AAD9-46C4-8CAE-B204472838E1&displaylang=en
12) *Overview of Synchronization Primitives* http://msdn.microsoft.com/en-us/library/ms228964.aspx
13) T. Leighton, *Introduction to Parallel Algorithms and Architectures: Arrays:Trees:Hypercubes* - Morgan Kaufmann, 1992.

Appendix I: Microsoft Parallel Processing Technology

Recent .NET Framework, 3.0 and later versions of .NET Frameworks support more than one high level parallel processing technologies (see figure). These provide the high level programming model missing in the legacy thread models.



The DSS/CCR runs in .NET Framework 3.0 (and 3.5) runtime. It provides an asynchronous message oriented programming model. This model helps develop a loosely coupled multi-task computing solution. It is available as a DSS/CCR development kit and also as part of the Microsoft Robotics Studio[1].

The remaining technology, available as libraries and core runtime, is part of the Microsoft .NET Framework 4.0. A Community Tech Release (CTP) for Visual Studio 2010 contains this.

PLINQ allows automatic parallelization of LINQ queries. The Thread Parallel Library (TPL) is available to be used for managed development in C#, and VB. The Parallel Patterns Library (PPL) as well as the asynchronous agent technology provides support for parallel development for native C++. The Concurrency Runtime provides the runtime to host the parallel objects. Additionally, new profiler tools are available for parallel programs.

The Windows HPC Server

The latest release of Windows HPC Server is based on .NET Framework 3.0 and provides a top notch modern and highly secured HPC run time environment. There is a Window HPC Pack that provides high quality administration, management, monitoring tools along with a top notch job scheduler. The Windows HPC Server data sheet, doc, case studies and licensing is available (see technology links table). The Windows HPC server is a supercomputer quality product as evidenced by the 10th rank in the international top500 list. It provides all traditional HPC application development support and has

[1] CCR and the Asynchronous Programming Model (ref. http://msdn.microsoft.com/en-us/library/bb977678.aspx)

Microsoft MPI library based on MPICH2. This makes easy port of tradition MPI applications. Additionally, it provides latest features such as SOA job definition and scheduling in addition to standard options of diverse schedule policies, integration with third-party scheduling services and the international grid computing standards such as HPCBP. It integrates Windows management and monitoring services leading to fast deployment support via Windows Management and Operations (MOM); system health reporting via Windows System Management Services (SMS) leading to high productivity computing in addition to high performance computing. Extensive world class support from Microsoft as well as third party for development, deployment and infrastructure are available.

Microsoft .NET Parallel Library

C# is a modern programming language that expresses events, objects, threads, lambda functions, anonymous delegates and callback methodologies. The new parallel library in .NET Framework 4.0 builds on these core language features. These libraries are usable from any .NET languages and directly supported on VB.NET and C++/CLI[2]. It is a runtime library instead of a compiler solution as Open MP

The primary goal of this library is simplify the development of parallel programs in .NET environment. It addresses the developer community who are accustomed to C# or other .NET programming languages, though in the traditional sequential programming point of viewpoint. The programming model therefore adheres to the shared memory model of parallel computing.

[2] Parallel Computing http://msdn.microsoft.com/en-us/concurrency/default.aspx

Appendix II: Microsoft Parallel Processing Technology

Microsoft .NET Parallel Extension library and the CCR/DSS asynchronous service oriented parallel processing technology are well suited to present the materials presented in the proposed course above. We present a few examples. We assume knowledge of C# 2.0.

As a developer steps into the realm of parallel programming easy but efficient schemes of parallel computing – such as data parallelism can quickly demonstrate the benefits. Data parallel feature is made available as a new extended type (Parallel) in the .NET 4.0. in the System.Threading namespace quite known to most .NET developers using multi-threading.

The Parallel type has For and ForEach methods to convert sequential iterations (for-loops, foreach-loops) into concurrently running sequential blocks of programs efficiently. The methods create suitable number of sequential blocks depending upon the number of processors in the underlying machine. This is done via the thread scheduling mechanisms in the .NET Framework along with Windows operating system. Having higher level types for defining parallelism hides the common developer pains associated with manually implementing this using low level Thread objects. However, a well disciplined approach to parallelization is not compromised.

If loop iterations are independent, i.e. no iteration need any value computed in another, then one can use suitable methods such as Parallel.For and pass the loop body and parameters as a delegate. A for loop of the type,

```
For (int i = 0; i < N; i++) results[i] = Compute(i);
```

may be converted to a version as follows, where each iteration may run concurrently.

```
using System.Threading;
...
Parallel.For(0, N, delegate(int i) {
    results[i] = Compute(i);
});
```

This is a call to the static For method of the Parallel type. The method takes the starting, ending values of parameter i for the delegate and the function is invoked for each value of i. Conceptually, this is very close to the loop structure and there is no need to add additional synchronization rules. This is so because there is no need for any coordination among the different calls.

The Parallel.ForEach method is used for looping over IEnumerable<T> objects. Since this method is part of .NET library, it can work with other .NET languages such as VB.NET or F#[3].

Parallel LINQ provides an easy to use parallelizing mechanism for LINQ queries[4]. This is very similar to the data parallel constructs. Again, the goal is to simplify adoption of parallel programming for conventional sequential programmers.

[3] Microsoft F# http://msdn.microsoft.com/en-us/fsharp/default.aspx

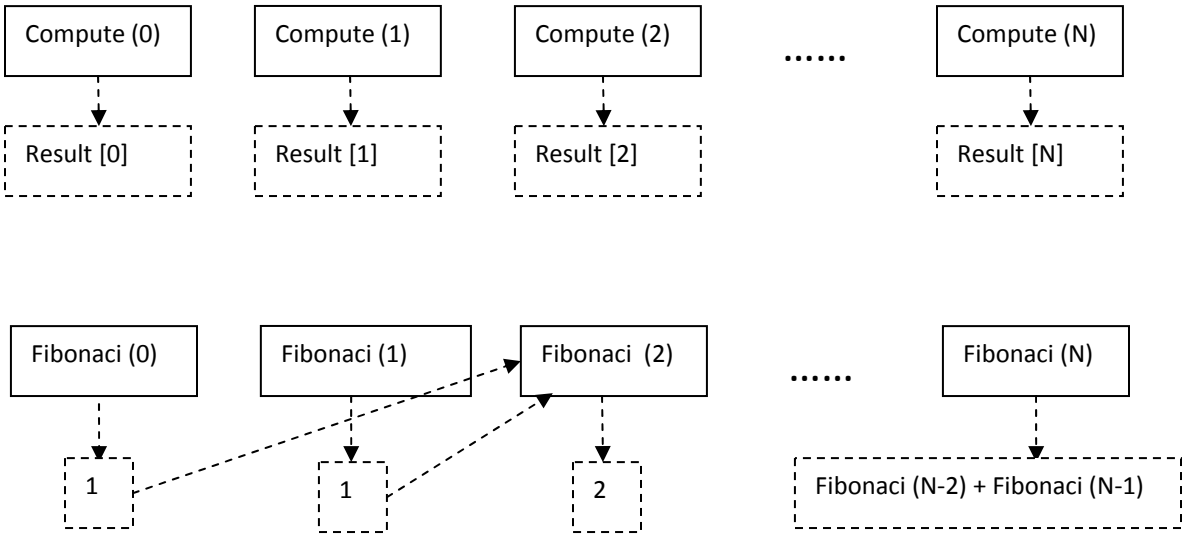
System.Threading.Tasks.Task type represents a task object. A task object is a unit of work in the parallel processing context. It is independently scheduled to run on a processor (general term for core, or processor). This is the basis of expressing task parallelism.

The Create method of Task allows one to create an instance of a Task type that is also associated with a code body that will be executed when this task is associated with a processor. Such association is made via Thread type which is how underlying operating system allocates process/threads to processors.

As a task instance often needs synchronization with other such task instances methods such as Wait and WaitAll are available for Task type. To implement a simple fork/join semantics one can use –

```
Task t1 = Task.Create(delegate { A(); });
Task t2 = Task.Create(delegate { B(); });
Task t3 = Task.Create(delegate { C(); });
Task.WaitAll(t1, t2, t3);
```

It is evident that the task type provides a direct access to the distribution of computational work in a system. It is lower level to the earlier loop parallelization methods.

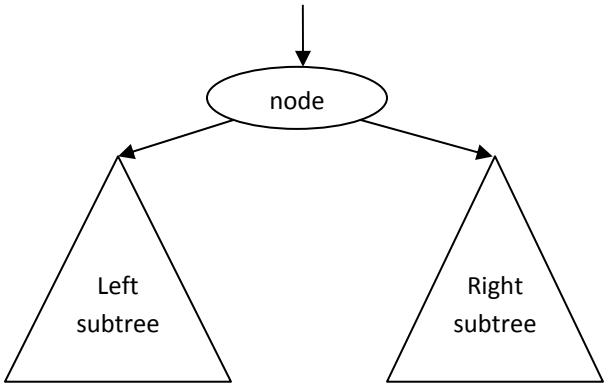


Consider the computation of the Fibonaci numbers where the N-th Fibonaci number is given by the sum of the previous two. The functions Fibonaci (i) depends upon the functions Fibonaci (i-1) and Fibonaci (i-2).

The dependency may be expressed as a general tree structure as follows, where “node” corresponds to the final computation and each tree, left and right corresponds to a recursive definition of the structure itself where the “node” is replaced by the corresponding two sub-computations. In case of the Fibonaci

[4] Running Queries on Multi-core processors http://msdn.microsoft.com/en-us/magazine/cc163329.aspx

calculation, node is Fibonaci(N) and the left and right subtrees corresponds to Fibonaci (N-2) and Fibonaci(N-1) respectively.



The structure may be defined and evaluated serially as follows:

```
class Tree<T>
{
    public T Data;
    public Tree<T> Left, Right;
    ...
}
```

In C#, iterating over this Tree sequentially might look something like the following:

```
static void WalkTree<T>(Tree<T> tree, Action<T> func)
{
    if (tree == null) return;
    WalkTree(tree.Left, func);
    WalkTree(tree.Right, func);
    func(tree.Data);
}
```

To parallelize this computation one may use Parallel.Invoke as follows:

```
static void WalkTree<T>(Tree<T> tree, Action<T> func)
{
    if (tree == null) return;
    Parallel.Invoke(
        () => WalkTree(tree.Left, func)  ,
        () => WalkTree(tree.Right, func) ,
        () => func(tree.Data));
}
```

Observe the Parallel.Invoke method takes several delegates and initiates tasks for each independently. The synchronization occurs via the return value mechanism of the called functions. Also, the parallelism is expressed in terms of dividing the entire computation in to tasks that run concurrently. Since,

WalkTree is called recursively; three tasks are generated each time it is called. This amounts to a large number of tasks being used. Tasks are mapped to physical processors via threads and too many tasks may cause excessive demand for threads and lead to resource contention. This is a key lesson in parallel processing and should be covered in details.

Finer control for task parallelism is implemented via the Task type. The concept of task is similar to a thread, however, at a higher abstraction level. It has its own local variables and environment. This is defined via constructors that can take parameters and a delegate for the method to execute. One can use lambda functions and anonymous delegates from C# 3.0. Wait methods are available to synchronize among tasks. Common semantics are available. For details see [].

Asynchronous task parallelism

Future<T> type derived from Task type provides a return value. This happens in an asynchronous manner. The entire mechanism of setting up callback and retrieval of result is hidden simplifying adoption and use.

Consider the example of counting all of the nodes in a large tree. Sequentially, this might be implemented as:

```
int CountNodes(Tree<int> node)
{
    if (node == null) return 0;
    return 1 + CountNodes(node.Left) + CountNodes(node.Right);
}
```

With Future<T>, this code can be parallelized as follows:

```
int CountNodes(Tree<int> node)
{
    if (node == null) return 0;
    var left = Future.Create(() => CountNodes(node.Left));
    int right = CountNodes(node.Right);
    return 1 + left.Value + right;
}
```

Comparing the asynchronous approach with the one with Parallel.Invoke or using Task directly one can see the benefit of the former quite easily. Note that unless the Value of a Future task type is retrieve the task is not started at all. This limits the number of tasks generated in the program and is more efficient in terms of implementation than the synchronous method given earlier.

Coordination structures

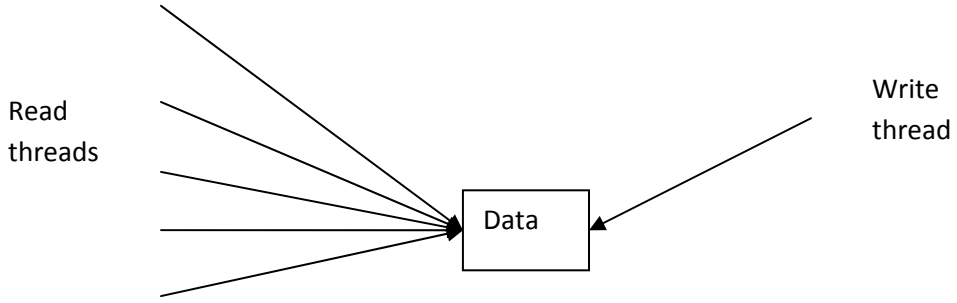
Coordination among multiple threads traditionally is done via control of interaction to avoid race condition. A race happens when the relative order of execution of threads result in wrong result. The goal in synchronization is to ensure this is avoided.

Methods used are locking, signaling and interlocked operations. Locking gives control of a resource to a thread at a time, or to a specified number of threads. The C# Lock statement is implemented using the Enter and Exit method of the Monitor class. It uses try…catch…finally to ensure the lock is released.

Although this form of coordination is essential it does not guarantee starvation, deadlock, fairness etc []. So, many powerful schemes are devised. For example, Monitor class provides TryEnter method that may block a thread for a specified interval and allowing detection of possible deadlock. The Wait method gives up control by a thread in critical section until resource is available, helping fairness and avoiding livelock. Mutex object may also be used for exclusive access to a resource. A thread calls the WaitOne method of a mutex to request ownership. The state of a mutex is signaled if no thread owns it.

Semaphores and reader-write locks are used for non-exclusive locking mechanism where a limited number of threads may be allowed to use a resource. Other mechanisms include Interlocked class, signaling via Join, use of WaitHandle and EventWaitHandles.

The coordination problem or pattern associated with the above synchronization primitives is well illustrated by the readers-writes problem []. Multiple threads read a resource concurrently, but require a thread to wait for an exclusive lock in order to write to the resource.



High level constructs such as thread-safe collections, more sophisticated locking primitives, data structures to facilitate work exchange, and types that control how variables are initialized are part of the .NET 4.0 parallel library. This considerably reduces the pain of developers in implementing correct and efficient coordination schemes.

The following table lists these higher level coordination structures. Counters are used to control thread execution. Threads perform decrement on counters and wait until it becomes zero. The decrement operation on such a counter is atomic and thread-safe (only one thread can get hold of such a counter and change its value at a time atomically). It also has an increment method (also atomic).

Table 1: High level thread-safe constructs

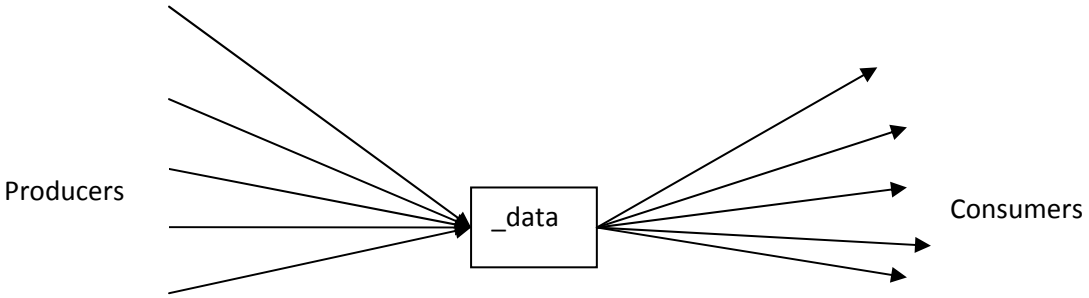
counters	CountdownEvent	ManualResetEventSlim	
locks	SemaphoreSlim	SpinLock	

Collections (namespace)	BlockingCollection<T>	ConcurrentQueue<T>	ConcurrentStack<T>
Lazy data structure	LazyInit<T>	WriteOnce<T>	

LazyInit<T> is a commonly-used tactic for delaying data initialization until the data is actually needed.

The high level coordination structure elevates the synchronization issue to higher level of abstraction that are more natural conceptually to sequential programmers while being in reality a good parallel implementation.

Consider the famous producer-consumer problem in which producers produces at a rate not necessary same as the rate of consumption by consumer. An intermediary collection structure may act as a buffer as the diagram show below.



The data structure for the buffer (_data) that holds strings may be expressed as follows.

```
private BlockingCollection<string> _data = new BlockingCollection<string>();
```

This could also be done by explicitly providing the underlying collection to be used:

```
private BlockingCollection<string> _data =
    new BlockingCollection<string>(new ConcurrentQueue<string>());
```

In the context of a producer-consumer problem described above, one or more producer threads can now add data to the queue:

```
private void Producer()
{
    while(true)
    {
        string s = ...;
        _data.Add(s);
    }
}
```

While one or more consumer threads are removing data from the queue, blocking as necessary until data is available:

```
private void Consumer()
{
    while(true)
    {
        string s = _data.Remove();
        UseString(s);
    }
}
```

Such a consumer loop can be made simpler by taking advantage of BlockingCollection<T>'s GetConsumingEnumerable method, which generates an IEnumerable<T> that removes the next element from the collection on each call to IEnumerable<T>.MoveNext. This allows for a BlockingCollection<T> to be consumed in standard constructs like a foreach loop:

```
private void Consumer()
{
    foreach(var s in _data.GetConsumingEnumerable())
    {
        UseString(s);
    }
}
```

It could even be used in a PLINQ query:

```
private void Consumer()
{
_data.GetConsumingEnumerable().AsParallel().Where(...).Select(...).ForAll(s
=>
    {
        UseString(s);
    });
}
```

BlockingCollection<T> acts as a wrapper around any concurrent collection that implements the System.Threading.Collections.IConcurrentCollection<T> interface, providing blocking and bounding capabilities on top of such a collection. Both the ConcurrentStack<T> and ConcurrentQueue<T> types implement IConcurrentCollection<T>, allowing them to be used with BlockingCollection<T>, but custom implementations of IConcurrentCollection<T> can also be used.

As is illustrated above, a high level buffer simplifies implementing the coordination scheme in comparison to conventional low level primitives. Also, this help in hiding much of the complexities of implementing such buffers and keeps the functionality close to what a sequential program developer can easily work with.

Handling Exceptions

In the parallel extension library all exceptions from different threads are aggregated into a AggregateException object. The original exceptions are accessible through the InnerException property of this object. This is a catchall approach and ensures that a developer can be made aware of all relevant exceptions and that all errors are properly bubbled up. Each exception has a valid stack trace.

Examples of scenarios where AggregateExceptions are thrown are from Parallel class – Parallel.For, Parallel.ForEach or Parallel.Invoke region; Task class – all exceptions thrown during the execution of all tasks will be at the tasks Wait method. The exceptions are also available from the Task's exception property. (is the latter Aggregate?). (need example); for Future<T> class – exceptions will be rethrown both from its Wait method and from its Value property; PLINQ – exceptions will occur when the query is executed – ForAll(), ToList(), ToDictionary(), ToLookup(), and MoveNext() on result of calling GetEnumerator() such as in a foreach loop.

Thread affinity needs to be honored for UI and COM based interoperation scenarios. This is an advanced issue and should be only presented in the context of interoperability.

Service oriented approach

Distributed memory model for parallel computing is based on message passing. This model has no shared memory and any resource sharing is via messages. The .NET library in the Microsoft Robotics Studio contains the Concurrency and Coordination Runtime (CCR) and the Decentralized Software Services (DSS) library to offer a loosely connected services oriented concurrency platform.

Although initially built with highly disperse concurrency requirement of a robotics computing environment the CCR offers basic concurrency, asynchronous message passing loosely connected computing model that inherently offers a general parallel programming framework. The parallel processing components are easily available.

We can look at software components as self-consistent services with known interfaces. A service can interact with another via service ports. This basic model is supported on one machine via CCR and across multiple machines via DSS. CCR provides mechanisms to define ports and services along with underlying asynchronous processing of messages that flow through the ports. As a message is posted to a message port of a service it is processed on a concurrently running thread.

Parallelism is inherent in the model. Any number of items in a port is processed on different threads. The model does not need any explicit locking or synchronization as all dependencies are incorporated via the ports. The DSS extends the model to multiple machines where inter node message communication is done via HTTP based protocol called DSSP.

The model is similar to the well know dataflow model of parallel computing []. The Microsoft Robotics Studio also consists of a graphic lingual called Visual Programming Language that reflects the basic dataflow nature of the model.

A program that defines a basic service class along with a Create method to create instances, a set of ports, and initialization of message handlers using a receiving task configured via a scheduler called Arbiter is given below.

```
/// PortSet that accepts items of int, string, double
public class CcrConsolePort : PortSet<int, string, double>
{
}

/// Simple example of a CCR component that uses a PortSet to abstract
public class CcrConsoleService
{
    CcrConsolePort _mainPort;
    DispatcherQueue _taskQueue;

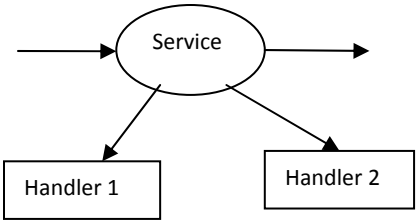
    public static CcrConsolePort Create(DispatcherQueue taskQueue)
    {
        var console = new CcrConsoleService(taskQueue);
        console.Initialize();
        return console._mainPort;
    }

    private CcrConsoleService(DispatcherQueue taskQueue)
    {
        // create PortSet instance used by external callers to post items
        _mainPort = new CcrConsolePort();
        // cache dispatcher queue used to schedule tasks
        _taskQueue = taskQueue;
    }

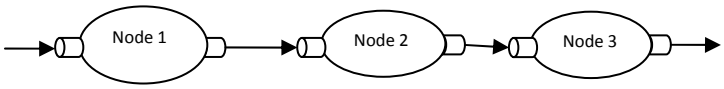
    private void Initialize()
    {
        // Activate three persisted receivers (single item arbiters)
        // that will run concurrently to each other,
        // one for each item/message type
        Arbiter.Activate(_taskQueue,
            Arbiter.Receive<int>(true, _mainPort, IntWriteLineHandler),
            Arbiter.Receive<string>(true, _mainPort, StringWriteLineHandler),
            Arbiter.Receive<double>(true, _mainPort, DoubleWriteLineHandler)
        );
    }

    void IntWriteLineHandler(int item)
    {
        Console.WriteLine("Received integer:" + item);
    }
    void StringWriteLineHandler(string item)
    {
        Console.WriteLine("Received string:" + item);
    }
    void DoubleWriteLineHandler(double item)
    {
        Console.WriteLine("Received double:" + item);
    }
}
```

Note that concurrency is built in via the Arbiter which will activate a receiver task for any item posted on the port of the service. The task or handle of the message is scheduled via a DispatcherQueue and corresponding Dispatcher and optimizes the underlying cores of the hardware the program run on.



A program is given by set of service instances and ports instances connecting them. A service encapsulates a component. A sequence of service instance that processes output from the previous element may be shown as



Note that the model does not constrain the concurrent processing of the messages on the port. This is the typical pipeline pattern.

The CCR builds on three types of elements. These are CCR Ports and PortSets, coordination primitives called arbiters, and the Dispatcher and DispatcherQueue.

The Port class is a first in first out (FIFO) queue of items which is a Common Language Runtime type and a corresponding set of receivers that is guarded by arbiters. Arbiters execute user code, often a delegate to some method when some conditions are met. Arbiters can be nested to implement extended coordination logic. The Dispatcher and DispatcherQueue isolates scheduling and load balancing from the rest of the implementation. CCR avoids a single process wide execution resource as in CLR thread pool and allows the programmer to have multiple, completely isolated pools of OS threads that abstracts the notion of threading behind them. Multiple queues per dispatcher allow for a fair scheduling policy.

Adding an item to the port is an asynchronous operation. The interaction between components may take place by one posting an item in a port of another component in a non-blocking manner. This is done via Post() method.

```
Port<int>   portInt  = new Port<int>();

portInt.Post(10);
```

The second component can process such an item based on condition as implemented via arbiters. Such operation may either be passive or active. In the first case no tasks are scheduled when items are posted. Example is the Test() method on a port to detect presence of an item in it. Details are found in the user manual [].

The PortSet class allows for enumeration of all the port instances and item types it supports. The generic PortSet also provides convenient methods that automatically invoke the correct Port<> instance plus implicit conversion operations that can cast a PortSet<> instance to a Port<> instance automatically.

Aribiters implement a set of coordination logics. For example, it can create a task, a choice among two or more operations, a receiver, interleave, join of messages etc. It is possible to compose arbitrary coordination logic using them.

A simple example of using an arbiter type is given below:

```
// create a simple service listening on a port
ServicePort servicePort = SimpleService.Create(_taskQueue);

// create request
GetState get = new GetState();

// post request
servicePort.Post(get);

Arbiter.Activate(_taskQueue,
    get.ResponsePort.Choice(
        s => Console.WriteLine(s), // delegate for success
        ex => Console.WriteLine(ex) // delegate for failure
));
```

The get message is posted on the input port. The Activate method schedules a task on _taskQueue which listens to the ResponsePort associated with the get message (a message has a operation, response port and a body) via a Choice function and if the message type is that of s prints the value of s, or if it is of type ex, prints the value of ex.

An extensive set of types are available to develop parallel programs using this model. The Iterators is used for nesting asynchronous calls while being very close to the commonly understood iteration types. A sort program on a linear array may be designed with identical service instance wrapped in an iterator.

The CCR addresses failure handling with two approaches. One is the explicit or local failure handling using the **Choice** and **MultipleItemGather** arbiters. Combined with iterator support they provide a type safe, robust way to deal with failure since they force the programmer to deal with the success and failure case in two different methods and then also have a common continuation. The other one is an implicit or distributed failure handling, referred to as Causalities that allows for nesting and extends across multiple asynchronous operations. It shares in common with transactions the notion of a logical context or grouping of operations and extends it for a concurrent asynchronous environment. This mechanism can also be extended across machine boundaries.

Expanding Engineering Education through Undergraduate Research Experience in Micro-Robotic Drug Delivery

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Abstract

This paper examines the use of MEMS research in bio-medical micro-robotic drug delivery as an education vehicle for expanding the effectiveness of undergraduate engineering education in order to meet advancing challenges of the future. Micro-robotic drug delivery is a diverse area of research with emerging applications in intraocular surgery and cancer treatments. This research requires integration of engineering sciences such as bio-systems, fluid mechanics, thermodynamics, chemistry, material sciences, and more. This allows various engineering disciplines to utilize their classroom knowledge in direct research with real, innovative applications in technology. This method of complimenting engineering education with curricula-related research has shown improvement in engineering accomplishment and learning that is advantageous to the future success of undergraduate engineering education.

Introduction

Engineering focuses on the development and discovery of important resources such as energy, materials, and information in order to provide tools and technology in service of advancing human civilization. Consequently, engineering activity has a global impact due to the international utilization of innovative discovery. For this reason, engineering education has the objective of presenting not only the engineering sciences but also how to apply them to direct applications in a manner that is judicious and conscience of societal and environmental impact[1]. In order to meet the future challenges of an advancing engineering industry, undergraduate education needs to prepare students in a vast spectrum of sciences and technical skills. This requires collaboration between classroom knowledge and laboratory practice. By utilizing the opportunities for undergraduate research projects, students can significantly advance their education by applying first-hand the curricula they are learning in class. This approach allows for a greater understanding of the advanced sciences and an early exposure to the laboratory skills, both technical and practical, utilized by the professional engineering industry.

One way of accomplishing this is through the pursuit of research in microelectromechanical systems (MEMS) and the technologies it encompasses. MEMS research is an innovative research area for undergraduates because it incorporates a diverse range of technical skills in various engineering fields and represents many current and emerging applications in society. With a history of over 30 years, MEMS research has supported the development of technologies such as switches, displays, pressure sensors, accelerometers, gyroscopes, inkjet printer heads, and lab-on-a-chip chemical detection systems. Discoveries such as these have not only inspired the industrial world, but have given rise to interest among

academic institutions in incorporating MEMS into their curriculum [2,3]. MEMS research has an interdisciplinary nature originating from the need to design and integrate electrical, mechanical, optical, and chemical sub-systems into a functional device [1]. This paper focuses on the use of MEMS principles in Micro-Robotic research as an innovative education vehicle to attract top students from various engineering backgrounds and give them the opportunity to expand their education by being actively involved in an exciting research project.

MEMS Micro-Robotic Research

MEMS research is a broad field with multiple areas of critical development and investigation. It requires a collaborative effort spanned by engineering disciplines such as robotics, automation, ultrasound, fluid dynamics, modeling, kinetics, magnetism, bio-systems, and other curricula as reviewed in table 1. In recent years, MEMS technologies have been integrated into many bio-medical applications. One of these applications is the development of micro-robotic drug delivery systems. The purpose of these systems is to provide a means for wireless, targeted drug delivery to various areas of the human body. These systems are of interest to the medical industry because they could provide less adverse methods for cancer treatment [4], replace high-risk intraocular micro-surgeries [5], and provide great improvements in future technologies such as those reviewed by Gilles [6]. The development of these systems requires a collaborative grouping of research in areas such as structural design, assembly, bio-compatibility, encapsulation, steering and guiding, imaging and tracking, insertion and retrieval, and actuation. Consequently, this MEMS research incorporates a diverse range of engineering disciplines. Of these areas, micro-robotic actuation has been one area of undergraduate research success. This aspect of research focuses on the investigation of alternative drug release mechanisms to improve the remote triggering of drug release from the robot structure. Existing methods use diffusion [7] and magnetic modulation as a means for triggered release but have shown disadvantages relating to release time and magnetic interference with emerging steering and guiding systems [8]. For these reasons, ultrasound is being investigated as an alternative actuation mechanism for drug delivering micro-robots. This research project is ideal for undergraduate student research because it involves knowledge and curricula from general chemistry, biology, physics, and core engineering sciences. It also presents an affordable opportunity for innovative research and undergraduate learning experience.

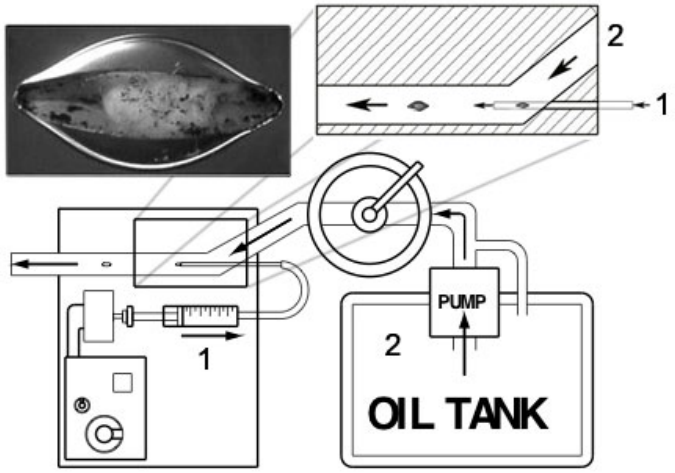


Fig. 1: Micro-robot encapsulation system showing fluid manifold and encapsulated micro-robot. 2 – Continuous Oil Phase. 1 – Sodium Alginate Disperse Phase

Subject/Curriculum	Relation to MEMS Micro-Robotics Research
Intro. Mechanics	Newton's Second Law
Fund. Tech of Chemistry	Kinetics, Beer's law of absorbance. Spectroscopy and concentration measurements.
Intro. Electricity and Magnetism	Magnetic forces and torques, circuit analysis.
Intro. CAD / Graphics	Photomask design, conceptual graphics
Differential Equations	Force derivation and modeling
Elements of Electrical Engr.	Electromagnetics and driving circuits.
Thermodynamics	Diffusion kinetics
Fluid Dynamics	Characterizing flow regimes, motion in low Reynolds number environments.
Instrumentation Lab	Control of B-Field and gradients
Fund. Of Engr. Materials	Bio-polymers: processing/use
Senior Lab	Device testing and analysis
Control Systems	Closed-loop position control

Table 1: MEMS disciplines and applications of engineering curricula.

The technical aspects of the this research focus on the development of a bio-compatible surface skin with the purpose of inhibiting drug leakage prior to remote actuation, the mechanisms inducing the drug dispersion, and the measurement and analysis of the release characteristics. The bio-compatible coating materials derive from the protocol reported by Saslawksi [9] and are used in a series of chemical soaks to induce the formation of a polymer based outer coating. The method of coating is also an important research area to ensure consistency of release characteristics and uniformity. The most efficient method implements encapsulation by means of a co-fluidic extrusion system (figure 1). This system was designed to disperse Sodium Alginate drug complex into a continuous oil flow via a capillary tip. This method allows the experimenter control of the droplet size and disperse frequency thus making it ideal for encapsulation of various micro-robots and MEMs devices. The development of this system employed many concepts from fluid mechanics and required an in-depth analysis to characterize the performance as a direct result of design parameters. This required an undergraduate researcher to apply fluid mechanical concepts, such as flow regimes, Reynold's numbers, and interfacial tension forces, to an actual design concept. Another aspect of the project focused on bio-compatible chemicals to use in the drug delivery process. Horseradish Peroxidase was chosen as a drug substitute and is contained in the Alginic coating during this extrusion process. The encapsulated micro-robots are then soaked in a 0.1M Calcium Chloride ($CaCl_2$) solution for up to 15 minutes. This salt solution promotes cross-linking with the NaAlg. and creates a drug-containing, durable surface shell surrounding the magnetic robot structure. The robots are then transferred into a polyethylenimine (5% wt.) solution for approximately 4 minutes. During this soak, a protective polymer coating forms and serves to isolate the drug containing sub-layer from the surrounding fluidic environment. The droplets are finally soaked in a Poly-l-lysine (2% wt.) solution where the poly-l-lysine is hypothesized to leak into the $CaCl_2$- $NaA\lg$. cross-linking and strengthen it. This aspect of the project utilized various chemistry concepts that govern the underlying principles of the surface skin formation. The undergraduate researcher had to

familiarize himself with these concepts in order to understand the formation process and optimize the relative effects of chemical concentration and soak times on skin formation. After the formation of the protective surface barrier, the droplets are prepared for drug release studies. Visual release results showing the effectiveness of the protective surface skin are shown below in figure 2.

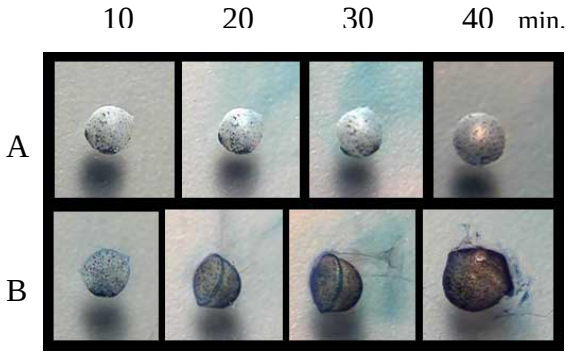


Figure 2: Visual release experiment showing the impact of the protective surface skin on release kinetics. **A** droplets have a protective surface skin while **B** droplets are bare. Drug release is observed by color change in surrounding fluid.

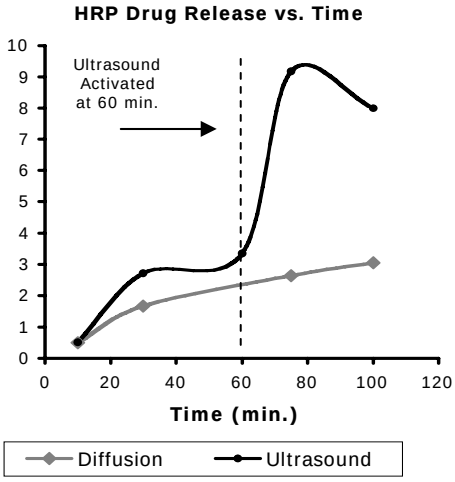


Figure 3: HRP drug release vs. time for both diffusion and ultrasonically stimulated micro-robots.

In order to test ultrasound as a proposed release mechanism for encapsulated micro-robots, undergraduate research assistants faced the task of designing affordable and efficient test experiments. This approach requires undergraduate students to use their scientific knowledge to assess the affordability of research practices and ensure efficient methods of hands-on experimentation. Student research assistants did this by using an ultrasonic bath designed to utilize ultrasonic cavitation as a mechanism for cleaning lab glassware and equipment. They tested the drug release effectiveness by sonicating robot samples for various time intervals and observing the robot behavior and release dynamics. In order to assess the ultrasonic power and effective causes of release, students had to employ research and analysis methods to characterize the results of their experimentation. They used spectrophotometry techniques and a selected chromogenic substrate, Tetramethylbenzadine (TMB), to quantitatively measure the amount of released drug with respect to ultrasound exposure time. This gave students the opportunity to apply common engineering instrumentation methods to discover and report the success of ultrasound as an alternative drug release mechanism for bio-medical micro-robots. The results of ultrasound as an actuation mechanism are shown above in figure 3.

Educational Impacts of Undergraduate MEMS Research

This project and other MEMS research areas present many advantages to engineering education and the advancement of learning in undergraduate engineering disciplines. One of these advantages is the heightened understanding of classroom curricula. By applying first-hand the engineering knowledge taught in the classroom, undergraduate students are able to increase their scope of understanding in industry applications and practical laboratory procedures. This not only expands ones understanding but also increases excitement and motivation in the

curriculum due its apparent utilization in real, innovative research. This increased excitement also permeates into the students overall perspective on their engineering education as a whole and serves as a backbone to further engineering accomplishment. Undergraduate involvement in research also gives students an early exposure to laboratory instrumentation and experimental procedures commonly undergone by the engineering industry. This allows students to develop significant technical and practical laboratory skills that are of interest to many engineering employers. It also promotes a clearer understanding of the discovery process and the steps undergone to make an engineering idea become a developed product. Another advantage offered by undergraduate research is the knowledge gained from technical research and reporting. Since research often leads to novel discoveries, undergraduate students are also exposed to the procedures encompassed in technical writing and publicizing new research. This creates a great opportunity for undergraduate students to submit papers to conferences and gives them the potential to be invited to conference proceedings for poster or oral presentations. Such an engineering experience also serves to enhance the chances that undergraduate engineering students will pursue their education up to masters or PhD proficiency. This is due to the inspiration that derives out of technical achievement and premises the engineering mindset that aspires for life-long technical excellence. Overall, the opportunity for undergraduate research presents many advantages to aid in the betterment of engineering education.

Conclusion

Undergraduate education is perhaps the most critical aspect of higher education because its purpose serves to educate and train the next generation of professionals that will confront advancing challenges of the future. For this reason, engineering education must continue to improve in order to prepare future engineers for the vast range of technical challenges they will address. One way of achieving this goal is by providing undergraduate engineering students with rewarding research opportunities to heighten their educational understanding and gain early experience with technical procedures currently taking place within the modern engineering industry. Active research projects can provide undergraduate students with many advantages such as increased achievement, greater motivation, broader understanding of engineering sciences and disciplines, and a mindset of technical excellence. Research areas within MEMS technologies present one of the most effective opportunities due to the variety of disciplines that are applied and the large range of emerging applications. Within MEMS technology, Micro-robotic drug-delivery research has shown great success in its purpose of expanding a mechanical engineering student's perspective on education, technical knowledge and skills, and engineering aspirations. By expanding engineering education beyond the limits of core curriculum, universities can greatly improve the success of many engineering graduates and ensure the development of a strong next generation of engineers who are technically trained to meet the advanced challenges of the future. This can be achieved by implementing programs that support and reward undergraduate engineering research as an effective approach to greatly enhancing engineering education and heightening the life-long success of future engineers, the engineering industry, and most importantly, the discoveries made to further advance humankinds understanding of the world and universe.

Acknowledgements

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References:

[1] Enikov, E.T. & Nelson, B.J. (2007). Accommodating the Diverse Technical Interests of Foreign Exchange Students through Participation in MEMS and Micro-Robotic Research. International Conference on Engineering Education – ICEE 2007.

[2] Lin, L. Curriculum Development in Microelectromechanical Systems in Mechanical Engineering. *IEEE Transactions on Education*, vol. 44, 2001, p. 61-66

[3] Adams, J.D., Rogers, B.S., Leifer, L.J. (2004). Microtechnology, Nanotechnology, and the Scanning-Probe Microscope: An Innovative Course. *IEEE Transactions on Education*, vol 47, p. 51-56.

[4] Ishihara, K., Furukawa, T. (1991). Intelligent Microrobot Drug Delivery System Measured and Controlled by Ultrasonics. Clinical Research Institute, Osaka National Hospital.

[5] Weiss, J. N. (1998). Treatment of Central Retinal Vein Occlusion by Injection of Tissue Plasminogen Activator Into a Retinal Vein. *American Journal of Ophthamology* 126(1):142–144.

[6] Gilles, G.T., Ritter, R.C., Broaddus, W.C., Grady, M.S., M. A. H. III, and McNeil, R. (1994). Magnetic manipulation instrumentation for medical physics research, Review of Scientific Instruments, vol. 65, no. 3, pp. 533–562.

[7] Dogangil, G., Ergeneman, O., Abbott, J.J., Pane, S., Hall H., Muntwyler, S., Nelson, B.J. (2007) Toward Targeted Drug Delivery with Wireless Magnetic Microrobots. Institute of Robotics and Intelligent Systems, ETH Zurich.

[8] Yevin, K.B., Vollmers, K., Nelson, B.J. (2006). Modeling and control of Untethered Biomicrorobots in a Fluidic environment using Electromagnetic Fields. *International Journal of Robotics Research*, vol. 25, p.527--536.

[9] Saslawski, C. Weingarten, J.-P. Benoit, and P. Couvreur. (1998). Magnetically responsive microspheres for the pulsed delivery of insulin, Life Sciences, vol. 42, pp. 1521–1528.

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TOWARDS A JOINT DEGREE PROGRAM IN AMBIENT COMPUTING[1]

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Abstract — *Funded by the US-EU Atlantis Program, International Cooperation in Ambient Computing Education (ICACE) Project is establishing an international knowledge-building community for developing a broader computer science curriculum aimed at preparing students for real-world problems in a multidisciplinary, global world. ICACE is collaboration among three US and three EU universities joined forces to create a core curriculum in Ambient Computing. The curriculum will include aspects of social science, cognitive science, human-computer interaction, organizational studies, global studies, and particular application areas as well as core computer science subjects. Programs offered at partner institutions will form trajectories through the curriculum. A degree will be defined in terms of combinations of trajectories which will satisfy degree requirements set by accreditation organizations. The curriculum is evolving with student and faculty exchanges on both sides of the Atlantic and expected to lead to joint- or dual-degree programs among the partner institutions in the future.*

Index Terms — Joint degree programs, ambient computing, computer science education, student mobility

1. Introduction

The field of computer science (CS) education is in the process of a major paradigm shift as a result of the challenges the CS community is facing in the definition, purpose, pedagogy, and curriculum drives of the field as well as declining students. On the one hand, a global market requires graduates with a broad computing education who can master the context and work in multidisciplinary and international settings. On the other hand, with the marrying of CS with other disciplines such as psychology (in the area of human-computer systems), language and communication (in the areas of usability and content creation), business (in the area of technology driven proximity marketing), sociology (in the area of social networking via computers and forensic and terror networks) computing, graduates are increasingly required to have multidisciplinary knowledge and abilities. This, coupled with the emergence of new subfields such as bioinformatics and significant growth in the body of knowledge in existing subfields such as software engineering means that taught undergraduate and even taught postgraduate CS degree programs can no longer cover comprehensively all aspects of the field.

Institutions across the world are addressing these challenges through development of new programs or courses that focus on computing in context rather than the computer. Three US and three EU universities formed a consortium to carry out a project entitled International Cooperation in Ambient Computing Education (ICACE). This consortium aims to broaden the perspective of computing students through curricular innovation and international mobility. The project aims at developing and delivering a CS curriculum that

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will give students the education needed for effectively addressing real-world problems in a multidisciplinary, global world. ICACE Project was one of the14 projects chosen for funding in 2007 by the EU-U.S. Atlantis Program. The total cost of the U.S. program is funded by The Fund for the Improvement of Postsecondary Education (FIPSE) of the U.S. Department of Education, while the Directorate General for Education and Culture of the European Commission is funding the European part of the project for a period of four years. The project is collaboration among Troy University (USA), University of Sunderland (UK), Fernuniversität in Hagen (Germany), University of Algarve (Portugal), University of Arkansas at Little Rock (USA) and San Diego State University (USA).

The ambient computing curriculum will include aspects of social science, cognitive science, human-computer interaction, organizational studies, global studies, and particular application areas as well as core computer science subjects. Programs offered at partner institutions will form trajectories through the curriculum. A degree will be defined in terms of combinations of trajectories which will satisfy degree requirements set by accreditation organizations. This is expected to lead to joint- or dual-degree programs among the partner institutions in the future. A total of 48 students is expected to take part in the mobility scheme which will involve spending one semester (4-6 months) at one of the partner insitutions across the Atlantic. This paper describes the goals and activities of the project and discusses current implementation issues.

2. The project's goals

The goals of the project align with the expectations of the EU-US Atlantis Program and include the following:

- To integrate multidisciplinary knowledge into current computer science courses for taught undergraduates and masters students.
- To directly influence curriculum developments in partner and other institutions by means of curriculum development teams, practical experience of student and staff exchanges and dissemination workshops. This will be furthered by staff exchanges which will provide 8-10 staff with benefits from alternative perspectives, new training materials and approaches. These will take place largely in the first half of the project as materials are redeveloped to embody a full multidisciplinary, global perspective and are made available on the electronic learning platform.
- To provide 48 students with benefits from global exchange and training activities and in addition, by means of local, national workshops and online communities of practice, spread the benefits to a further 60 non-exchange students and around 20 academics.
- To disseminate proven practices, models and study programs.

3. Planned Activities

The project and its aims have been developed not only to meet a need for computing workers of all levels but also to meet the needs of the institutions involved. A range of activities have been planned to achieve the project's goals. The planned activities cover development of international curricula, organizational frameworks for mobility, language and cultural preparation and assessment, promotion and dissemination, and evaluation.

3.1 Development of International Curricula for Ambient Computing

The terms ambient, pervasive, and ubiquitous computing have been used to characterize a future with electronic environments that are sensitive and responsive to the presence of people in an invisible way. Weiser [1] referred to technology that “recedes into the background of our lives” and can be used “without even thinking about” it as "ubiquitous computing". The European Union’s Information Society Technologies Program Advisory Group (ISTAG) used the term “ambient intelligence” to describe a vision where “people will be surrounded by intelligent and intuitive interfaces embedded in everyday objects around us and an environment recognizing and responding to the presence of individuals in an invisible way” [2]. Such extension of computing into everyday life presents challenges across computer science and necessitates understandings of the social, cultural and psychological phenomena surrounding the context in which the computer is used. In the ICACE project, we assume that the notion of ambient computing entails understandings of those social, cultural and psychological phenomena as well as the notions of ubiquitous computing and ambient intelligence.

The ICACE project aims at developing and delivering CS curricula that will give students the education needed for effectively addressing real-world problems in a multidisciplinary, global world. The ambient computing curriculum will be a framework for unifying the CS curricula offered by partner insitutions. It will include aspects of social science, cognitive science, human-computer interaction, organizational studies, global studies, and particular application areas as well as core computer science subjects.

CS programs offered at partner institutions will be formed into trajectories (a set of cohesive, coordinated local contexts for understanding CS) through the courses that comprise the curriculum. These trajectories will be enhanced and refined over the course of the project such that on its completion a common degree will be defined in terms of combinations of trajectories which will satisfy degree requirements set by accreditation organizations on both sides of the Atlantic. This is expected to lead to follow-on activities in developing joint- or dual-degree programs among the partner institutions. It is anticipated that existing courses across the partner institutions will cover most of the areas needed in the curriculum with new and modified course content being developed during the project to address additional needs. The global studies aspect of the curriculum will start internationalization of education at home and will be the basis for additional internationalization through student mobility.

In connection with development of international curricula, a project curriculum team will be set up to take a multidisciplinary view of computing and will comprise members from all institutions on both sides of the Atlantic from each of the disciplines that may be relevant to ambient computing—sociology, psychology, business, language, computing and communication. This team will meet via Skype conferencing at project start and thereafter six monthly meetings to discuss trends, areas of currency and importance for curriculum development. The curriculum team will determine courses which need enhancing and developing. It will then agree to develop courses at one or more institutions. This will enable curricula to be kept up to date and to provide courses to students at partner sites which might not otherwise be possible. They will also bring

together staff to produce the learning content. Such staff will be invited to undertake staff exchanges for such curriculum development.

Biennial workshops will be held with a multidisciplinary, global and real-world focus in order to involve students in curriculum development. These workshops will engage student participants of all levels (undergraduate and graduate masters) in project work on real-world tasks which require integrative and multidisciplinary skills. Staff and graduate students of the institution hosting the workshops, who are not able to undertake exchanges will be encouraged to offer their expertise and participate in the activities to raise the quality and achievement of the student groups. The first of these workshops is hosted by San Diego State University and will be held on May 20, 2009. The website for this workshop is hosted at http://icace.sdsu.edu. The focus of the first workshop is on how to educate engineering students for today's global economy and how to internationalize our curricula. The workshop also aims to create a forum for discussion of Ambient Computing curriculum**.** We invite presentations that address both cultural, curricular, logistics and technical issues around educating global engineering workforce in this era of change.

An important goal of the project is to address the social aspects of learning and knowledge-building. Faculty, students and administrators in the partner institutions will aim at establishing an online knowledge-building community where a common goal will be development of individual and collective understanding in CS. In this community, technology will be used for building the social context as well as for knowledge sharing and process support. Social networking tools including myspace type facilities, wikis, blogs, user groups and forums will be used for collaboration and reflection as part of the learning landscape as well as for preparing students for study abroad. A particular attention will be paid to utilizing existing digital libraries such as National Science Digital Library and MERLOT that have collections relevant to CS for shared repositories of learning materials.

3.2 Development of Institutional Frameworks for Mobility

The commitment and the formal administrative arrangements for the project were stated in the Memorandum of Understanding (MoU) which was signed by all partners in advance. According to MoU, exchange students will be expected to pay the appropriate tuition relevant to their home institutions and each institution agrees in advance to allow for the appropriate transfer for credit and grades to the home institution. The partners have agreed to use European Credit Transfer System (ECTS) credits as a common currency of exchange so that courses can be compared and weighted against each other. Students on the program will be issued a EUROPASS style record of achievement during their exchange.

Each institution will set up an ICACE project team comprising: the institutional contact, academic program managers, student service providers (e.g., accommodation, international office, EFL/Modern languages units) to ensure that all arrangements for exchanges are in place and working well. The chair of this group will be the institutional contact for the ICACE project and will email an action plan to members of the group as well as project partners.

The project partners will meet regularly to have oversight and management of all aspects of the project: curriculum issues, exchanges, and finance. There will be additional monthly meetings of the contact persons at each institution via Skype to monitor the achievement of tasks and ensure good financial budgeting.

Communications, collaboration and information access is organised by means of a content management system, which is provided by FernUniversität in Hagen and which underpins the project for both staff and students. The software allows the establishment of overlapping communities with community-controlled privacy and visibility of information and services maintained by each community. Skype conferencing will be used monthly to monitor completion of project tasks and budgets. Partners will also communicate by email. The communication among participants of the program and project members will later be published as a FAQ to provide first step help to future combatants of international exchange experience. The project portal hosted at http://icace.dvt.fernuni-hagen.de/ also serves as the main website to give information to the public and will link to the social networking environment.

3.3 Language and Cultural Preparation and Assessment

There is a need for appropriate language and cultural orientation training for students taking part in the exchange program in order to become acquainted with different approaches and cultures. It is expected that preparatory courses will be run by home institutions before departure, that induction and further courses will be run by the host institution after arrival. It may be expected that students have a reasonable mastery of the language of the host institution or that the host will, in exceptional circumstances, be able to hold courses in a common language (e.g., English) for participating students. The modern languages and foreign languages units may also run sessions for departing students on customs and cultural issues in order to orient the students before arrival. There will be additional practice offered by electronic means before departure. This will include the use of electronic language tutors and social networking. An online student community linking staff and students at all partner sites will be built. This will enable social networking so that customs can be discovered and discussed, language practised and friendships developed. The online community will also offer online radio, TV, newspaper links so that students can begin to understand local events, history and places. Students will be encouraged to find out about the traditions of the nations, submit written reports on what they have discovered, make oral presentations and compile a list of the 10 things that they wish to do when abroad.

On arrival students will be offered additional modern languages support by the appropriate language training unit within the host institution. This will also ensure that all students make contact with others, are aware of several members of staff who can offer support and have a forum in which to discuss culture and customs. Students will be assigned both a tutor for their pastoral care and a mentor from the host institution's peer group. The tutor will be expected to: give the student a tour of the area, offer transport to local shops, organise an opportunity to socialise, discuss matters of personal safety and health as well as act as a resource for getting questions answered. The student mentor will be on a

similar course of studies and will be able to act as a link with the peer group, offer advice on expectations and help with language issues in class

3.4 Promotion and Dissemination

Partners will aim at raising awareness of the scope of the project and its aims with program management teams at undergraduate and graduate levels by briefings in the institutions. From project commencement there will be a project newsletter which is aimed at keeping the program in the view of students and staff. ICT will be used to create an online community across all institutions not only for language, culture and academic reasons but also to showcase exchange experiences and increase the hunger of students to participate. It is intended to integrate undergraduate and postgraduate students. This offers a number of advantages: maturity and experience of the older participants can be used to support and encourage those who are younger. Also, by breaking down artificial academic divides it brings together a community which offers an experience much more close to the mixed ages, experiences, backgrounds and cultures of the workplace.

The dissemination strategy, outlined below, will ensure that the results of the project will be used by the target groups, target sectors, and potential users. Certain activities will be directed towards individual target groups. For example, dissemination towards the universities involved in this project will be done on an on-going basis and the formation of Special Interest Groups (SIGs) will help ensure that information about the project is spread down to grass roots level in each partner country and beyond.
The experiences acquired in a previous Transatlantic Mobility Project taught us that comprehensive information, trust building, cultural, and language preparation are core elements that need to be addressed in a dissemination strategy as well. The main elements of the dissemination strategy include:

- A comprehensive web portal.
    - Providing course broker functionality to find courses matching a student's particular interest and needs and combine them to admissible course packages and curricula.
    - Listing the working papers and experience reports from students and faculty and guidelines.
    - Listing contact information, related university sites.
    - Giving access to student administrative services and personal information including a self-presentation of faculty and exchange students.
- Social software including wikis, bulletin boards, chat tools, network formation tools to support permanent and sustainable interaction between faculty and exchange students. These tools will also be linked from within the project portal.
- The project SIG through which the interested public throughout the world will be informed about the project and able to contribute their experiences and discuss their problems with the project participants. The main SIG will have sub-SIGs formed on a national basis where interested parties will be invited to enrol. For example, the Californian SIG will invite members from academia and industry thematically related to the project's curriculum topics such as Nokia, Qualcomm and also companies that have an interest in hosting exchange students for a short practical. This will be

repeated in the partner countries. The aim behind the formation of nationally significant SIGs is to maintain and foster relationships on an on-going basis at a local and national level.

- The book of the project, which will be published within the life of the project and distributed to stakeholders and decision makers on educational mobility throughout the world.
- The project will maintain an open access Technical Report series to enable the rapid publication of project results. Exchange students will be encouraged to contribute research articles and experience reports in this series. The writers workshop being part of the project curriculum aims to raise their technical writing skills.
- Two road shows, one on each side of the Atlantic will be held in the first year of the project at which the local students will obtain the possibility to learn about the mobility program, curricular components and cultural information and meet the faculty involved in the exchange program.

3.5 Evaluation Plan

The project will be evaluated against its goals and objectives. The goal of the project is to co-operate to exchange, evolve and combine educational offers related to ambient computing, and to allow selected exchange students to custom-design their curricula and study at least one semester abroad (on the other side of the Atlantic). The evaluation plan outlines key evaluation questions, strategies, and data collection/analysis procedures for the formative and summative evaluation of project implementation, results, and impact in connection with project objectives that lead to the project goal. An external evaluator will develop a formal and comprehensive evaluation plan for the project. He will meet with partner institutions, analyze and report evaluation activities, participate in annual program and/or consortium meetings and contribute to annual and final project reports. Formative evaluation will be used to guide project development and implementation including curriculum development and dissemination. Summative evaluation will assess achievement of project objectives and document the impact of project including impact on student learning. Key evaluation questions are intended to examine the areas of curriculum development (student responses to the curriculum and new courses, faculty responses to new needs, institutional responses to the project) and student experiences with international mobility.

4. Status of the project

The project has completed its first year, finalising agreements between partners, developing databases of modules, examining curricula and looking at gaps which need to be filled. These completed sets of modules wil be turned into trajectories of modules which allow degrees to be awarded for study at different EU/US partners.

Student mobility has so far been limited in comparison to the anticipated levels, but we expect to see increased mobility in the second year. One major issue concerning student mobility is the requirement for a full semester (minimum of four months) study abroad. In general student interest in mobility has been lower on the US side. SDSU received 5 students from University of Sunderland and no SDSU student chose to study in Sunderland. SDSU received 8 students from FernUniverstat in Hagen in the same period

while only 5 students from SDSU choose to study in Germany for a short time. In the current project cycle, we have 6 students from Germany and only one student from SDSU joined the program. Several factors including the lifestyle of our students contributed to this according to our first assesment. We are working on improving student interest in the program by emphasizing the importance of international experiences in a global world. We are also organizing a workshop at SDSU to increase student awareness in international opportunities.

Curriculum development efforts have focused on collection and standardization of curriculum descriptions, database and broker interface design and data input and interface implementation. Partners have also started to explore how to mechanize the anticipated curricular changes within their individual institutions and some new courses have been proposed.

A project portal has been created to bring together all academic requirements and practical information from the partner universities necessary for student mobility. This portal can be visited at http://icace.dvt.fernuni-hagen.de/. In addition this portal offers a secure file management system which is used for internal communication among project partners. Work has also been undertaken to build a community of practice of staff and students which will not only support staff and students on exchanges but the general academic area beyond the lifetime of the current project.

5. Acknowledgment

The ICACE Consortium is composed of Coskun Bayrak, University of Arkansas Little Rock, Arkansas; Chris Bowerman, University of Sunderland, U.K. (EU Project Leader); Bernd Krämer, FernUniversität in Hagen, Germany; Emrah Orhun, Troy University, Alabama (US Project Leader); Yusuf Ozturk, San Diego State University, California and António Ruano, University of Algarve, Portugal. The project proposal, on which this paper has been based, was jointly developed by the consortium partners.

6. References

[1] Weiser, M, "The Computer for the 21st Century", *Scientific American*, (Special Issue: Communications, Computers, and Networks), Volume 265, Number 3, September 1991.

[2] IST Advisory Group Ambient Intelligence: from vision to reality. Retrieved November 22, 2008, from ftp://ftp.cordis.lu/pub/ist/docs/istag-ist2003_draft_consolidated_report.pdf

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Engineering 101: Peer Teaching with LEGO NXT Robotics

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Abstract

The vast amount of knowledge and the multitude of disciplines encompassed by engineering can often be intimidating and difficult, creating an educational barrier for beginning students. The goal of an introductory engineering class is to present engineering as an exciting and welcoming field of professionals who work together to solve problems. An introductory engineering class that lacks creativity, teamwork and encouragement often fails to inspire students and may turn some away from engineering. This paper describes a modern approach to team-based learning and peer teaching in the context of an introductory course for freshmen engineering students. More specifically, the use of LEGO NXT© construction kits was tested as tool to enhance the experience of group projects. LEGOs are approachable, intuitive and have application in numerous construction projects. The low cost, reusability, and availability of a variety of sensors for LEGO kits make them ideal teaching materials compared to other expensive, specialized products. Our project involved presenting students with a task of designing a ribbon-climbing robot which must detect a randomly placed marker and report its height through a wireless communication link. The students were provided with basic mechanism design formulas and calculations allowing them to optimize their design. The project culminated in a final competition between the teams in the class. The project emphasized self- and team learning. The teamwork and the final competition encouraged flexibility, interaction and support between the students, behavior necessary of successful engineers.

Introduction

Engineering is often a daunting subject for incoming students. Lack of knowledge about their chosen field can be very intimidating to new engineering students, and may result in difficulty maintaining high retention rates in engineering disciplines among undergraduates [4]. Introductory courses aim to inform students about both their field of interest and what skills and processes are needed to be a successful engineer [1]. However, it is often difficult to construct a course that introduces concepts of the different engineering disciplines while developing team working and project design skills that does not also require prerequisite knowledge, specifically

within math and science. Students frequently enter college without sufficient knowledge in these areas that would allow for more complex projects in their introductory courses [4]. This often results in introductory engineering courses that are remedial and boring, potentially deterring students from pursuing engineering.

Beginning courses often employ projects that are contrived such that a "correct" solution is made apparent at the beginning and does not require an iterative design process. For example, the introductory course ENGR 102 at the University of Arizona uses a catapult project in which students must launch a ball a certain distance by utilizing different configurations of rubber bands on a pre-constructed wooden catapult. One student could easily arrive at the "correct" solution without consulting their team, making it both a pointless and boring exercise that does not meet the intent of an introductory engineering course. In order to create a more exciting and relevant project for undergraduates, a replacement project employing the LEGO NXT© construction kit was implemented in ENGR 102 classes. LEGOs are an ideal educational engineering tool, incorporating a highly versatile construction set that is approachable, intuitive, and not prohibitively expensive allowing iterative designs and implementation of projects with a team [2].

Methods

Students were given the task of building a robot capable of climbing a ribbon. ENGR 102 students were provided with basic information about the LEGO NXTs, specifically graphs on motor information (Fig 1; Fig 2).

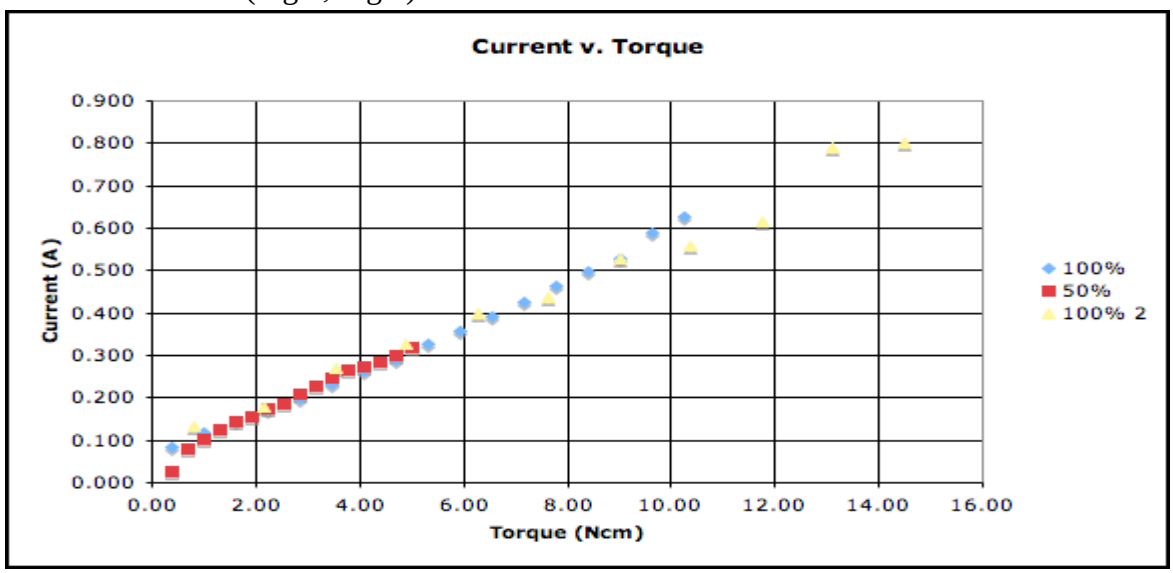


Figure 1: LEGO NXT motors Current vs. Torque Graph. The Blue and Yellow data points are with the motor running at 100% power: blue with a small hub for the pulley, yellow with a large hub. The Red data points are with the motor running at 50% with the small hub[5].

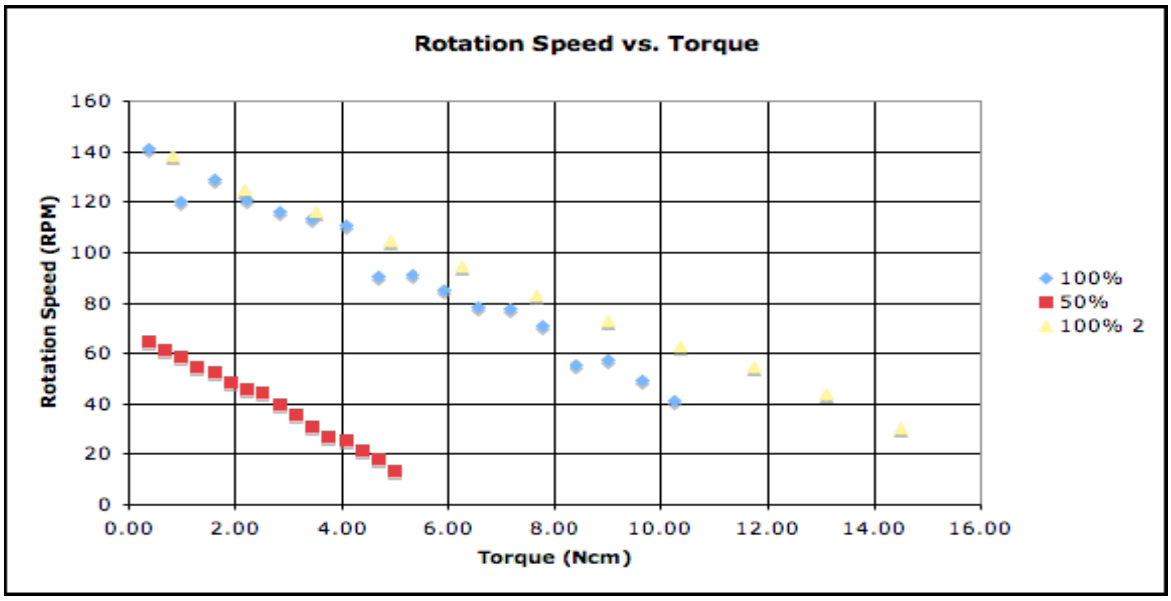


Figure 2: Angular Velocity vs Torque of a LEGO NXT motor. The Blue and Yellow data points are with the motor running at 100% power: Blue with a small hub for the pulley, Yellow with a large hub. The Red data points are with the motor running at 50% with the small hub[5].

Given the graphs and an overview on basic physics, the students were given the details of their assignment: design a robot that could climb a ribbon two stories, stop at markers at unknown distances along the ribbon, send information on height of the markers (from the bottom of the ribbon) wirelessly to a robot on the ground, and return to the ground after making it to the top. The final setup for the competition can be seen in Figure 3.



Figure 3: Ribbon set up with two robots attempting to complete their goals. Note one robot is winding the ribbon while the other is rolling along the ribbon[3].

The students' last goal was to accomplish all these tasks in the shortest amount of time possible. The project culminated in a two day competition. The first day gave the students a chance to test their designs outside at the full two story height. The second day was the actual competition in which the students placed their designs head to head with their fellow teams. The goals of the project forced the students to take important factors under consideration, including the final weight of their robot, number of motors to use, and which sensors were most appropriate for the various task. The students were also required to learn the LEGO programming language, based on Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW), a visual based programming language.



Figure 4: A team of students admiring their hard work on competition day[3].

Results

Many students were very receptive the project – they enjoyed being given a specific goal with few constraints, similar to real life engineering situations. The project required introductory programming and basic mechanics principals, thus introducing some basic concepts from Mechanical, Computer and Electrical engineering, while remaining simple enough for entry level engineering students to succeed. The two day competition as well as in-class testing required the students to use an iterative design process if they wanted to be successful. Between the first and second day of the competition, many teams discovered flaws in their initial designs and corrected these flaws before the final day of competition.

Discussion

The goal of the LEGO ENGR 102 project was to design a project for introductory engineering classes that covered a spectrum of engineering disciplines while being simple enough for

incoming freshman to understand. Furthermore, it was important that the project was interesting and necessitated teamwork while requiring the students to go through an iterative design process. In this regard the project successfully met its goals. Students remained interested in the project, working in teams and brainstorming alternate designs to maximize the speed and efficiency of their robots.

The ENGR 102 class use of the LEGO NXT opens many opportunities to expand or change the 102 project entirely to fit the needs of the students. Currently our lab has been able to power an NXT using silicon solar panels. This would allow a solar variant of this project to be incorporated, introducing yet another pertinent and exciting subject, renewable energy, to incoming engineering freshman. While being more complicated than running an NXT off of a battery, the concepts of supplying enough voltage and current through series and parallel panels is a simple subject that can be broached with incoming or first year students while maintaining their interest. Other projects demonstrating the versatility and possible direction for future introductory engineering projects include an autonomous LEGO soccer field with remote controlled soccer playing robots, another system developed in our lab.

LEGOs are extremely versatile and with their many sensors (touch, light, ultrasonic rangefinder, as well as many aftermarket custom sensors) can be made to model many systems that today's upcoming engineers might encounter when moving into the workforce. This system prepares students for the problem solving and designing process required of engineers while being presentable in manner that is both welcoming, relevant, and within the intellectual reach of incoming freshman engineers.

Acknowledgements

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[1] General Catalog Spring 2009 Course Description: ENGR 102 – Introduction to Engineering (2009) Retrieved Feburary 1, 2009, from University of Arizona General Catalog Web Site: http://ruby.ccit.arizona.edu/academic/catalog/display-course-description.php?url=http://catalog.arizona.edu/courses/091/ENGR.html&courseID=ENGR102

[2] M. Cyr, V. Miragila, T. Nocera, C. Rogers, A Low-Cost, Innovative Methodology for Teaching Engineering Through Experimentation. Journal of Engineering Education, 86(2), 167-171, (1997)

[3] P. Brown, (2008) ENG 102 Lego Robots. Retrieved February 1, 2009, from ENG 102 Lego Robots. Web Site: http://picasaweb.google.com/uaeng.petebrown/ENG102LegoRobots#

[4] Seymour, E. Guest Comment: Why Undergraduates Leave the Sciences. American Journal of Physics, 63(3), 199-202, (1995)

[5] T. Brown, (2008). LEGO NXT Motor Analysis. Retrieved February 1, 2009, from University of Arizona LEGO Robotics Outreach Club homepage Web Site: http://roboclub.arizona.edu/pages/gallery/nxt-motor-tests.php

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Teaching Online in Electrical Engineering; Best Practices Experiences and Myths

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Abstract- Online teaching is here to stay. We cannot longer deny or refuse to teach on line, therefore we must reinvent ourselves and develop skills that we did not have or did have and did not know it. This paper attempts to describe the practices we have had in the teaching of electrical engineering courses online. We will show how effective, ELLUMINATE^{TM} has become versus the classic face-to-face classroom teaching. To do so we split one class in two sections; the first one is the online section and the second one is the classroom face-to-face section. To reduce duplication, while the on line section is taking the class; the classroom face-to-face section takes the class via an LCD projector.

The time has arrived where all students have a laptop or have a PC at home. 90% of the students taking these classes own a laptop with wireless communication. It is very encouraging to see that the students in the classroom face-to-face class have their own laptops connected to the online class so that they can minimize note taking and pay more attention to the lecture. The question is; how do I make sure that students outside of the classroom are connected to the online class? The answer is in the software that we use. Basically, we have a list of students logged on to the left side of the screen. Furthermore, there is an interactive aspect of our system via sound and video. I do prefer sound only so that those students that do not have access to a large broadband ISP, at least they can listen and talk without many interruptions or slowing down their system.

Discussion-Higher education is making a change from classroom education to online education. The enrollment of online education keeps going up at a very fast rate in the United States. In 2004 [12] about 2.35 million students where enrolled in online courses. The following table indicates the "online course penetration-Fall 2004"

The following table applies for institutions with 3000 to 7500 students

Level	Doctoral/research	Masters	Bachelors	Associate	Specialized
Undergrad	64.3%	67.6%	33.9%	77.5%	31.7%
Graduate	78.9%	65.8%	32.2%	100.0%	58.2%
Continuing Ed	74.1%	48.5%	29.1%	70.8%	26.3%

For instance, the table indicates that 78.9% of all institutions in the United States offer online courses at the doctoral/research level. The Associate (two year institutions), all offer online courses at the graduate level. This is because only very few of the two year institutions offer

graduate level courses. The increase of approximately 360,000 online students/year has exceeded the overall rate in higher education enrollment/year and keeps growing [12]

The following table applies for institutions with 15000+ students enrolled [12].

Level	Doctoral/research	Masters	Bachelors	Associate	Specialized
Certificate	60.3%	40.8%	17.2%	32.2%	22.8%
Associate	43.9%	23.3%	25.7%	42.8%	23.0%
Bachelors	38.4%	34.45	19.0%	23.1%	22.8%
Masters	65.7%	45.3%	25.8%	50.0%	35.0%
Doctoral	16.4%	13.3%	0.0%	0.0%	9.3%
Professional	24.7%	11.9%	11.1%	19.0%	8.4%

It is believed that "students need more discipline to succeed in an online course" [12] and 70.0% of the institutions surveyed agreed, only 2.6% disagreed. Along the same line "teaching an online course takes more faculty time and effort, 38.2% of the institutions surveyed agree.

The "legitimacy of online education," [12] has been a great issue for most faculty. This myth can be clarified by indicating that 36.4% of the public institutions surveyed agree that online teaching is a legitimate approach to teach and only 4.9% disagree. Indeed 58.6% remain neutral.

"*The one percent solution*," [13] became an eye opener. It indicated that in a two year institution 1% of the courses attracted 44% of the enrollment and the passing rate of these courses is 64%. The conclusion is that in any institution there are courses that attract the majority of the enrollment and they could be targeted for online teaching.

Universities have been developing strategic plans to tackle the implementation of online teaching. The major hurdles needed to overcome are; *changing the mindset of faculty*, *budgets*, *teacher training in new technologies, online student population's new studying habits and quality of instruction.*

Change

Change is never easy; perhaps it is the most difficult hurdle in online teaching. Faculty, need to be fully aware of the linking of *pedagogy, technology and learning-styles* [2]. Furthermore, it has been our experience that the need of "electronic textbooks availability" is a critical event that facilitates online teaching of electrical engineering in a very large scale. (Which by the way, it is happening very fast)

Budget

Online teaching is expensive. Simply put: technology costs large sums of money. Only the software and hardware used to deliver lectures absorbs a large percentage of the budget. For example, at CSUN we use Webct™, Elluminate™, in the software area; LCD projectors, Smart boards, Tablet PCs and smart classrooms in the hardware area.

Training
Many of the faculty teaching online had to be retrained and supported by technicians. This, also, costs money and time. At CSUN we have workshops throughout the calendar year and staff dedicated to support online teaching

Students
As mentioned before change is not easy and online students have to change their studying habits and personal time planning. One major change is the ability to self study (self discipline). We would assume that college students would have such skill, but we are finding out that that is no the case.

Quality of instruction
Quality of instruction is a big problem. Not everybody can do well taking an online course, therefore, this issue becomes an assessment issue. The monitoring of quality instruction and its effectiveness is still in progress and there is no a definite answer available. A common assessment is student achievement and satisfaction, but it is not enough to arrive to a conclusive result. 80.2% of the institutions surveyed [1] agree do not agree that "It is more difficult to evaluate the quality of an online course than of a face-to-face course."

Finally the big question becomes; *where is online teaching going*? *Why online teaching*? The answers will be attempted on this paper.

Online in EE-The previous discussion was created to set up the scenario of what we have done since the Fall semester of 2006. In this section we will indicate the implementation of an online graduate level course in Electrical Engineering. This course has been taught for several years in the face-to face (classroom) mode and it has had the usual outcomes of such way of teaching. However, online teaching created a challenge of great magnitude at the logistical and instructional, and learning level.

We use "Elluminate™" as well as "Smartboard™" as our technology medium. This system was effective but only to certain degree. For example, since we did not have our lectures prepared in "power point format" and did not have an electronic version of the textbook, we needed to scan our lecture notes. That was a major time consuming issue. The advantage of Elluminate™ over Webct™ was the ability of having sound, video and pc screen via internet. In combination with Smartboard™, it made the delivery of the material quite easy compared to Elluminate™ alone.

The delivery of the material using this system created a challenge. We first used our scanned notes to do so and it became very clear that the level of detail in the explanation and discussion achieved in the face-to-face mode was not achieved in the online mode. We had to adjust and do the best we could. The major change was the delivery of the material in a mostly verbal mode. Another change was the presentation of the major highlights of the discussion and the consistent questioning of the faculty trying to get some real-time feedback from students.

Since our goal is to engage our students and create the environment for deep learning of electrical engineering, we came up with a "funnel" approach. Figure 1 shows what we consider

the way we must engage [3] students into deep learning. Keeping that in mind, we started to create our own online model for this class.

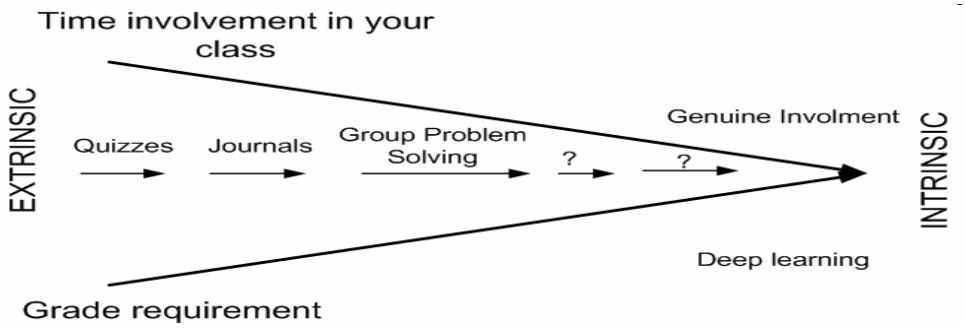


Figure 1 Student Engagement

Soon into the semester, it was obvious that a change was needed to deliver the content of the course more effectively. It was decided to require the use of Matlab™ in some assignments and it was used as a tool to explain EE concepts. While this method worked for a while, there were some issues with the access of Matlab. Students had to buy their on version since they could not get to campus to use the University computers. Power World is software that we have been using sporadically. Since the student version is free, the access to it was not a problem

Lectures-We posted lectures in Webct™ at least four days in advance. Students had a chance to read the lecture and print it. Two very important observations came to light; one *that students did expect to see the material in advance* and two *that students would print the notes.* Handwritten notes were acceptable because Elluminate™ and Smartboard™ allowed us to write on top of the notes; consequently we have Image, Sound and Editing (ISE) all real-time. Ideally you want to upload the power point images provided by most textbooks and then use ISE.

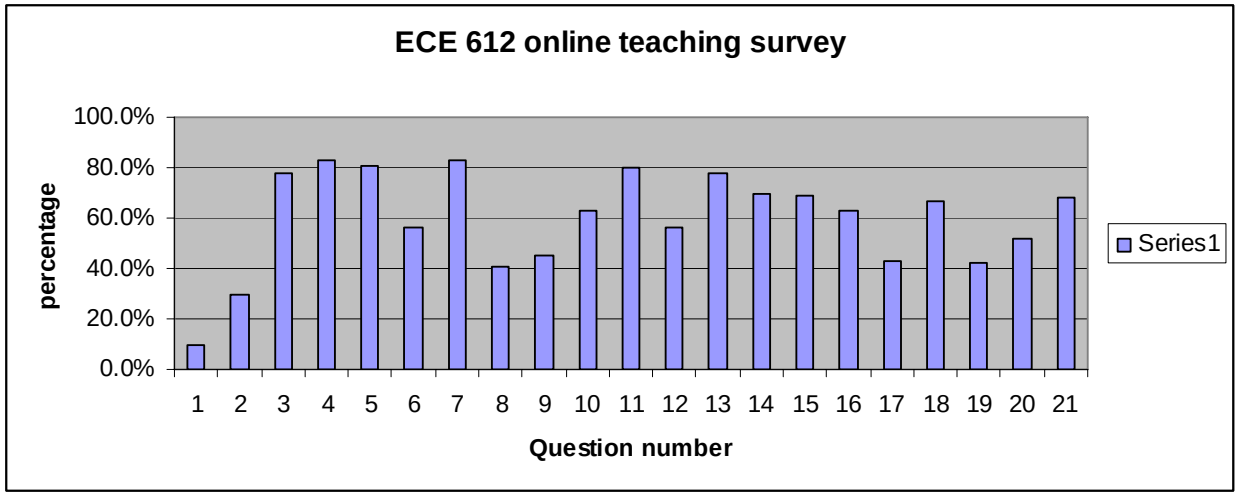
Expectations- Partlow and Gibbs [4] found that online courses should be relevant, interactive, project-based, and collaborative and should, furthermore, give learners some choice or control over their learning. Another study performed by Keeton [5] found out that *instructional strategies that promote an environment of learning, supports and encourages inquiry, broadens the experience of the subject matter and elicit active and critical reflection by learners is a reasonable expectation for teaching a class online or not*. In our case most of the arguments given by [4] and [5] were accomplished. Simply put, we came to the realization that a project oriented course in engineering is not a bad idea, group work was mandated and encouraged and definitely we had a great level of interaction online. Data analysis was by default the most important aspect of the course because of the nature of the class.

However, Bonk [6] found out in a survey that between 23 to 45 percent of online instructors used hands on experience, interactive labs, data analysis, and computer simulations.

Online teaching surveys [8]
Bonk and Kyong performed a survey in November of 2003 and obtained 562 responses. The survey was confined to the United States and had 10 questions. There are some fascinating results; for instance in the area of online success, 24.7% indicated that monetary support is top priority, and then it followed the technical competency of the online instructors with 22.9%. In the area of pedagogical techniques to be used more widely online in the coming decade, 65.4% indicated that group problem solving and collaborative task was at the top followed by problem based learning with 58.1%.

Class Survey- We performed a survey in class in order to obtain some feedback about online teaching. These are some findings;

Question Number	question	Average
1	Have you taken an online course before?	10%
2	Have you used the internet to study and analyze mathematics?	30%
3	Was the pace of the course adequate?	78%
4	Was the delivery of the material by the instructor clear?	83%
5	Was the communication between you and the instructor clear during the online session?	81%
6	Was the online course more convenient for you than the classroom lecture?	56%
7	Was the testing adequate?	83%
8	Did you feel that you spent more time studying with the online class than the regular classroom lecture format?	41%
9	Did you feel that you spent more time doing homework with the online class than the regular classroom lecture format?	45%
10	Did you feel that you spent more time solving quizzes with the online class than the regular classroom lecture format?	63%
11	Did you feel that your study habits had to change, adapt, for the online class?	80%
12	How much change, adjustment, you had to make in question 11?	56%
13	Material for the lecture was provided before the online class. Did it help you understand the lecture more?	78%
14	Lectures online were archived. Did it help you learn and understand more?	70%
15	Having instant access to the lectures and lecture notes online helped you learn more?	69%
16	Note taking was reduced greatly when online lecture was delivered. Did it helped you understand the material, learn, more?	63%
17	Did you feel that you were engaged into the material and the learning process more so than in the classroom setting?	43%
18	Was the mathematics of the course delivered adequately?	67%
19	Would you take another mathematically intensive online course?	42%
20	Would you recommend a mathematically intensive online course to a friend?	52%
21	What is your overall rating of an online course like this?	68%



Even though questions 4, 5, 7, 11, and 13 standout with about an average 80%, we feel that a great improvement needs to be made. Questions 18, 19, 20 and 21 apply to the overall course and the mathematics of it and the average was below 70%. This, in turn, indicates that our students, technology and instructor are not "linking" adequately.

Conclusions-Frustration was the common denominator in this online class. HOPE is the adjective that we have to have in order to succeed with online teaching. The premise that was used for years applies; not everyone is able or capable of taking an online course. The reasons; different learning styles, habits created for years in the classroom (change!), pace of the material, etc.

Students' ability of self learning and self discipline is a major factor for an online class. These issues will be resolved after a few classes taken online. Notice that only 10% of the students surveyed had taken an online class before.

Online instruction has become a myth and in all honesty smart classrooms with classroom instruction are the best solution. Online learning should be used only for circumstances where there is no alternative; otherwise we should remain in the classroom environment where body language, emphasis, eye contact make the difference.

Finally the survey given in class was performed with a small population sample, 10 students. The purpose for the survey was to obtain feedback and adapt for the next cycle of online teaching. As mentioned before there is no reliable assessment that can give conclusive results, but this fact does not mean that we should stop trying. Furthermore, online teaching is here to stay.

Bonk [8] created a survey with industry to find strategies for online learning. The table below shows the results. It is clear that almost a complete project oriented in combination with simulations could be the way to follow.

	Response Options	Response Rate %
1	Authentic cases and scenario learning	63.04
2	Simulations or gaming	50.00
3	Virtual team collaboration and problem solving	46.52
4	Problem-based learning	42.17
5	Coaching or mentoring	39.13
6	Guided learning	37.39
7	Self-paced learning	34.35

Instructional strategies to be more widely used in the coming decade

Bibliography

[1] E. I. Allen and J. Seaman, *Growing by Degrees: Online Education in the United States, 2005* (Needham, Mass.: The Sloan Consortium, 2005).

[2] C. J. Bonk, *The Perfect E-Storm: Emerging Technologies, Enhanced Pedagogy, Enormous Learner Demand, and Erased Budgets* (London: The Observatory on Borderless Higher Education, 2004); and K.-J. Kim, C. J. Bonk, and T. Zeng, "Surveying the Future of Workplace E-Learning: The Rise of Blending, Interactivity, and Authentic Learning," *E-Learn Magazine*, June 2005, <http://www.elearnmag.org/subpage.cfm?section=research&article=5-1> (accessed August 8, 2006).

[3] Bruno Osorno, "Celt student engagement group report," California Sate University Northridge. May 2005

[4] K. M. Partlow and W. J. Gibbs, "Indicators of Constructivist Principles in Internet-Based Courses," *Journal of Computing in Higher Education*, Vol. 14, No. 2, 2003, pp. 68–97.

[5]. M. T. Keeton, "Best Online Instructional Practices: Report of Phase I of an Ongoing Study," *Journal of Asynchronous Learning Networks*, Vol. 8, No. 2, 2004, pp. 75–100

[6] C. J. Bonk, *Online Teaching in an Online World* (Bloomington, Ind.: CourseShare, 2001).

[7] M. T. Keeton, "Best Online Instructional Practices: Report of Phase I of an Ongoing Study,"

[8] The Future of Online Teaching and Learning in Higher Education: The Survey Says... By **Kyong-Jee Kim** and **Curtis J. Bonk**, Volume 29 Number 4, 2006. http://www.educause.edu/apps/eq/eqm06/eqm0644.asp

[9] C ynthia Derochers, "CELT student engagement group," California State University Northridge, Spring semester 2005

[10] Ray Landis, "Studying Engineering," Presentation and textbook, California State University Northridge. May 2005.

[11] Bergen, Vittal, "Power Systems Analysis," Textbook, Prentice-Hall, 2nd Edition, 2000

[12] “Growing by Degrees; Online Education in the United States, 2005” I. Elaine Allen, Jeff Seaman. Report sponsored by the Sloan Consortium, 2005
[13] “The one Percent Solution,” By Caro; A Twigg. Sequence: Volume 30, Number 6, 1995

Bibliographical information

Bruno Osorno is a professor of electrical and computer engineering at California State University Northridge. He has been teaching Electrical Engineering for over 25 years and his areas of interest are Electrical Power Systems and Energy. Currently He is in charge of the Electrical Power Systems program at CSUN. Electrical protection, electrical power systems simulations and applications and computer simulations of power electronics are current topics of research. He has published more than 20 technical papers. He has consulted for NASA-JPL, DWP and SCE. Also, he has over 8 years of professional experience in the area of industrial power systems with a global corporation.

Curricula for Using Waste Tires in Civil Engineering Applications

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Albert M. Johnson, California Integrated Waste Management Board

The United States generates about 300 million waste tires each year. Approximately 40 million of these are generated in California alone. Waste tires stored in stockpiles can pose significant public health and environmental issues. Stockpiled waste tires provide an ideal breeding ground for mosquitoes and rodents, which can transmit diseases. Tires placed in stockpiles can ignite resulting in tire fires that are difficult to extinguish. Although the Environmental Protection Agency does not consider scrap tires as hazardous waste, tire fires release hazardous compounds which pollute the air, soil and water. Nationwide, millions of dollars has been spent to clean up tire fires.

BACKGROUND

The California Integrated Waste Management Board (CIWMB) is tasked with diverting these tires from the waste stream to being recycled into useful products. Tire derived products possess some desirable engineering properties, especially for civil engineering applications, which is the fastest growing market for waste tire products. These applications include roadway construction, landfill applications, septic leach fields, gas and leachate collection systems, retaining walls, lightweight embankment fill, and vibration attenuation for railways.

Not all of the general public understands sustainability and utilizing waste tires as recycled products. Using recycled materials in real applications may face many challenges, especially if the knowledge of how to use the recycled materials such as waste tires has not been well disseminated. These challenges involve many different people, including engineers. Engineers may not have adequate knowledge about the physical properties, long term performance, design guidelines, and construction specifications. They may not want to take the risk of using recycled tires instead of conventional materials.

To promote sustainable and successful waste tire applications in civil engineering, a curriculum development and dissemination project was funded by CIWMB. Undergraduate engineering students are the future engineers; they need to learn how to utilize recycled materials such as waste tires in civil engineering applications as well as traditional materials such as steel, wood, and concrete. The primary purpose of this project was to produce and disseminate teaching materials that could be used in undergraduate civil engineering courses on utilizing waste tires in civil engineering applications.

OBJECTIVES

The objectives of this research are to:

- synthesize the knowledge of utilizing waste tires in civil engineering applications
- develop effective teaching materials to educate university students about utilizing waste tire products in civil engineering
- promote sustainability by using waste tires in civil engineering applications through university education

The goal of this paper is to summarize the curricula of civil engineering applications of waste tire products and to make faculty aware of the existence of the course materials and resources developed on this project.

APPROACH AND PROPOSED CURRICULA

Utilizing waste tires in civil engineering applications is a multi-disciplinary and complex subject. No single class currently available in civil engineering can cover all the aspects of it. At the beginning of the project, two different approaches were compared:

1. developing only one new class to include all aspects of waste tire applications
2. add teaching modules to different levels and related civil engineering classes

The second method was chosen because it is more flexible and can reach more students. It also gives students more opportunity to be exposed to waste tire educational materials.

Therefore, it was proposed to develop waste tire application teaching modules for a variety of civil engineering courses from freshman level to senior level. Each module contained one or more lectures. Figure 1 illustrates the courses that training modules were developed for.

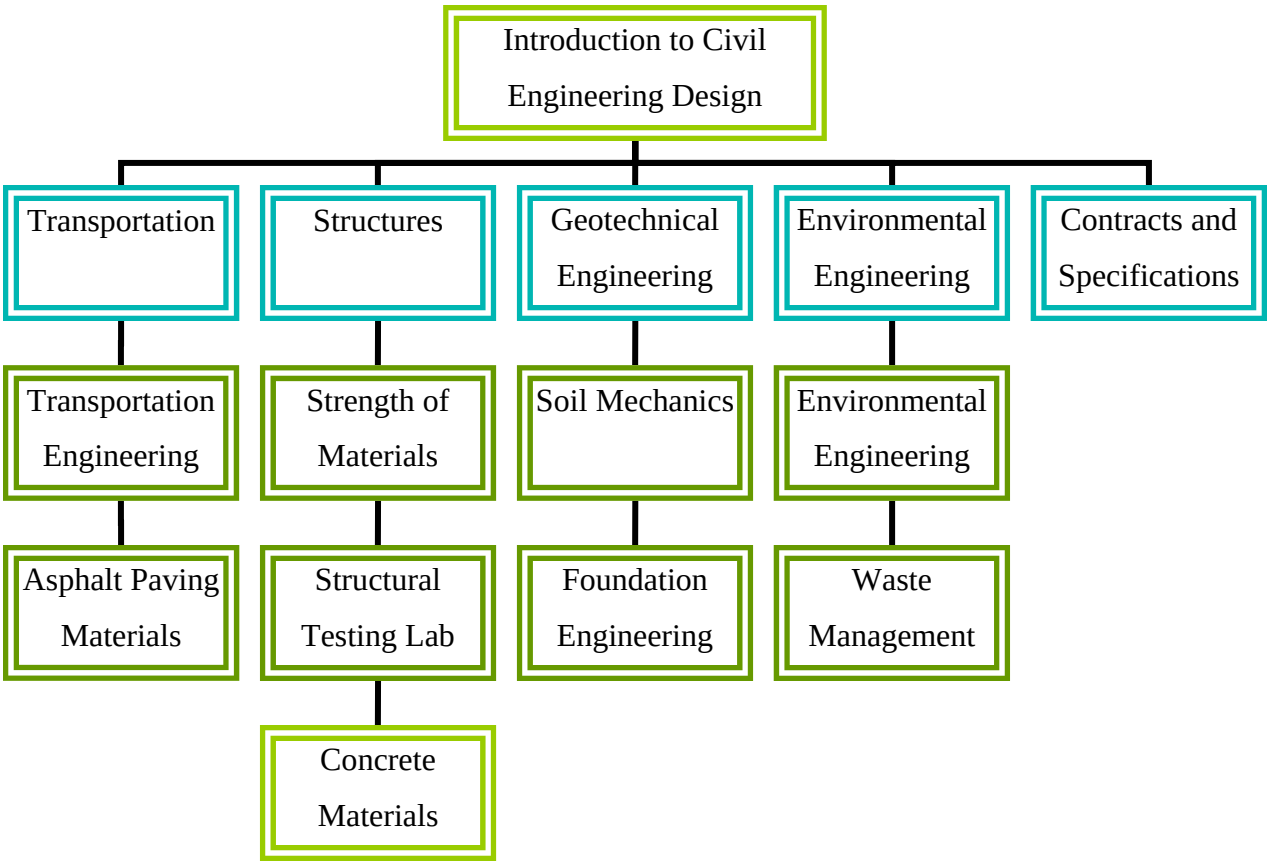


FIGURE 1. Roadmap for Waste Tire Applications in Civil Engineering Curricula

By offering teaching modules for waste tire applications at different class levels, more students are reached than would be by a single elective class. By the end of university education, a student may be exposed to waste tire applications multiple times. It was deemed as a more effective way of teaching students about unconventional materials, such as waste tire derived materials.

CURRICULA DEVELOPMENT

A series of course modules have been developed for a variety of undergraduate Civil Engineering courses, including the following areas:

- Introduction to Civil Engineering Design
- Mechanics of Materials and Materials Testing Laboratory
- Soil Mechanics and Foundation Engineering
- Contracts and Specifications
- Environmental Engineering
- Solid Waste Management
- Reinforced Concrete Design
- Transportation Engineering and Pavement Materials

The following sections describe the objectives, scope, and major components in each teaching module or class. For each module, assignments or evaluation worksheets were also developed.

Teaching modules are independent of each other. Each module emphasizes a different aspect of utilizing waste tire products in civil engineering applications. Some may discuss geotechnical engineering applications, while others may illustrate pavement material modification. In addition, they don't need to be offered all together. The format of the training materials can be flexible so professors or instructors can tailor the teaching module to their teaching needs as they please. Material from different lectures may be combined or edited as the instructor sees fit.

Introduction to Civil Engineering Design

The goal of this lecture is to introduce university students to waste tire materials and give them an overview of utilizing waste tire products in a variety of types of civil engineering applications. It is important for students to understand the significance of utilizing recycled materials to preserve valuable natural resources. Students should also understand the significance of protecting the environment. They should also learn to promote healthy and sustainable development of our society.

The lecture introduces waste tire materials by discussing the potential negative environmental impacts if waste tire materials are not managed properly. In 1983, a tire fire burned about 7 million tires in Rhinehart, Virginia. The fire burned for nine months, polluting water with poisons, such as lead and arsenic. In 1998, a grass fire ignited an estimated 7 million tires at an unlicensed tire disposal facility in Tracy, California. It was extinguished after 26 months with water and foam. In September 1999, lightning ignited stockpiled tires in the town of Westley, California. The fire burned for three months. It took seven years to clean up the site and cost about 20 million dollars.

The lecture covers the benefits and challenges of using waste tire derived products in civil engineering and transportation applications. It discusses physical properties of waste tire derived aggregate (TDA). More importantly, it gives an overview of the major applications in civil engineering and transportation, including TDA as backfill materials for retaining walls and bridge abutments, lightweight fill for embankments, insulation layer for roadway base, vibration damping materials for rail lines, and rubberized hot mix asphalt for pavement. It also presents a roadmap of civil engineering classes that cover waste tire applications.

Mechanics of Materials

This lecture mainly covers the physical properties of tire derived aggregates. TDA are pieces of shredded tires that are generally between 1 inch and 12 inches in largest dimension (*1*). The common properties of TDA affecting engineering performance are: gradation, specific gravity, absorption capacity, compressibility, resilient modulus, time dependent settlement of TDA fills, shear strength, hydraulic conductivity, and thermal conductivity.

This lecture also covers a general model which is a combination of Maxwell and Kelvin models using spring and dashpot elements. The model can be used to analyze the energy dissipation and vibration mitigation characters of TDA. TDA has been used as a vibration damping material for a light rail line by Valley Transit Authority (VTA) in the Bay Area of California. The results

show that it is a very cost effective vibration attenuation material. The average vibration level of a light rail line has been reduced by 10 dB for the 30 to 250 Hz range comparing with a standard control section. This is a great noise reduction because dB is in log scale. The project also saved VTA approximately $1 to $2 million compared with a floating slab vibration mitigation technique.

Structural Testing Lab

The lecture portion of the structural testing lab on TDA discusses the stress-strain relationship for TDA. This lecture introduces the common methods of measuring shear strength of granular materials, including soil, crumb rubber, and tire buffing. In the lab portion of the class students test the shear strength of crumb rubber using standard direct shear apparatus.

A literature review and comparison of shear strength parameters from many different sources were conducted. The shear strength of the TDA primarily depends on the: (a) size and shape of the tire rubber pieces, (b) density of packing, (c) magnitude of the compressive normal loading, (d) gradation, and (e) orientation of tire shreds.

Contracts and Specifications

This lecture has two modules. One is on ASTM international standards; the other is for specifications on rubberized hot mix asphalt. A series of ASTM standards related to waste tire applications are covered. The major one is ASTM D6270, which has detailed definitions of tire rubber, material characterization, usage, construction practices, guideline for fills, and leachate etc (*1*). The lecture also provides students the necessary background on ASTM International.

The specification lecture starts with various types and aspects of specifications. As examples, standard specifications are illustrated using Caltrans standard specifications on RHMA – O (open graded rubberized hot mix asphalt) and RHMA – G (gap graded rubberized hot mix asphalt) (*2*).

Soil Mechanics

Tire Derived Aggregate (TDA) has many unique physical properties that can be used in Geotechnical engineering. The in-place density of TDA ranges from 45 lb/ft^3 to 58 lb/ft^3, which is about 1/3 the unit weight of soil. TDA can be used as a lightweight material to construct embankments on weak, compressible foundation soils. TDA has high permeability, more than 1 cm/sec, which can replace conventional aggregate to be used as gas collection media or leachate collection material. TDA is a good thermal insulation material, which has a thermal insulation 8 times greater than the gravel (*1*). In cold climates, placing a 6 to 12 inch tire shred layer under the road can prevent subgrade soils from freezing. In addition, excess water may be released when subgrade soils thaw in the spring. The high permeability of tire shreds allows water to drain freely from beneath the roads, preventing damage to road surfaces (*3*).

In the lecture material, the Dixon landing interchange project at the intersection of I-880 and Dixon Landing Road in the Bay Area is used as a case study to illustrate the design, construction, and cost benefit of the project (*4*). The embankment for the interchange needed to be constructed on top of about 30 feet of San Francisco bay mud, which is a highly compressible soil. It required using lightweight fill material for most fill sections to reduce the total settlement. For

most projects building on a soft clay type of soil, using TDA as a lightweight fill material is significantly cheaper than other alternatives. The Dixon Landing interchange project used 6,627 tons or 662,700 passenger tire equivalents (PTE) of TDA. The cost savings to Caltrans was $447,000 compared to using standard lightweight aggregate for the project. When the purchase price of the TDA is subtracted, the cost savings was still $230,000 (*5*).

Another case study for the soil mechanics class is using TDA as subgrade insulation for Witter Farm Road, Orono, Maine (*3*). Frost in this cold climate region can cause heaving of the road which can crack the asphalt, while the thawing weakens the road subbase leading to rutting of the gravel and cracking of the asphalt. From the test results, the frost depth was reduced from 55 inches in control section to about 30 inches in a TDA fill section (*3*).

The lecture also introduces using TDA for Marina Drive slope repair in Ukiah, CA (*6*). A road slide damaged the Marina Drive making it unusable. Using TDA as lightweight backfill material replacing typical backfill soil, less excavation is necessary and a more cost effective design can be utilized. The project used about 2,000 ton or 200,000 PTE tires (*7*).

Concrete Materials

Rubber included concrete or rubberized concrete consists of mixing tire rubber into Portland cement concrete mix by replacing a portion of aggregate with crumb rubber. It changes the physical properties of concrete.

One of the most important factors to consider in using waste tire products in the production of concrete is the mix design. From the literature review shown in Table 1, the major mix design factors are proportions of crumb rubber by volume or by weight of mix, water-cement ratio, rubber type, and rubber content.

A fair amount of research has been done in using waste tire particles in Portland cement concrete. Although compressive strength and stiffness of concrete mixes decrease dramatically with increasing rubber content, the ductility, toughness, and tensile strain have been shown to increase with small amounts of rubber particles. Rubberized concrete may be more flexible and crack resistant for lightweight paving. It may provide vibration damping and sound transmission mitigation. It can be used for energy absorption due to dynamic force, such as earthquakes. It may also increase the freeze-thaw durability of concrete.

TABLE 1. Summary of Rubberized Concrete Mix Designs from Literature

Author	Rubber Type	Rubber Content	Method of Mix Design
Kaloush et. al. (*8*)	1mm Crumb Rubber	0, 50, 100, 150, 200, and 300 lb/cuyd	Replaced fine aggregate with crumb rubber by weight, increased w/c ratio
Fedroff et. al. (*9*)	Super fine powder	0, 10, 20, and 30%	By weight of cement in mix adjusted w/c ratio to get 3 to 5 inches of slump
Tantala et.al. (*10*)	Buff Rubber	5 and 10%	Replaced 5% and 10% of coarse aggregate with buff rubber by volume
Schimizze et.al. (*11*)	Fine/Coarse Reclaimed Rubber	5% of mix design by weight	Lowered both 1. fine aggregate and 2. fine and coarse aggregate to get 5% rubber by weight
Biel and Lee (*12*)	3/8" minus rubber droppings	0 to 90% in 15% increments	Replaced fine aggregate with crumb rubber by volume gave 0 to 25% rubber by volume in mix
Eldin et.al. (*13*)	Ground tire chips, fine crumb rubber	0,25,50,75,100% by volume	Test specimens replacing either coarse or fine aggregate

Foundation Engineering

Lateral earth pressure is defined as the pressure exerted by a fill material on the wall of a structure like a retaining wall. It can be determined from the coefficients of lateral earth pressure, which are calculated by dividing horizontal stress by vertical stress. TDA can also reduce lateral earth pressure up to 50 percent compared to conventional soil backfill material. It also has good drainage properties to prevent water build up behind a wall. Therefore, TDA is a very good material as backfill for retaining walls and bridge abutments. It can reduce the design thickness of the wall and use less reinforcing steel (*3*).

This lecture introduces a full scale retaining wall testing project conducted at the University of Maine (*3*). The testing facility has four walls and a reinforced concrete foundation. The size of the testing facility is 16 ft. high by 15 ft. long by 14.7 ft. wide. The lateral earth pressure, horizontal displacement, interface friction between wall and TDA, were measured during the

test. It was found that the horizontal stress at rest for TDA is 45 percent less than that of conventional granular fill (*14*).

The lecture also introduces a case study of constructing of a real world retaining wall with TDA. Caltrans and the CIWMB have constructed a 300 linear foot retaining wall, called Wall 119, with TDA as lightweight backfill material along route 91, in Riverside, California. The retaining wall is 12 ft. tall, with 9.8 ft. of compacted TDA enclosed in a geotextile membrane. It has about 2 feet of soil cover. At designated locations, the forces were measured using pressure cells; the strains were measured with strain gauges; temperatures of tire shred materials were measured using temperature sensors; and the displacement of the wall was monitored by a tilt meter. The retaining project was very successful and it used 837 tons of TDA. The following picture shows the construction of the Wall 119.



FIGURE 2. TDA as Backfill for Retaining Wall 119 in Riverside, CA (*15*)

Environmental Engineering

This lecture focuses on the environmental aspects of utilizing waste tires in civil engineering and transportation. First, it introduces the negative impact if waste tire materials are not recycled and managed properly. Then, it describes the engineering properties of TDA and rubberized asphalt. It shows the beneficial usage of waste tire materials in civil engineering applications, such as lightweight fill, landfill applications, vibration damping, and rubberized asphalt pavement.

Consequently, it addresses the environmental assessment research on using TDA and rubberized asphalt. Significant amounts of research, both laboratory evaluations and field tests, have been conducted on various environmental impacts. It provides students with the knowledge of what environmental factors that they should pay attention to when they use waste tires in civil engineering applications. Generally, recycled rubber derived from scrap tires is a safe recyclable material (*16*). It is important to recognize that the impact of scrap tires on the environment varies

according to the local water and soil conditions, especially pH values. It may not be safe to use when the pH is too high or too low (*17*).

Solid and Waste Management

The construction of modern mechanized landfills requires large quantities of material which possess the same material properties as TDA. TDA is a free draining material and its permeability is greater than 1 centimeter per second. TDA can be used in many landfill applications such as operational layers, and gas collection systems.

Federal guidelines require landfills to employ a layer of material with a high void content to sit in between the waste and the impermeable layer of a landfill in order to contain leachate until removal. This layer is known as the operations or drainage layer. TDA is an excellent material for this application due to its high permeability. It is necessary that all leachate produced in a landfill is collected due to its toxic nature. Landfills have leachate collection systems which require a highly permeable material such as TDA.

Landfills are required to control and collect methane gas produced during the anaerobic digestion of organic wastes. The methane generated within the landfill tends to follow the path of least resistance. TDA is an excellent material for gas control systems due to its high permeability. Landfills use gas collection trenches to extract and capture the methane gas. Vertical trenches passing through the impermeable landfill cap allows methane gas to vent out of the landfill into a collection system. The vertical trench is composed of perforated pipe surrounded by TDA. This system allows the methane to vent out of the landfill into a collection system. Landfills also use trenchless gas collection systems. In these systems, methane is allowed to vent through the non permeable cap at the toe, located at the bottom of the lift. TDA is placed atop the toe to allow the methane to enter a perforated collection pipe. Due to TDA's high permeability and durability it is routinely used to protect and insulate parts of the collection systems. TDA is used to insulate horizontal collection pipes as well as protect gas well heads.

Transportation Engineering

The goal of the transportation engineering lectures is to inform students of the history, benefits, limitations and practice of using asphalt rubber (AR) as a paving material. These lectures are divided into four modules, each dealing with a different aspect of asphalt rubber applications.

The students are first introduced to the history of using asphalt rubber as a paving material. Case studies of full scale AR overlay projects in California are presented. These studies outline the strategy of using AR as an overlay to repair existing distressed pavements, as well as discussing the design and results of the AR overlays. The benefits of using AR pavements as a replacement for conventional asphalt are also discussed. The second module introduces the structural design of AR pavements. A 2005 Caltrans study is referenced in this module to review the revised practices of using AR in new pavements as well as an overlay (*18*). Students are informed on the recommended design strategies for new pavements and overlays using AR. An overview of the revised practices for using AR in overlays and new pavement is also presented. This module also presents cost analysis comparing AR and conventional asphalt.

Students are introduced to the manufacturing and construction process of AR in the third module. The module discusses the general paving process with an emphasis on the different practices between AR and conventional asphalt. An overview of the manufacturing process informs students how AR is produced and also highlights the operational differences when dealing with AR such as the laydown and compaction temperatures for successful placement of AR. The last module of the lecture goes into detail about AR binder production, AR mix production, inspection of paving and troubleshooting. Some or all of these modules could be included in transportation and pavement engineering classes.

Asphalt Paving Materials

This lecture consists of asphalt rubber (AR) binder design, the different types of AR mixes and cautions for using AR. The lecture defines the different types of asphalt rubber binders and discusses how each type is produced. Crumb Rubber Modifiers (CRM) are the form of waste tires added to the binder. The interaction between the CRM, the asphalt and the affecting factors are explained. When designing an AR blend, it is necessary to develop a binder profile which evaluates the compatibility, interaction, and stability between materials over a period of time.

The students are introduced to the most commonly used types of rubberized hot mix asphalt concrete, including Rubberized Hot Mix Asphalt – Gap graded (RHMA-G), Rubberized Hot Mix Asphalt – Open graded (RHMA-O), and Rubberized Hot Mix Asphalt – Open graded – High Binder content (RHMA-O-HB). The mix design, advantages, and standard specifications are described for each rubberized asphalt mixture type.

OUTCOMES

Teaching materials for utilizing waste tire products in civil engineering applications have been developed for eleven different civil engineering courses. The teaching materials are available on a website hosted by CSU, Chico. All these lectures have been taught at the undergraduate level at California State University, Chico in a variety of civil engineering courses. Students have greatly improved their knowledge on utilizing waste tire products in civil engineering applications. They were able to demonstrate their knowledge of, and interest in waste tire applications through their term projects, lab reports, presentations, and homework assignments.

A website was created to store the teaching materials, which includes PowerPoint presentations, lecture notes, sample assignments and sample solutions and student work. The link for the website is:

http://www.ecst.csuchico.edu/cp2c/dxcheng/Curricula/CIWMBEducation.php

Professors and instructors can easily access the teaching materials by logging onto the website. If you log in as a professor, you will be able to use all of the teaching materials. The public can also access part of the teaching materials by logging in as a guest. Generally, they can only access the PDF versions of the presentations. A snapshot of the webpage for professors is shown as following figure.

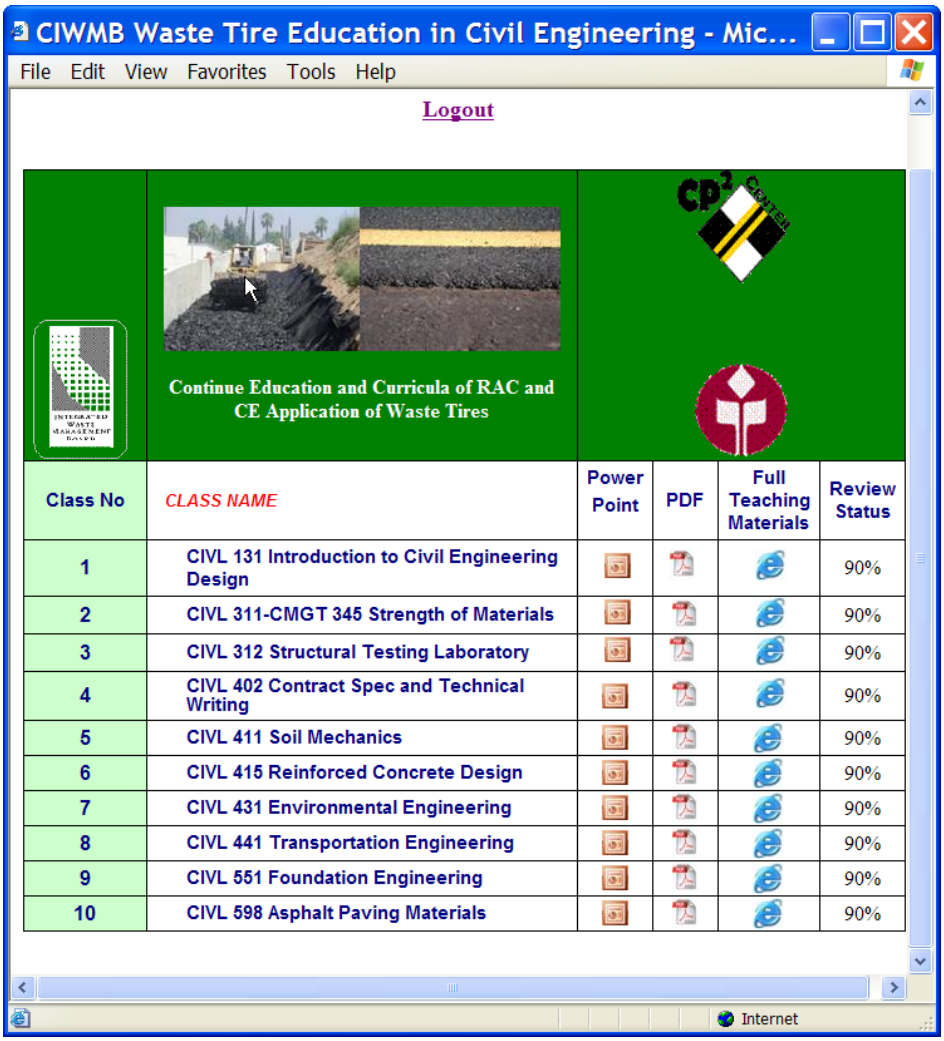


FIGURE 3. Sample Webpage to Access Teaching Materials for Waste Tire Applications

These course materials are available to be integrated into various courses in the undergraduate Civil Engineering curriculum and serve to introduce students to sustainable building practices and "green" construction.

CONCLUSIONS

Each year, civil engineering applications and asphalt rubber combine together to consume more than 60 million waste tires. In order to promote the beneficial usage of waste tires in civil and transportation engineering, educational curricula, including a series of lectures for undergraduate courses were developed. The following conclusions can be drawn from the curricula development project:

- Waste tire applications cover a wide range of civil engineering areas, including geotechnical, environmental, structural, and transportation.

- Teaching modules or lecturing materials were developed to cover freshman level to senior level classes. The freshman class gives students an introduction and overview of waste tire products and their applications. Junior classes cover the material properties, testing, and standards. Senior classes cover the waste tire applications in civil and transportation engineering.

- Outcomes show that introduction of curricula in a variety of courses is an effective way to teach waste tire applications and can reach more students. Students have demonstrated a knowledge of and interest in the sustainable use of waste tire materials through their school work.

Students in civil engineering are the future engineers and their knowledge of waste tire applications will affect the sustainable usage of recycled materials such as waste tires. It was a good experience promoting the education of the sustainable usage of recycled waste tires in civil and transportation engineering by developing teaching materials. The education on the use of other recycled materials can follow a similar approach.

REFERENCES

1. ASTM D 6270, Standard Practice for Use of Scrap Tires in Civil Engineering Applications, August 1998, reapproved 2004.

2. Caltrans Standard Specifications, Section 39, 2007.

3. Humphrey, D.N. Civil Engineering Applications Using Tire Derived Aggregate (TDA), CIWMB, Sacramento, 2003.

4. Tire Derived Aggregate as Embankment Fill, KENNEC, Inc. Website. http://www.usetda.com/page.php?id=18. Accessed July 30, 2008.

5. IT Corporation. Civil Engineering Application of TDA Dixon Landing Road On-Ramp Highway 880, Milpitas, California, June 2007.

6. Kennec, Inc. Using Tire Derived Aggregate for Slope Stabilization. http://usetda.com/page.php?id=2&ic=8. Accessed July 30, 2008.

7. Kennec, Inc. Project Manual and Specifications, Marina Drive Slide Repair, CR 266 at M.P. 0.63, Mendocino County, California, June 2007.

8. Kaloush, K.E., G.B. Way, and H. Zhu, Properties of Crumb Rubber Concrete, In *Transportation Research Record: Journal of the Transportation Research Board, No. 1914,* Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 8-14.

9. Fedroff, D., A. Shuaib, and S.Z. Savas, Mechanical Properties of Concrete with Ground Waste Tire Rubber, *Transportation Research Record 1532,* TRB, National Research Council, Washington, D.C., 1996, pp. 66-72.

10. Tantala, M.W., J.A. Lepore, and I Zandi, Quasi-Elastic Behavior of Rubber Included Concrete (RIC) Using Waste Rubber Tires. http://www.seas.upenn.edu/~lepore/pwrptfiles/. Accessed May 17 2002.

11. Schimizze, R.R., J.K. Nelson, S.N. Amirkhanian, and J.A. Murden, Use of Waste Rubber in Light-Duty Concrete Pavements, Proceedings of the *ASCE 3rd Materials Engineering Conference, Infrastructure: New Materials and Methods of Repair*, 1994, pp. 367–374.

12. Biel, T.D., and H. Lee. Use of Recycled Tire Rubbers in Concrete. Infrastructure: New Materials and Methods of Repair, November 1994, pp. 351-358.

13. Eldin, N.N., and A.B. Senouci. Observations on Rubberized Concrete Behavior, Cement, Concrete and Aggregates, Vol. 15, No. 1, June 1992, pp. 25-31.

14. Tweedie, J.J., D.N. Humphrey, and T.C. Sanford, Full-Scale Field Trials of Tire Shreds as Lightweight Retaining Wall Backfill Under At-Rest Conditions, *Transportation Research Record 1619,* Washington D.C., 1998, pp. 64-71.

15. Kennec, Inc. Tire Derived Aggregate as Retaining Wall Backfill, Wall 119, Riverside, CA, http://www.usetda.com/page.php?id=12. Accessed July 20, 2008.

16. Humphrey, D.N. and M. Swett. Literature Review of the Water Quality Effects of Tire Derived Aggregate and Rubber Modified Asphalt Pavement. Report for U.S. EPA, November 2006.

17. Liu, H.S., J.L. Mead, and R.S. Stacer. Environmental Impacts of Recycled Rubber in Light Fill Applications: Summary and Evaluation of Existing Literature. Chelsea Center for Recycling and Economic Development, University of Massachusetts, Technical Report #2, August 1998.

18. California Department of Transportation. Recommendations for Using RAC in New Pavements and for Structural Overlays. Sacramento, CA. December, 2005.

Learning Communities Improve Retention in Engineering and Computer Science

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Abstract

As a comprehensive university, California State University, Fullerton (CSUF) serves approximately 37,000 students from a variety of cultures and backgrounds, with the recent increases tied to the immigrant population from Mexico as well as Central and South American countries. The majority of this surge has been from first-generation college students. The college, in an attempt to reverse its historical legacy for high student attrition, provides support and services that will help its diverse student population succeed academically and socially. The overall retention effort centers on a number of initiatives but this paper focuses on one such program, *The Engineering and Computer Science (ECS) Scholars Program* that is intended to create learning communities during the freshmen years. The *ECS Scholars* program is a learning community established in collaboration with Title V Retention Programs, the University Learning Center (ULC), the Center for Academic Support in Engineering and Computer Science (CASECS) and Freshmen Programs. The *ECS Scholars* program launched in the fall 2006 semester focuses on the academic success of *first-time freshman* (FTF) in engineering and computer science. While the ECS Scholars program is an at large initiative not aimed at any single community, its impact on underrepresented groups is found to be significant.

Introduction

It is evident that the demographics of FTF entering four-year institutions of higher education in the United States is more diverse and multicultural than in previous decades.[1] While undergraduate enrollment has increased 21% from 1995 to 2005, the percentage of female enrollment has increased 27% in the same period. In addition, the percentage of minority college students has also increased. Minorities constituted 15% of the college population in 1976 but by 2005 that rose to 31%. In 2003 the Supreme Court of the Unites States recognized that sex and race, if used only as a subjective basis in acceptance decisions, bestows educational benefits that impact all members of an institution's student population.[2] Research shows that a diverse student population produces graduates capable of having complex points of views as well as enhanced capacity to take multiple perspectives into account.[3] Moreover, exposure to diversity allows greater cognitive insight and openness to enlist creative ideas from foreign cultures.[4] Modern engineers and computer scientists are expected to possess such skills in order to be successful in an increasingly globalized work force. Even though the need for diversity is well understood, statistics show a decreased enrollment of Women, Hispanics, and African-Americans in undergraduate engineering and computer science programs.[5,6]

Even when enrollment increases within these groups of FTF, thanks to aggressive recruitment efforts, retention and graduation rates remain relatively low.[7] Tinto argues that there

is no unilateral solution for this "revolving door" at institutions of higher education, but the adaptation of *learning communities (LC)* is a well corroborated educational solution.

Learning Communities

In the simplest model of an LC a certain group of FTF participates in *block scheduling* i.e., register for the same classes that also meet at the same time.[8] In another form, students take classes with a larger groups of students unaffiliated to the LC, and then convene together in smaller discussion sections (Freshmen Interest Groups) facilitated by upperclassmen. More structured programs will congregate all students in one class that meets several times a week and conduct all instruction in one setting. Other settings combine facets of the aforementioned, and link students via a *first year seminar* (FYS) course. Joe Cuseo purports that FYS is "an integral part to success of all students, regardless of their level of academic preparedness."[9] Some LCs also have a service-learning component, a pedagogical approach that interweaves faculty and student intellectual ingenuity to solve social problems.[8] Furthermore, LCs have three integral components: shared knowledge, shared knowing, and shared responsibility. Connecting courses so that they appear to be related promotes the networking of ideas and elevates thinking to a higher level (shared knowledge). Enrolling participants in the same classes induces social interaction and enhances intellectual interface, and allows students to care for the development of each other's learning (shared knowing). Lastly, students who participate in LCs learn to become responsible for one another and become "mutually dependent" so that advancement is done as a cohesive unit with each member making contributions to the group (shared responsibility).

Learning communities have some key parts of the successful Treisman's Model.[10] In the early 1980's Uri Treisman created programs that enlisted African-American students to excel in mathematics rather than a program created solely to help them evade failure. Like LCs, Treisman's emphasis is on collaborative learning among the students through the use of "small group teaching methods." Students are not just expected to be remediated, but expectations are raised based on what Treiman observed to be the strength of some groups of students on his campus: *their ability to merge academic and social lives*. Treisman argued that it was also important to have faculty sponsorship in order to "nourish" the program and enable it to survive. The same requirement applies to LCs. In addition to faculty, Tinto also states that successful LCs must recruit the services of student affairs professionals since they are usually trained to teach linked courses.[8] Participation by both parties increases mutual appreciation between faculty and student affairs professional and enhances the services rendered to students in a coordinated manner.

In order to further corroborate the efficacy of LCs, Zhao and Kuh conducted a cross sectional study with the National Survey of Student Engagement (NSSE).[11] The validity of assessment of student participation in the NSSE is well established. The NSSEE specifically assesses: (a) possible link between student success and a particular learning community, (b) self-reported gains in the college experience and (c) overall satisfaction with the college experience. After sampling over 80,000 students across 365 four-year universities they found that participation in LCs is "uniformly and positively linked" with (a) academic performance, (b) engagement in worthwhile academic activities (faculty interaction, collaborative learning), (c)

increase college attendance and (d) general satisfaction with the college experience (personal and social development). Overall, they argue that learning communities significantly impact the educational and personal experience of FTF to a degree that persists throughout the undergraduate experience of that student.

The concept of learning communities as presented by the current literature is consistent with the needs of diverse undergraduate engineering and computer science students. Students in science majors are often stuck in a void while learning science and engineering.[12] This may occur because they are not meeting the cognitive levels expected by faculty, are not able to interpret mathematical models adequately, have English language literacy problems or simply were not exposed to the necessary prerequisite science knowledge in high school. The problem is augmented by the general lack of a refined pedagogical approach to science teaching in higher education as teaching is often centered on lecture style teacher-dominated approach. This approach lessens as students advance towards core content, but is pervasive in introductory courses for first year students. The same trend is true in engineering programs in higher education; students do not experience emphasis on cooperative teamwork (a key pedagogical approach in engineering education) until they reach higher level courses. Coll and Eames[12] support key factors that positively influence the efficacy of learning in engineering students, the influence of social interaction on a student's academic choices (student-to-student relationships), quality and nature of teacher-student relationship, quality of science instruction, quality of student-centered teaching, and incorporation of best teaching practices based on research.

Additionally, pedagogical solutions that seek to meet the needs of diverse engineering students should implement strategies that complement the typical steps they take when seeking help: first they reach out to fellow students for advice and then to their instructors, subsequently informal study groups and then finally formal learning services (tutoring centers, etc).[13,14,15] These approaches should also accommodate their preference for interactive approaches to learning, more interaction with instructors and tutors, practical classes and emphasis on cooperative teamwork. Cronje and Coll assert that interactive approaches to learning enhances better comprehension of basic engineering skills, the appreciation for science, and an appreciation for the type of work conducted by a professional engineering or scientist. Similarly, successful computer science programs must provide a three dimensional perspective of potential careers in computer science.[6] Fisher and Margolis assert that an environment must be created where these perspectives are "valued and respected." Four year institutions can apply a social context to computer science education by: interconnecting other disciplines to computer science, an emphasis on the interaction between humans and computers and a component that encourages the application of computer science skills to community issues. They recommend that the program should also address the self confidence issues of students.

Current Situation

The overall fall 2006 ECS FTF class had a 1-year retention rate of 49% whereas overall fall 2007 ECS FTF class had a 1-year retention rate of 53% showing a slight improvement. The overall fall 2006 ECS cohort had a 2-year retention rate of only 31%. These are appalling statistics.

Description of the ECS Scholars Learning Community

The ECS scholars LC has been in existence since 2006. Students participate in this program only during the fall and spring semesters of their first year; they are not provided intervention after their first year at CSUF. The program is currently sponsoring its third cohort. The ECS Scholars LC is designed for FTF majoring in engineering or computer science aimed at reversing the unacceptably large attrition during the first year. ECS Scholars experience a smooth transition to college life by maximizing campus resources, opportunities for individual and community development, and on-going interaction with faculty, student affairs professionals, and peers from the College of ECS.

The ECS Scholars LC offers rewarding and unique benefits centered on the following aspects:

- Develop friendships and connections with students and faculty within the College of ECS. Students are block scheduled and placed in a FYS course each semester of their first year (1 unit in the fall and 2 in the spring semester) with an instructor with a PhD in Engineering or Computer Science.
- Receive specialized academic advisement for general education and major coursework under the guidance of CASECS and a graduate-student academic advisor.
- Learn how to study for core math, science, engineering and computer science courses in specialized Freshmen Interest Groups lead by upperclassmen.
- Receive intensive tutoring and academic assistance in core classes on a one-on-one basis
- Opportunities for service-learning experience related to their field of interest; students must complete 20 hours at government or non-profit organizations.
- Receive counseling on transitional issues from a student affairs professional, a co-instructor in both sections of the FYS courses.

The ECS Scholars Program started in 2006 with the following program goals and objectives (the same goals persist each year):

Goal: The first academic year fall-to-fall persistence of 75 first-time-freshman students in the College of Engineering and Computer Science will be 80% as well as 80% of the cohort will maintain adequate academic standing at the end of their first academic year.

Objective 1.1 The 75 students who participate will attend a block of classes in fall 2006 and spring 2007.

Objective 1.2 Participants will attend study groups that cover study techniques and strategies, as well as course content that support the blocked classes.

Objective 1.3 Participants will have access to at least three hours each week of individual tutoring.

Objective 1.4 Participants will be assigned a peer advisor in the College of Engineering and Computer Science.

Objective 1.5 Participants will be required to meet with the CASECS academic counselor at least once each semester.

As mentioned before, the ECS scholars program is supported by CASECS. This center provides a learning environment for all students in ECS regardless of their year in school. Upon

entering the ECS scholars program students are automatically CASECS members. CASECS students receive priority registration for courses, space for student-to-student collaborative learning among all grade levels, and academic counseling; these features aid members of the ECS Scholars program. Another key partner is Freshmen Programs of CSUF. Freshmen programs joined the ECS Scholar support team after the first year of the program (2007 cohort). Freshmen programs facilitates the following for the ECS scholars program: (1) one unit (UNIV 100A) FYS course for ECS Scholar students in the Fall semester, a class that is vital to academic planning, orientation, and transition to Cal State Fullerton, (2) a two unit (UNIV 100B) course in the Spring semester that offers further integration into areas of Engineering and Computer Science via the Service Learning component, (3) maintenance of registration planners that direct students into blocked-scheduled sections linked to their UNIV 100 LC (they work with departments to select appropriate courses, coordinate scheduling for the FYS courses), (4) a graduate-student academic advisor to help ECS Scholars understand the university registration system, coordinate major and general education requirements, and resolve other problems that may prevent successful registration, (5) assistance with implementation of mid semester grade check (early intervention) and connect students academically at-risk with resources to help them succeed in their classes, (6) professional development for instructors and student affairs professionals, and (7) assessment of all professional development programs as well as peer evaluations for all instructional team members.

A third partner in the ECS Scholars program (a partner since the inception of the program) is the ULC. The mission of ULC is to provide all CSUF students with academic support in an inviting and contemporary environment. The staff members of the ULC are carefully selected and trained to assist students with their academic assignments, general study skills, and computer user needs. The ULC provides the ECS Scholars with: Freshmen Interest Groups (provide collaborative learning groups across disciplines) led by trained upperclassmen, one-to-one tutoring, academic workshops, and online writing tutoring. Through the ULC's continual training of Study Group Leaders and a deeper partnership with ECS, a solid foundation of success has been laid for all ECS students served. ULC tutors have a positive impact on the ESC scholars they served in 2006 (n=19) as indicated by the 88.6% overall satisfaction rating indicated in Figure 1.

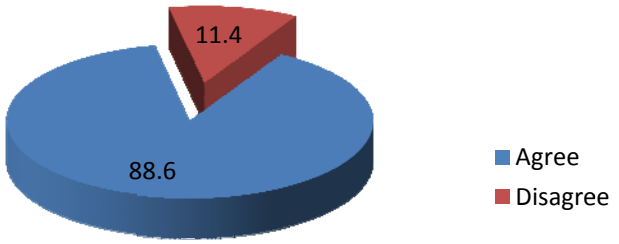


Figure 1: 88.6% of all ECS Scholars were satisfied with the knowledge they received, courteousness of the tutors, and the tutors ability to create group discussion.

ULC tutors participate in training throughout their employment. Issues of cultural sensitivity, conflict resolution, and cutting edge tutoring techniques are taught through the Peer Tutoring Certification process. These results can be immediately seen in the evaluation responses of the students that receive the ULC's services. As shown in Figure 2, great pride is taken in meeting the needs of CSUF's students in a friendly and courteous manner.

In the collaborative process of tutoring, it is important for ULC group leaders to create a dialogue with students that enable them to actively participate in their individual education. As part of the Peer Tutoring Certification, tutors learn to ask engaging questions that challenge and stimulate independent thinking. Figure 3 shows that 83.3% of ECS scholars surveyed, felt their Study Group Leader successfully facilitated group discussion.

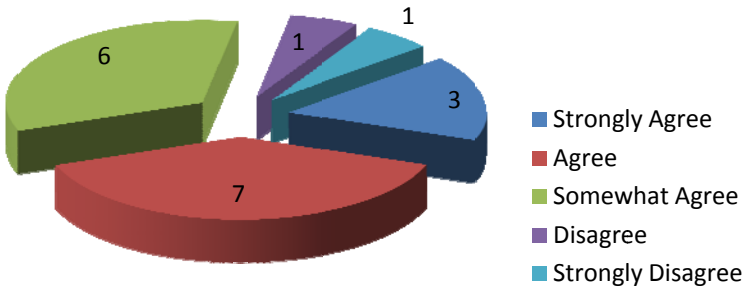


Figure 2: Of the 18 ECS Students surveyed 88.9% agreed their Study Group Leader was helpful and friendly.

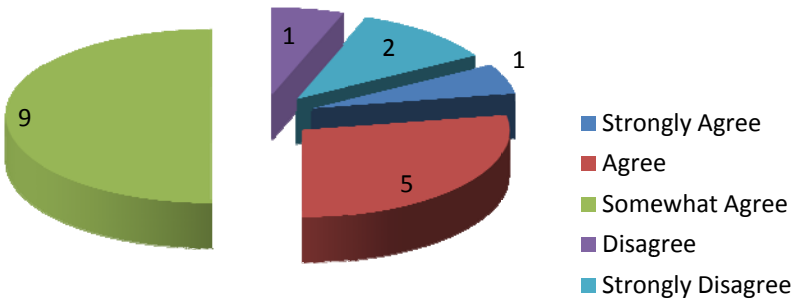


Figure 3: 83.3% of ECS students surveyed somewhat agreed, agreed, strongly agreed that their study group leader successfully facilitated group discussion.

The ULC's Study Group Leaders are very knowledgeable about the subjects tutored. Only students that demonstrate excellent writing skills and have an exemplary academic track record are hired as learning assistants. Tutors are also personable and able to explain complex concepts in simple terms. This results in 94.4% of the students served reporting an increase in knowledge of the subject area they studied, as shown in Figure 4.

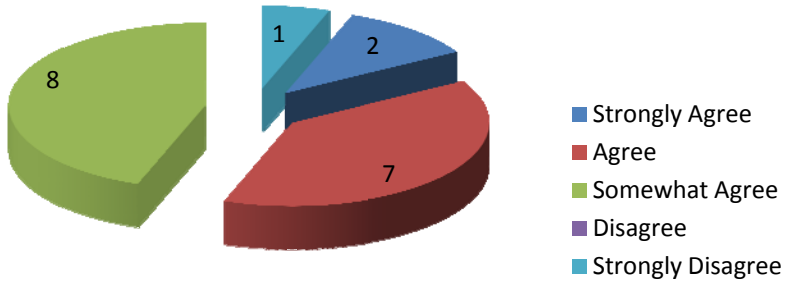


Figure 4: 94.4% of students surveyed somewhat agreed, agreed or strongly agreed that their study group leader aided in personal increase of knowledge in the subject area.

Attendance and Perceived Preparedness for Study Groups

The ULC hopes to strengthen collaboration with ECS to increase student participation in study groups. The results displayed above clearly indicate that the ULC provides an invaluable resource that supports academic participation and success. As Figure 5 illustrates, 55.5% of students surveyed did not regularly attend study groups. In order to make the most of this resource, future goals to improve regular attendance to study groups have been established. As the partnership between ECS and the ULC progresses, greater regular participation in study groups will result in a richer academic experience for ECS students.

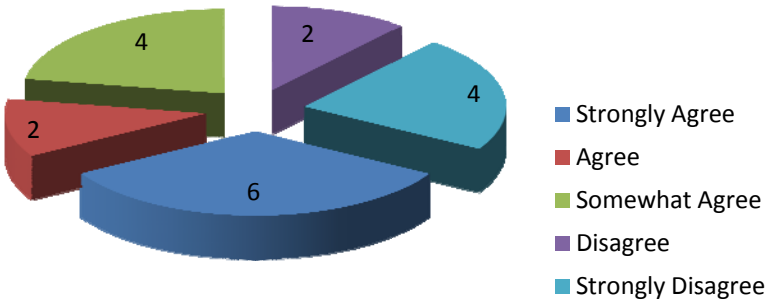


Figure 5: Fifty-five percent (55.5%) of students stated that they had not attended study groups regularly when asked if they attended study groups.

Future efforts will focus on encouraging proper study skills. Figure 6 indicates that only 50% of students come prepared for study group. To rectify this, Study Group Leaders will not only give an overview of the subject area, but will help students learn what types of questions to ask as they are reading and engaging the study material. This approach will encourage individual participation in study outside of the classroom and study group atmosphere.

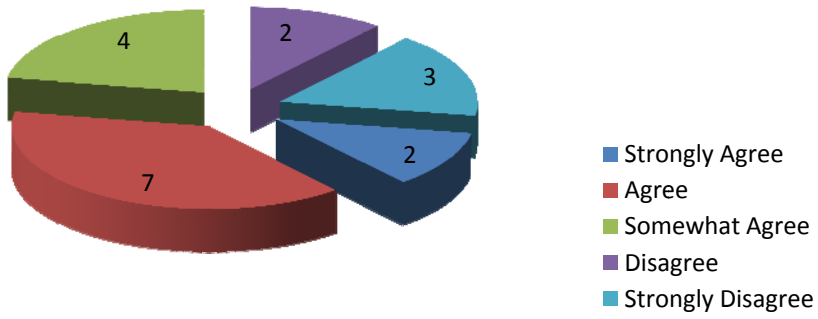


Figure 6: Fifty (50%) of students admitted that they did not come to study group prepared on a regular basis when asked if they prepared for the study groups.

The distribution of ECS students in the fall semesters of 2006 and 2007 are given in Table 1. This table shows the different categories of the overall student population as well as those who were part of the ECS scholars program. Note that the overall enrollment in the college as well as participation in the ECS Scholars program increased from 2006 to 2007.

Table 1: Student categories in Fall 2006 and Fall 2007

ECS Fall 2006 FTF

	Native American	Asian	African American	Hispanic	White	Nonresident	Unknown	Total
Men	3	77	35	131	87	17	21	371
Women	0	28	8	25	26	1	5	93
Total	3	105	43	156	113	18	26	464

Fall 2006 ECS LC

	Native American	Asian	African American	Hispanic	White	Nonresident	Unknown	Total
Men	0	0	1	12	0	3	0	16
Women	0	1	0	2	0	0	0	3
Total	0	1	1	14	0	3	0	19

ECS Fall 2007 FTF

	Native American	Asian	African American	Hispanic	White	Nonresident	Unknown	Total
Men	4	82	28	142	82	33	21	392
Women	1	17	9	26	27	3	4	87
Total	5	99	37	168	109	36	25	479

Fall 2007 ECS LC

	Native American	Asian	African American	Hispanic	White	Nonresident	Unknown	Total
Men	1	8	2	16	5	2	4	38
Women	0	1	1	2	4	0	0	8
Total	1	9	3	18	9	2	4	46

Note: "Nonresident" implies non-citizen

Academic Impact of ECS Scholars Program

The pass rate in various freshmen courses for ECS Scholars is significantly higher than the general pass rate for ECS students. Table 2 demonstrates the passing rates of ECS relevant courses taken by the 2006 LC in Fall 2006 and Spring 2007. Pass rates are compared with pass rates of all FTF in 2006. Table 3 demonstrates the passing rates of ECS relevant courses taken by the 2007 LC in Fall 2007 and Spring 2008. Pass rates of those the 2007 cohort were compared between those that attended the study groups and those that did not attend the study group.

ECS Scholar's Retention in the College of ECS

The 2006 Fall LC of the ECS Scholars program had a one year retention rate of 79% as opposed to 49% for the overall ECS FTF the same year. The Fall 2007 LC had higher one-year

Table 2: Pass rate of the 2006 ECS Scholars LC in important courses

Fall 2006		
Course Name	**% Passed in LC**	**% Passed of FTF**
Math 125 Pre Calculus	90.00 (n=10)	48.65 (n=37)
Math 150A Calculus I	90.00 (n=10)	50.00 (n=8)
Math 150B Calculus 2	100.00 (n=0)	0.00 (n=3)
Math 270A Mathematical Structures I	100.00 (n=1)	100.00(n=2)
Fall 2006-All Mathematics Combined	*90.48*	*48.00*
Spring 2007		
Math 125 Pre Calculus	50.00 (n=2)	52.17 (n=23)
Math 150A Calculus I	75.00 (n=8)	56.25 (n=16)
Math 150B Calculus 2	33.30 (n=6)	83.33 (n=6)
Math 270A Mathematical Structures I	100.00 (n=1)	75.00 (n=4)
Math 270B Mathematical Structures II	100.00 (n=1)	100.00 (n=1)
Spring 2007-*All Mathematics combined*	*61.00*	*60.00*

retention rate of 80% (slightly higher than the first cohort) whereas the overall Fall 2007 FTF had a one-year retention rate of only 53% the same year. The fall 2006 LC had a two-year retention rate of 42%, whereas the overall fall 2006 ECS FTF had a two-year retention rate of

only 31%. The 2007 LC has not reached their second year in ECS and one-year retention data of the 2008 LC will be assessed at the end of the Spring 2009 semester. The term "Retention" is defined as in "ECS retention", including only those who still major in ECS and excluding those who moved to other programs at CSUF.

Table 3: Pass rate of the 2006 ECS Scholars LC in important courses

Fall 2007		
Course Name	**% Passed that attended study groups**	**% Passed that did not attend study groups**
Math 125 Pre Calculus	65.38 (n=26)	28.57 (n=14)
Math 150A Calculus I	100.00 (n=13)	50.00 (n=2)
EGCE Engineering Surveying	75.00 (n=8)	50.00 (n=8)
EGME 102 Graphical Communications	100.00 (n=4)	66.67 (n=3)
Spring 2008		
Math 150A Calculus I	100.00 (n=9)	80.00 (n=5)
Math 270A Mathematical Structures I	75.00 (n=4)	80.00 (n=5)
CPSC 120 Intro. to Programming	100.00 (n=2)	00.00 (n=0)
CPSC 121 Programming Concepts	77.78 (n=9)	33.33 (n=3)
EGCE 206 Computer Aided Drafting	100.00 (n=4)	100.00 (n=9)
EGEE 245 Com. Logic and Architecture	100.00 (n=2)	00.00 (n=0)
EGME 245 Laboratory	100.00 (n=2)	00.00 (n=0)

Conclusion

The ECS Scholars program contains the integral parts of a structured LC: 1) block scheduling, 2) incorporation of Freshmen Seminar Groups, 3) Service Learning Component and 4) collaboration between faculty and student affairs professionals.[8] The program allows students to take advantage of interpersonal interactions that usually take place in upper level courses or may otherwise not occur without such a program. ECS Scholars participate in shared knowledge and the FYS course covers a wide range of topics that spark the interest of students in different areas of Engineering and Computer Science.[9] The program fulfills the Triesman's model: the merging of student's academic and social lives (as facilitated by Freshmen Interest Groups and CASECS).[8,10] By the end of the first semester students form formal friendships and depend on one another for academic support (shared responsibility) and thereby fortify the student-to-student relationship that enhances the educational experience of engineering students.[8,12]

The ECS Scholars Program also caters to the needs of Computer Science students.[6] The FYS courses' curriculum emphasizes the interdisciplinary application of Computer Science with career presentations by career specialist and alumni of the college. The service learning component allows the application of computer science skills to community issues. Students are given a three dimensional perspective on multiple careers in computer science via exposure to computer science oriented student clubs, access to computer science faculty, and invitation to

multiple career fairs. In addition, the one-on-one advisement sessions with the student affairs professional enhances the self confidence of the student.

Above all, the first two cohorts of the ECS Scholars program have closely achieved the projected a one year retention rate of 80% (79% for the 2006 cohort and 80% for the 2007 cohort). Participation in study groups needs to improve, but students who attend are benefiting both academically and socially. In addition to the Freshmen Interest groups, the students also had access to over three hours of one-on-one tutoring. Participants met regularly with a CASECS academic counselor and the graduate-student academic advisor provided by Freshmen Programs. Overall, students in the LC had better passing rates compared to those that were not in the LC. Although no statistically significant inferences can be made, the effectiveness of Freshmen Seminar Sessions is seen when comparing pass rates of LC students who consistently attended the sessions versus those that did not. The 2006 and 2007 cohorts had access to peer mentors in the FYS courses and the 2008 cohort had access to them outside of class. The ULC continually provides the leaders of the Freshmen Interest Groups with training and supplemental instruction will be incorporated to increase efficiency and attendance. Students are taught how to efficiently prepare for study group sessions in the FYS courses and by the Freshmen Interest Group Leaders. The services rendered by the student affairs professional were also critical in helping students deal with transitional issues.

Overall, the ECS Scholars program has been an unqualified success in retaining student in the College of Engineering and Computer Science. The Title V grant that funds this successful initiative is ending in the middle of CY 2009. While it is hoped that the funding will continue, some aspects of the program such as block scheduling will continue regardless of funding.

Acknowledgments

This paper is dedicated to the memory of Dr. Donald Castro for his enlightened vision on the educational mission of the university and his unwavering support to the issues of retention of underrepresented students. His untimely passing has created a void for all those who knew him. The authors would also like to thank Dr. Hye Sun Moon, Senior Research Analyst at the Institutional Research and Analytical Studies Department, Fran Zareh-Smith, Director, University Learning Center and Dr. Nancy Page-Fernandez, Director, Freshmen Programs (all at CSUF) for their contributions and support.

References

1. U.S. Department of Education, National Center for Education Statistics. (2008). *Digest of Education Statistics, 2007* (NCES 2008-022). Retrieved February 6, 2008 from http://nces.ed.gov/fastfacts/display.asp?id=98
2. Grutter v. Bollinger (2003). Supreme Court of the United States.
3. Gottfredson, N., Panter, A., Daye, C., Allen, W., Wightman, L., & Meera, D. (2008). Does diversity at higher education institutions influence student outcomes? *Journal of Diversity in Higher Education, 1 (2),* 80-94.
4. Leung, A., Maddux, W., Galinsky, A., & Chiu, E. (2008). Multicultural experience enhances creativity, *American Psychologists Association, 63 (3),* 169-181.

5. Watson, K., & Froyd, K. (2007) Diversifying the U.S. engineering workforce: A new model, *Journal of Engineering Education, 96*, 19-32.
6. Fisher, A., & Margolis, A. (2002). Unlocking the clubhouse: the Carnegie Mellon experience, *SIGCSE Bulletin*, 34 (2), 79-83.
7. Tinto, V. (2008, August). When access is not enough, Carnegie Perspectives. Message posted to http://www.carnegiefoundation.org/perspectives/sub.asp?key=245&subkey=2626
8. Tinto, V. (2003) Learning better together: The impact of learning communities on student success in higher education (White Paper). Retrieved from http://www.maine.edu/system/asa/vincenttinto.php
9. Cuseo, J. (2008) Academic credit (White Paper). Retrieved from http://www.uwc.edu/administration/academic-affairs/esfy/cuseo/
10. McNeilly, J. (2007). Merit workshop: Treisman's Model (White Paper) Retrieve from http://www.math.uiuc.edu/MeritWorkshop/uriModel.html
11. Zhao, C., & Kuh, G. (2004). Adding value: Learning communities and student engagement, *Research in Higher Education, 45 (2)*, 115-138.
12. Coll, R., & Eames, C. (2008). Developing an understanding of higher education science and engineering learning communities, *Research in Science & Technological Education, 26 (3)*, 245-257.
13. Cronje, T., & Coll, R. (2008). Student perceptions of higher education science and engineering leaning communities, *Research in Science & Technological Education 26 (3)*, 295-309
14. Shapiro, S., & Levine, H. (1999). Creating learning communities: A practical guide to winning support, organizing for change, and implementing programs. San Francisco: Jossey-Bass.
15. Unnikrishnan, R., & Garcia, G. (Eds). (2007) Proceedings from the Fifth International Latin American and Caribbean Conference for Engineering and Technology'07 (*LACCEI): Enhancing Engineering and Computer Science Education for a Diverse Community.* Tampico, México.

Biographical Information

Raman Menon Unnikrishnan is the Dean of the College of Engineering and Computer Science at California State University, Fullerton. He is active in teaching and research in the areas of Control Systems, Power Electronics and Signal Processing. He has been a consultant to several industries and governmental agencies, and has been involved in technical and professional education for industries. He is active nationally and internationally in the field of engineering education and engineering accreditation.

Prior to joining CSUF in 2001, Dr. Unnikrishnan was on the faculty of the Rochester Institute of Technology in Rochester, NY where he also served as Associate Dean for Graduate Studies and Research from 1989 to 1991 and as the Head of the Electrical Engineering Department from 1991 to 2001. He received his BSEE degree from the University of Kerala in India, MSEE degree from South Dakota State University and the Ph.D. degree in electrical engineering from the University of Missouri-Columbia. He is the recipient of the *Eisenhart Award for Excellence in Teaching* at RIT, a special professionalism award from the Xerox Corporation and an IEEE Region 1 *Award for Leadership* on advancing the continuing education needs of the engineering community. In 2000, he received the IEEE *Third Millennium Award* for Outstanding Achievements and Contributions. In 2006 he received the *Missouri Honor Award* for being an outstanding alumnus. Since 2008 he has been a Commissioner of the Engineering Accreditation Commission of ABET. Dr. Unnikrishnan is a Fellow of IEEE.

Ricardo V. Lopez is the Retention Coordinator for the College of Engineering and Computer Science at CSUF. He helps coordinate the collaborative management of the ECS scholars program as well as directs several retention efforts aimed at helping ECS first-time freshmen. He has worked in the field of education for over 5 years with various non-profit organizations and several Southern California school districts. He is also actively involved in the field of Public Health research and advocacy. In 2006 he was accepted into the Minority Training Program in Cancer Control Research (MTPCCR) at UCLA where he conducted research at the Jonson Comprehensive Cancer Center. He earned his undergraduate degree at UCLA in Molecular, Cell and Developmental Biology and his Master of Public Health at CSUF. He is the lead author of published manuscripts on the knowledge and perception of Human Papilloma virus and Cervical Cancer among college-age students.

Laboratory Projects Introduced in Teaching Manufacturing Processes Course

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Introduction

Mechanical engineering students should graduate with strong practical and interpersonal skills [1, 2]. Manufacturing Processes is a fundamental mechanical engineering course offered to junior students in engineering schools [3]. The primary objective of this course is to give students exposure to understanding of a range of modern manufacturing processes and practices. Students are expected to be able to select appropriate manufacturing processes and fabricate parts after completing the course. Normally, this course includes laboratory activities and fabrication projects. Students use different manufacturing equipment and make parts to get a "real" feeling of the manufacturing process. In the past two years, the author has introduced several innovative projects while teaching this course in University of the Pacific's School of Engineering and Computer Science. The goal of the projects is to inspire students' interest in the manufacturing engineering field. Students are expected to use the knowledge learned in this and other engineering courses such as Engineering Graphics and Materials Science to solve synthesis engineering problems. These projects are also aimed at helping students to better understand the fundamentals discussed in the classroom, making learning more enjoyable and improving student satisfaction. This paper will discuss these projects.

Lego block design and fabrication project

The lego block design and fabrication project is a class-wide team project. One objective of this project is to provide students with an opportunity to work with other students in order to improve their communication and team work skills. Each student is required to design a block piece as shown in Figure 1. All blocks have identical outer dimensions. Students are allowed to design geometric features on two planes of the block. The block designs form mating patterns with those designed and fabricated by other students. The instructor specifies the assembly order of the blocks. During the design phase, students must complete their designs and pass them to other students in a scheduled time frame. Students have to interact with each other frequently to discuss the design details and negotiate necessary modifications. Students must completely understand each others' drawings and check for possible mismatches both in dimension and shape. Once each design is completed, the drawing will be arbitrarily given to another student for fabrication.

The blocks are machined using manual Bridgeport mills and NC machines. Through conducting this project, students improve their Solidworks modeling skills learned from Engineering Graphics class. Students also learn that they can be very creative in terms of design; however there could be many constraints in reality of part fabrication. A design must comply with the manufacturing equipment's capability and availability as well as manufacturing time and cost

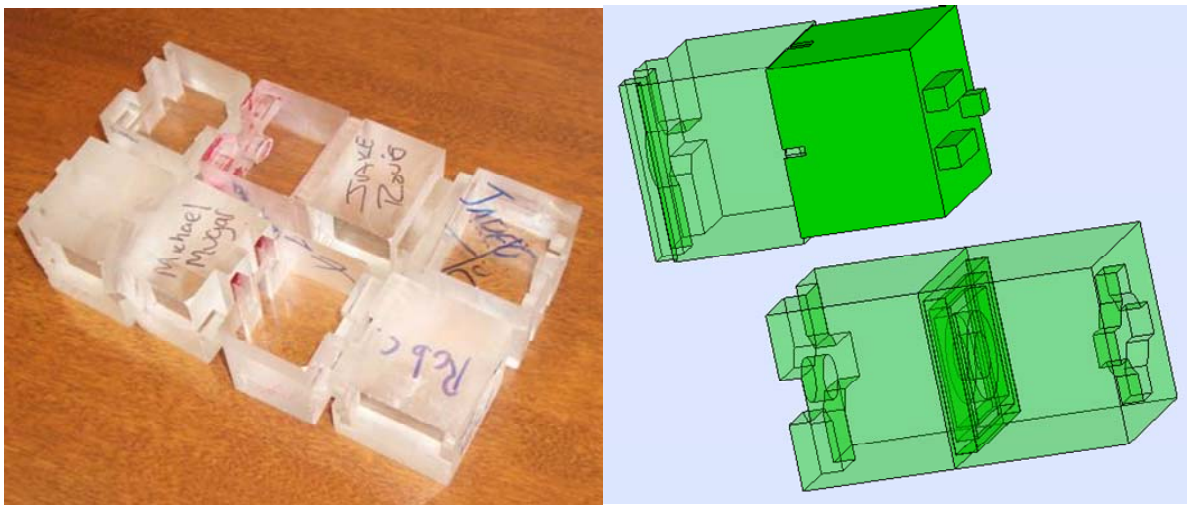


Figure 1 Examples of designed and fabricated lego blocks

requirements. Most importantly, students learn the importance of the team work and how to deal with project progress delays, iterative design modification caused by other team members and other challenges that arise over the course of a project. Figure 2 shows the design assembly and fabricated parts in the Fall 2008's class.

CNC programming and machining project

The CNC machine tool is one of the most important pieces of manufacturing equipment in industry. Almost all industrial products and every day consumer goods include components directly made using CNC machine tools. This project allows students to experience the operation of a modern NC machine. This activity obviously helps students to have a better understanding of the machine structure and component functions. This project also asks student to, using computer aided manufacturing (CAM) technology, create an NC program, which is used to drive the machine to move and act as desired. Using CAM to generate NC programming requires students to determine a machining strategy, operation sequence and cutting tools. Students must also decide the cutting conditions such as cutting speed, depth of cut, feed rate, and other parameters for each operation based on knowledge learned in classroom.

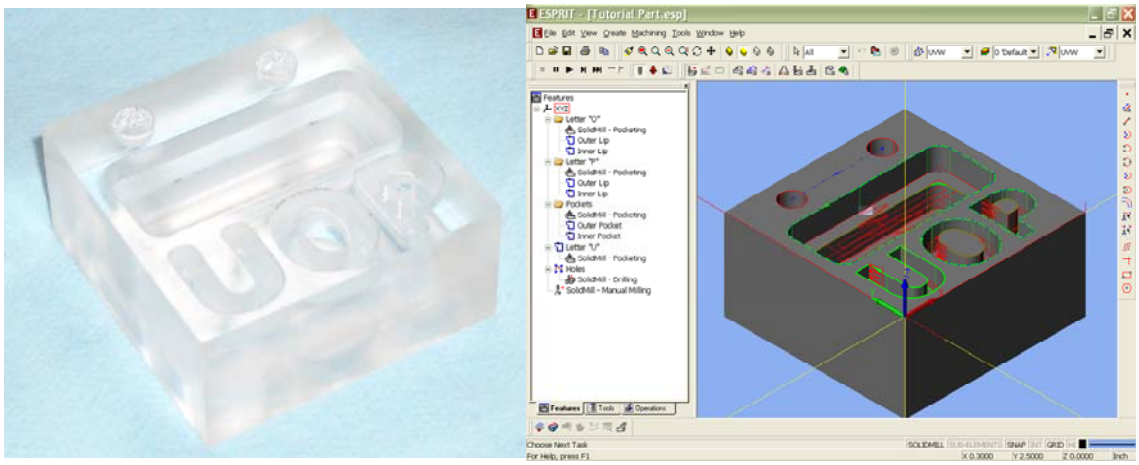


Figure 2 NC programming and machined part

This practice helps students to solidify their understanding of metal cutting theory. A commercial CAM system called “Esprit”, which was donated by the DP Technology Corporation, was used for this project. Students were impressed by the intelligent functions and cutting simulation embedded in this software package. Each student designs a part as shown in Figure 3 and then creates an NC program using Esprit. The NC programs are then uploaded to a CNC machine center (HAAS VF-1) for machining. Students machine the parts themselves under the supervision of the instructor, giving them hands-on experience with CNC machine tools. Through completing this project, students practice the entire part manufacturing cycle from design to manufacturing using the modern manufacturing technology. Students also experience the “joy of ownership” of the parts they make in the laboratory activities.

Part rapid prototyping project

Part rapid prototyping is a non-traditional part fabrication technology used to make product prototypes for design verification before mass production in industry. Using this technology, a part can be fabricated within hours. It is widely used in many engineering fields. This project requires students to design a part by following specifications determined by the instructor. Students then make the parts using a 3D printer purchased from Z-Corp.

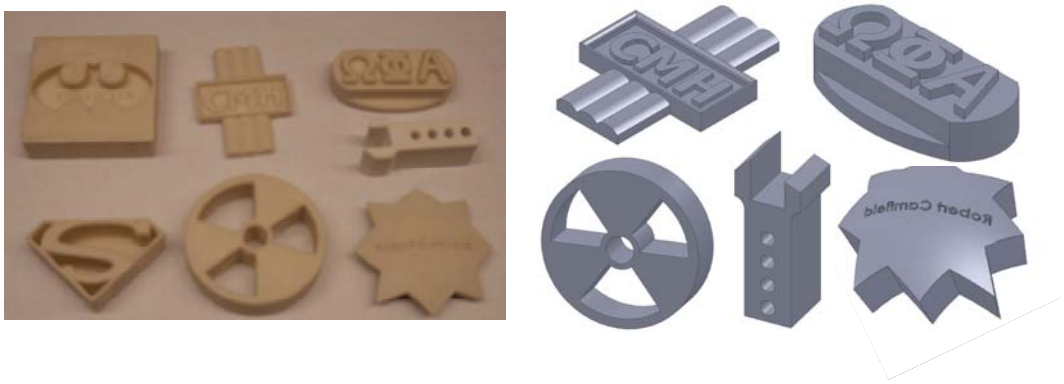


Figure 3 Examples of designed models and fabricated parts

Concluding remarks

Several student projects introduced in teaching manufacturing processes course were shared in this paper. These projects provided students with an integrated environment to work as a team and apply the knowledge and skills learned from other courses to solve engineering problems. These projects improved student's learning and satisfaction.

Reference

1) Liu, J., (2005). "Digital Engineering Technology in Machine Tool ." Keynote Speech for CIRP/SME SME/CIRP International Conference on Manufacturing Engineering Education, June 22-25, California.
2) Liu, J. (2008), Brown, A, "Enhancing Machine Design Course through Introducing Design and Analysis Projects, " Proceedings of 2008 ASEE PSW conference, March 27th~ 28th 2008, Arizona.
3) Kalpakjian, S and Schmid, R (2001), "Manufacturing Engineering and Technology, 2nd , Prentice Hall(ISBN 0-201-36131-0)

Author's Biography

Dr. Liu has published more than 70 technical journals and conference papers. He was awarded four patents. His research and teaching interest includes manufacturing system and processes, machine design and analysis, and CAM/CAE.

Using an On-line Survey Tool to Streamline Outcomes Assessment

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Abstract

Outcomes assessment required to meet ABET accreditation criteria can be very time consuming. Deciding what and how to measure can take many hours of faculty time on both a department-wide and individual basis. Data gathering and analysis is another time consuming activity. Finally, preparing self-studies and other reports can consume many hours as well. It was College of Engineering's Assessment Committee conclusion after two rounds of ABET Assessment under the ABET 2000 criteria that a more strategic and systematic approach was needed for gathering and organizing data. In an effort to simplify assessment processes, the IME Department at Cal Poly Pomona has been increasingly using SurveyMonkey on-line surveys to gather data from students, alumni, faculty, and industry. One of the reasons for widely adopting SurveyMonkey is the ability to create a data base that makes it easier to collect and analyze data, share results, and prepare descriptive statistics of results over time. The purpose of this paper is to show how SurveyMonkey can be used for various assessment situations and demonstrate how easy it is to create a data base in the process.

Introduction

One of the top objectives of the College of Engineering Administrative and Assessment Committees and after the last ABET accreditation cycle was to streamline and simplify data collection and analysis processes. In 2005 the process of gathering together relevant data and analysis in order to report by criteria and a-k designation was extremely time consuming for many programs. One of the main reasons for the large time requirement was that assessment data and other reported information was in various forms such as hard copies and raw data reports. Subsequently entering data into a spreadsheet and performing analysis was very time consuming.

The IME Department decided to re-engineer as many assessment tools and instruments as possible so that an on-line survey tool could be used for input and serve as a data base. SurveyMonkey was the on-line survey service used, however there are a number of other on-line services that would work similarly (such as Zoomerang). SurveyMonkey was chosen primarily because at the time it had good features, very few restrictions on the number of surveys that could be collected, and was competitively priced. Another attractive feature was that surveys could be easily transferred between paid users. Other services may offer more features and should be considered when deciding which service to use.

The purpose of this paper is to show how SurveyMonkey is being used for both formative and outcomes assessment. Outcomes assessment can be conducted at the course and/or program levels. Emphasis will be on the variety of things that can be done, time savings, and the ability to create data bases of gathered data. First

After the 2005 ABET accreditation visit the College of Engineering Assessment Committee and Administrative Committee used a survey to set the agenda for the next year regarding priorities to work on. In reality the results were used for several years.

Design and Deployment Features

- **Relatively inexpensive for the features provided** – Both SurveyMonkey and Zoomerang offer monthly "Pro" packages for approximately $19/month. Annual packages are available for $200/year. The number of surveys and responses allowed is well within the amount needed.

- **Ease of creating a survey from scratch or starting with a previous survey** – Survey building is very user friendly and old surveys can be imported as templates for new surveys.

- **Color schemes and customized page design** – There are many color schemes and formats to choose from. Customized designs can be created with a little more effort.

- **Paging and end of survey options** – Surveys can be one page long or broken into separate pages. Responders can be sent to various "thank you" or other pages as designated by the designer.

- **Can embed survey links in email, web pages, or send to an email list with reminder capability** – Links are provided allowing for embedding survey links in various documents. Surveys can also be sent to an email list allowing for tracking and reminder messages. Practice has shown that the reminder feature does produce good results with second and third reminders.

- **Surveys can be opened or closed for data collection as necessary**.

Analysis and Sharing Features

- **Sharing survey results** – Unfiltered survey results can be shared with others with various levels of interaction allowed. Sharing can be password protected. Sharing is a useful feature for displaying assessment results with colleagues. The boilerplate display screens are very aesthetic.

- **Ability to filter the results by response alternative (e.g., demographic or specific question choice) and save filters by name** – The same survey can be used for various courses, student groups, years, and semesters. Results can then easily be filtered to a specific demographic combination. This avoids having to create a new survey for each time you want to use the survey.

- **Ability to collect surveys with options required for IRB approval** – setting are available to create various levels of anonymity and confidentiality, depending on what is needed for IRB approval. (e.g., IP address, email address, and other information can be included or excluded, depending on settings).

- **Can create crosstabs for up to five choices for any question** – Powerful, but limited option.

- **Survey data downloadable in various forms depending how needed** – Data can be downloaded to a spreadsheet as raw data or summarized various ways.

- **A virtual database can be created by carefully choosing questions** – Demographic questions can be discretely used to create a data base allowing for analyzing data over time. This is a useful feature for outcomes assessment.

Examples of survey use

Below is a partial list of surveys divided into categories. Almost all examples are related to outcomes assessment. Examples are shown at the College of Engineering level, program level and course level. In some courses SurveyMonkey is being used for course management and/or formative assessment as shown with a few examples. The following link is to the IME Department Assessment Page which includes links to several of the surveys. Readers are welcome to look at these surveys and use them as needed:
http://www.csupomona.edu/~rosenkrantz/imeassessmentdocs.htm

College Level Assessment

- **Cal Poly Pomona Project Symposium Feedback** – Industry visitors to senior project presentations were surveyed for their overall assessment of outcomes vs. importance. A gap analysis was easily created using summarized survey data.

- **College of Engineering Assessment Interest** Survey – College faculty and administrators involved with preparing the self study were surveyed to identify assessment committee priorities for the near future.

Program Level Assessment

- **Cal Poly Pomona IME Department 2005 Alumni Survey** – Survey administered every three years to assess progress on objectives and obtain feedback regarding changing curriculum needs.
- **Student Advising Survey** – Comprehensive survey to explore student attitudes and practices so the IME Department could revise the advising program based on actual student feedback.

- **IME Basic Knowledge Survey** – Survey used to assess student retention of knowledge and concepts from five selected lower division courses. Very valuable in finding out where to put place efforts to increase learning. The use of valid and reliable concept surveys should be encouraged.

- **ME Summer Class Needs Survey** – A quick survey of ME students regarding what summer course offerings would be the most valuable resulted in higher-than-expected summer course attendance.

Course Level Management & Assessment

- **IME Outcomes Assessment Survey** – Survey of student progress in a-k outcomes for a selection of courses. This survey is the main outcomes assessment tool that looks for improvement over time and weaknesses that should be targeted for special attention.

- **IME 312 Statistics Knowledge Survey** – Utilizes a pre and post knowledge survey to assess student learning by topic and by level of learning from Bloom's Taxonomy.

- **EGR 403 On-line Introductory Survey** – Survey used to find out student interests, strengths, and weaknesses for the purpose of forming student project teams

- **EGR 403 Team Member Evaluations** – Student assessment of team members. Used midway through and at the end of the project to assessment contribution to the team project.

- **IME 301 Project Proposal** – Survey used as a proposal form for student data collection and analysis projects. This method is faster and more efficient than Blackboard

First Year Experience

- **Engineering First Year Experience Survey** – Survey designed specifically to assess the results of the EGR 100 first year experience course for incoming students.

- **IME 112 Team Evaluation Survey** – Introductory course team evaluation survey.

- **IME 112 Time Use & Management Survey** – Survey based on time management assignment results. Provides feedback to both students and the instructor about student habits and practices.

- **IME 112 Outcomes Survey** – Student assessment of specific features and outcomes from for the introductory course.

Capstone Course Sequence Assessment (IME 460, IME 461/471, IME 462/472)

- **IME 460 Fall 08 Sample Senior Project Report Assessment** – Survey made using the senior project written report rubric. Students use this to practice scoring written reports as part of a Senior Project preparation course.

- **IME 460 Sample Senior Project Presentation Assessment** - Survey made using the senior project oral presentation rubric. Students use this to practice scoring video tapes of oral report reports as part of a Senior Project preparation course.

- **IME 460 Senior Project Report Assessment** – Faculty are asked to input their assessment of written senior project reports using SurveyMonkey.

- **IME Reflective Piece Results** – A single evaluator is asked to input an assessment of a reflective piece written by students after completion of the senior project. The survey covers three outcomes scored by a rubric.

- **IME Department Senior Project Assessment** – Survey developed to gather feedback from industry about the professionalism of students who completed Senior Projects at their company. The survey link is sent out in an email message.

Additional information regarding downloading

The italicized section below is a copy of the download option page in SurveyMonkey. It shows the various options available for downloading results. Spreadsheet, HTML, and pdf formats are available along with choices for raw or summarized data. Note that the descriptions are not that clear so expect to experiment with downloading to find the exact format to meet your needs.

Choose Type of Download

Summary Report
Download a summary report of your survey that you can save or print.

All Responses Collected
Download the entire response set of your survey, for importing into a spreadsheet or database.

Columns:

Choose whether question choices are condensed or expanded to fit one or multiple columns.

Cells:

Choose what data appears in the spreadsheet.

Choose Format

CSV Format
The summary is formatted as a comma separated values file.

Spreadsheet Format
The summary is formatted to open with spreadsheet software.

XML Format
The summary is formatted as an XML file.

HTML Format
The summary is formatted in HTML, and can be easily posted on a website.

PDF Format
The summary is formatted as a PDF, and can be easily printed.

Orientation:

Paper Size:

Open-Ended Responses (optional)

Include Open-Ended Responses in Download

Apply Existing Crosstab (optional)

Use Current Crosstab Named "New Crosstab"

Conclusions and Recommendations

There are many more uses of a survey tool than just for the common “end of course” survey. On-line surveys can save much time and effort compared to handwritten surveys and OCR forms.

An on-line survey took can be creatively used for a variety of time-saving data collection processes.

Sometimes the difficulty in summarizing and analyzing data delays the effort and ultimately affects the implementation of changes. If properly planned out, the number of hours required for analysis, feedback, and planning for change can be reduced and program effectiveness can be promoted sooner.

Creation of descriptive statistics for generating a thoughtful self study is time consuming. Having data in a form that is already in a spreadsheet format makes this task much easier.

References

Allen, K. 2006. *The Statistics Concept Inventory: Development and Analysis of a Cognitive Assessment Instrument in Statistics*. School of Industrial Engineering, University of Oklahoma.

Nuhfer, Edward, and, Knipp, Delores, *The Knowledge Survey: A Tool for All Reasons*, (2003, *To Improve the Academy*, v. 21, pp. 59-78.)

Biography

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Bio-molecular Engineering Verified by High Sensitivity Detection

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Abstract
An interdispinary, industry-academic collaboration was conducted to aid students at the Pitzer College Vaccine Development Institute and the Claremont Colleges to study the progression of Tobacco Mosaic Virus (TMV) on plants. Symptoms of the virus, including discoloration and mottling, usually takes weeks to develop. The students genetically inserted the gene for green fluorescent protein (GFP) into the virus genome. The genetic modification allows the viral infection to be detected within a few days via fluorescent imaging. The detection of the fluorescence was aided by UVP, LLC. Fluorescent images of a tobacco relative (*Nicotiana benthamiana)* agroinfected with GFP-TMV was captured daily using an macro imaging system to document the intensity and area of the viral expression. The quantitative data is used to observe the movement and expression of the virus under various conditions and when changes are made to the viral gene sequences. Students were exposed to the technical aspects of fluorescence imaging besides being able to rapidly verify their biological work.

Introduction

The Vaccine Development Institute at Pitzer College aims to produce low cost vaccines by genetically engineering Tobacco Mosaic Virus to express immunogenic epitopes on the surface of the viral coat protein. Vaccines and therapeutic drugs produced in this manner have previously been shown to be highly efficient in eliciting an immune response (Kohl et al., 2006). Moreover, this production method is significantly faster and less costly than other more traditional methods involving bacterial or mammalian cells (Grill, Palmer & Pogue, 2005).

TMV is a rod-shaped RNA virus that infects members of the *Solanaceae* family of plants, which includes tobacco, tomatoes, and potatoes. The virus causes mottling and discoloration of the leaves, but is not fatal to the infected plant. These symptoms appear in new growth and often take weeks to become clearly apparent. In order to more quickly detect and quantify the spread of TMV through a plant, the virus was tagged with GFP and visualized using an UVP BioSpectrum® Imaging System. The GFP tag allows for detection of the virus in plant tissue as early as two days post-infection, and for monitoring the spread of the virus through the plant. Early detection confirms the success of cloning procedures and the correct functioning of the virus.

Method

Engineering the TMV genome

GFP was enzymatically inserted into the PacI-AvrII-NotI multiple cloning site of the pJL TRBO vector (Figure 1). The pJL TRBO vector, as previously described by Lindbo (2007), was designed to maximize production of the inserted protein. It contains the entire TMV genome, except the gene encoding the viral coat protein, bordered by 25-bp repeat sequences, which enable the incorporation of the viral genes into the plant genome after infection. Competent

Agrobacterium tumefaciens cells were transformed by heat-shocking with the TRBO-GFP construct. *A. tumefaciens* is a plant bacterium that utilizes a tumor-inducing (Ti) plasmid to transfer genes directly into the host's genome. After transformation, the bacteria can be cultured and injected directly into the leaves of *Nicotiana benthamiana* plants. Plants are maintained in a controlled environment at 27°C with 16 hours of light per day. GFP expression in the plant tissue is visible 2 days post-infection (dpi).

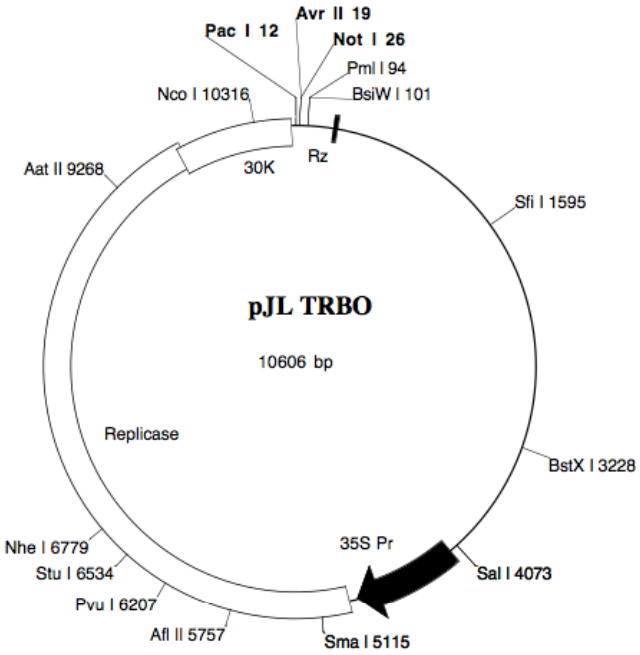


Figure 1. pJL TRBO vector with PacI-AvrII-NotI multiple cloning site. Replicase and 30K protein are part of the TMV genome. TMV coat protein is not present. 25-bp repeats are not shown.

Control for quantitative fluorescence imaging

Two days after the transfection, glowing patterns can be observed when the plants were illuminated with a UV handheld lamp. To verify that the visually detected pattern was TMV-GFP, a leaf was removed and placed in a spectro-fluorometer to acquire its emission spectrum. As shown in figure 2, the visually glowing area (area 1) significantly increased in emission intensity at about 520nm relative to the non-glowing area (area 2). 520nm is the signature wavelength of GFP.

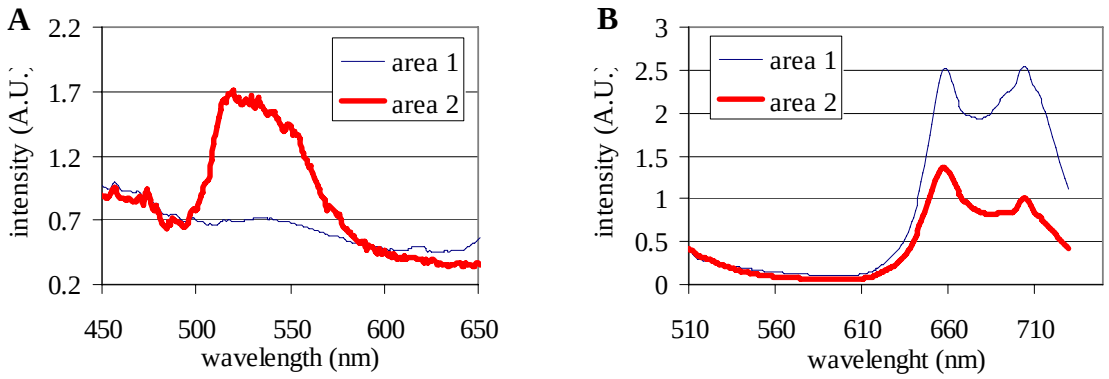


Figure 2, Emission spectra of an infected leaf under A) 365nm UV and B) 480nm excitation illumination. Area 1 expressed visually detectable fluorescence. Area 2 was far from the point of infection and is used as a reference.

GFP could be excited by blue (480nm) light as well as UV. To compare the difference, an emission spectral scan was also taken using 480nm excitation wavelength. When excited with 480nm, the inelastic scattering of the excitation light spread over the wavelength of GFP emission. The signal to background ratio is reduced. It was determined from the emission scan that 365nm UV should be used for excitation and an emission filter passing light between 500 to 600nm should help discerning the GFP signal. A shorter wavelength (<500nm) contains mostly the scattered excitation light. The longer wavelength region (>600nm) has signal irrelevant of the infection. Its spectral signature matches the autofluorescence of chlorophyllchlorophyll (Halfhill et al., 2003).

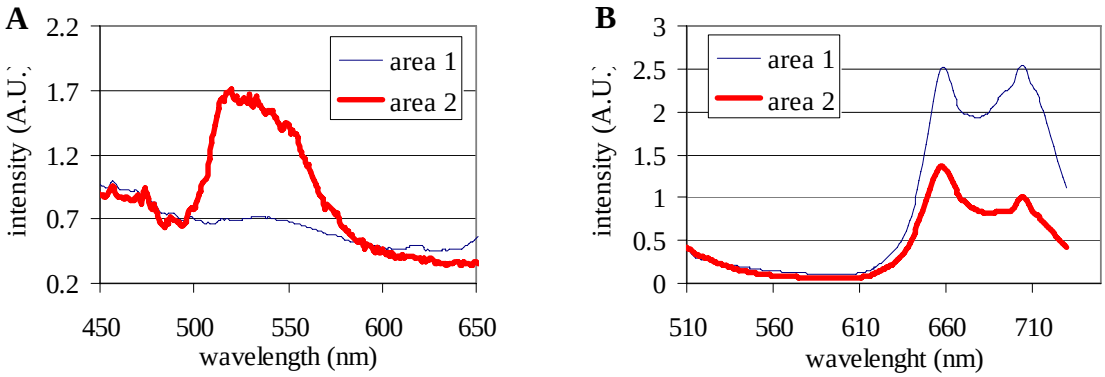


Figure 2, Emission spectra of an infected leaf under A) 365nm UV and B) 480nm excitation illumination. Area 1 expressed visually detectable fluorescence. Area 2 was far from the point of infection and is used as a reference.

Instrumentation for time lapsed, non-invasive, in-vivo whole plant imaging

To monitor the expression and propagation of the virus over time in one live *A. tumefaciensN benthamiana* plant, an UVP BioSpectrum Imaging System was used to perform fluorescence imaging on the infected plant. Built-in 365nm overhead UV was used for excitation. To ensure the maximal dynamic range, the system was set to automatically acquire fluorescent images

using a series of 10 different exposure time settings (25msec to 12.8sec). The cooled CCD camera has no noticeable noise at the long exposure time. The plant was set on the mechanical lift inside the imaging darkroom such that the height of the leaves of interest can be controlled to keep a constant distance with the UV light source and the camera. When the intensity of the excitation light and the distance of the observation are held at constant, the fluorescence intensity is mostly varied by the concentration of virus.

Results

Leaves of the plants were infected with bacteria which contains the GFP-TMV RNA. The bacteria can either be injected orwasere infiltrated using the agro -infection method, as shown in figure 3A. The plants were grown under normal control condition and daily moved to the imaging system for measurements. As early as 48 hours after infection, fluorescence can be observed around the point of infection (figure 3B). Unintentionally, one leaf was showing signs of direct viral infections without the punch mark from agro infection. This can be created from an accidental drop of the infectious fluid on the leaf. This leaf showed fluorescence two days later. The speed of propagation and the intensity of fluorescence are both higher in the stems than in the leaves (figure 3C).

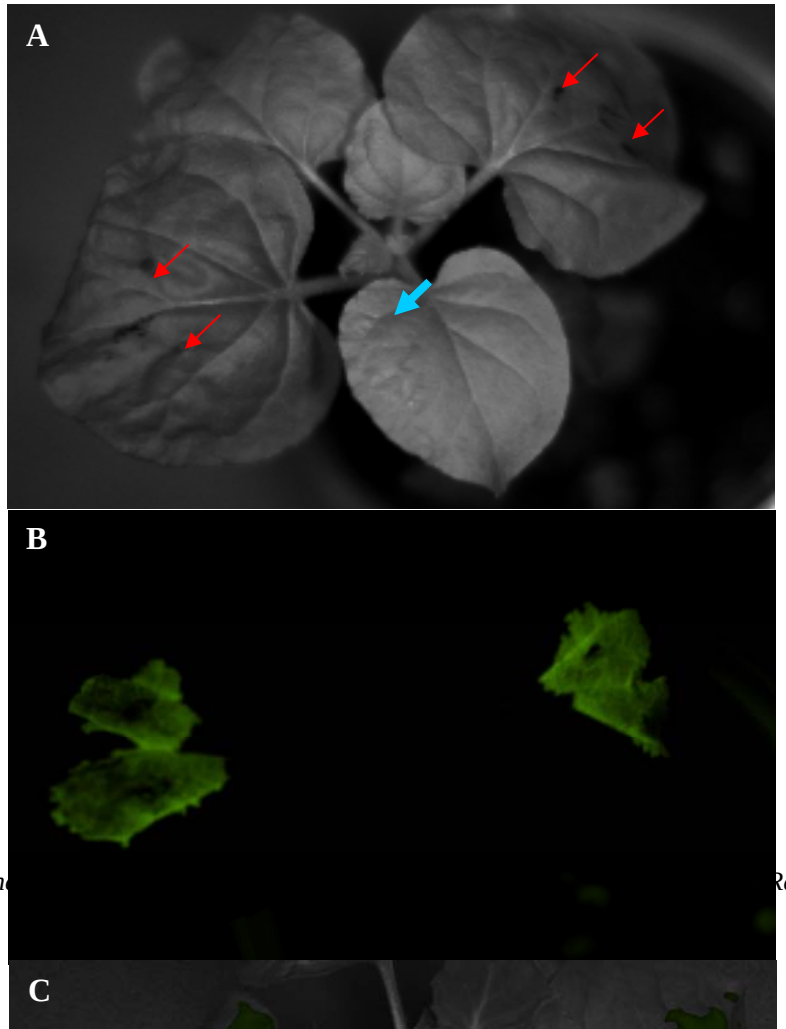


Figure 3A) , white White light image of one plant 24 hours after infection. The thin red arrows indicate the point of injectioninfiltration, and the blue arrow points to an infiltrationarea of initial viral replicationviral infection point without the agro infection punch mark. **B)** theThe fluorescent image of the same plant at 2-dpi in green pseudo color. **C)** theThe overlay of the fluorescent image and the white light image at 10-dpi.

The fluorescence images allows quantitative studies of the viral expression. On different leaves of the same plant, the fluorescence around the infiltration area was observed two days earlier than the infection (figure 4A). The averaged intensity in all detected areas shows that the amount of detected GPF-TMV reaches its maximum 4-dpi. If the bacteria were initially infiltrated, the fluorescence doesn't reach maximum until seven days passed infection. Figure 4B shows the average intensity of five infected areas Ffrom two different plants, five infection points showed maximal expression at the same dpi. .

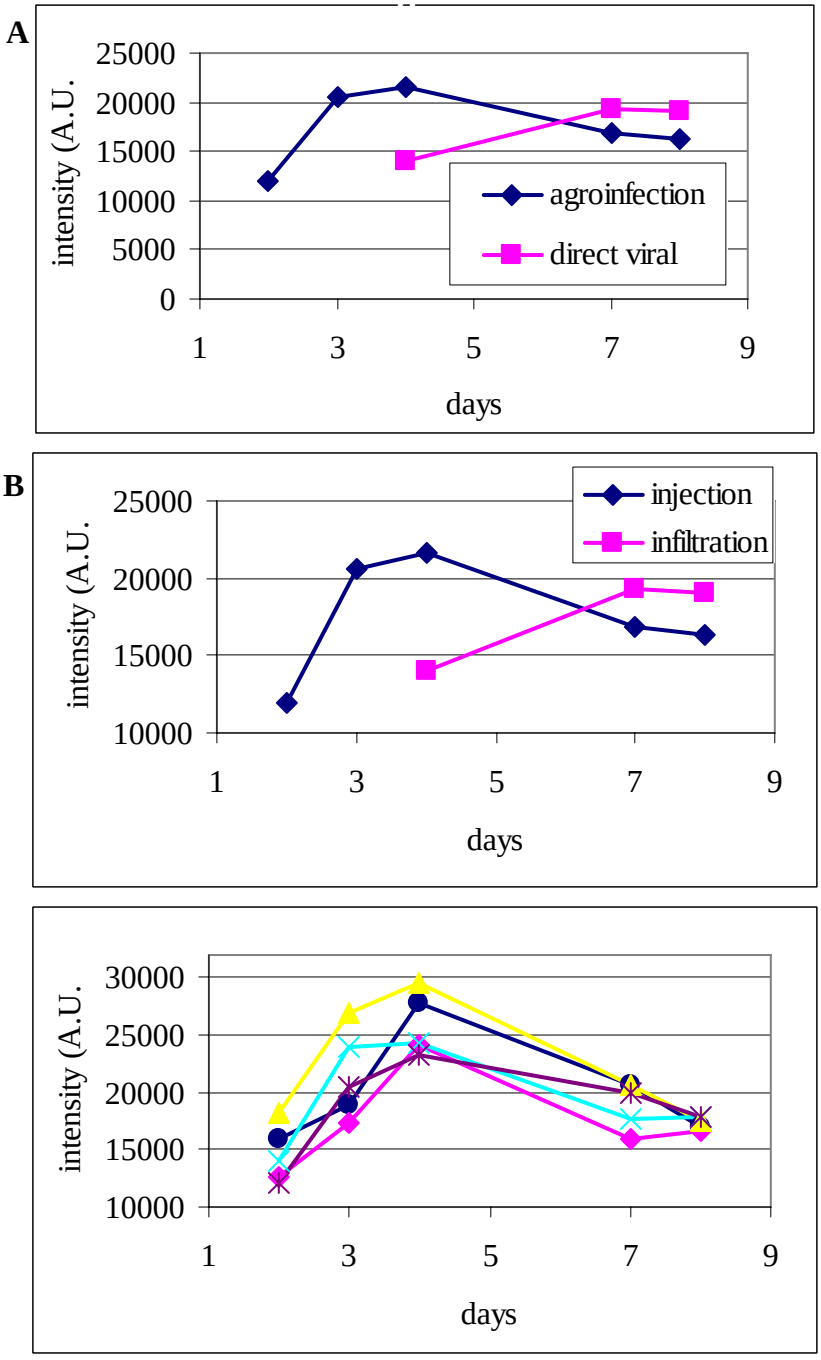


Figure 4, quantitative comparison of viral expression from **A)** different infection methods on the same plant and **B)** injected infection on five leaves of two different plants.

The result of the fluorescence macro imaging suggests that using the designed TMV plasmid would give the highest yield if the plant tissue was harvested at 4-dpi.

Discussion

GFP as a quantitative reporter in live plants

Lindbo (2007) had previously published on using the pJL TRBO vector to report the viral expression in live plants. The amounts of GFP destructively extracted from plants were used to compare the effectiveness of pJL TRBO and other vectors. Although the intensity of fluorescent images shown by Lindbo do seem to correlate with the amount of GFP extracted, it was impossible to compare the day-to-day increase of the viral expression on the same leaf using the destructive method.

To report the viral expression quantitatively with the non-invasive fluorescent method, several variables must be well controlled. Because the produced fluorescence is the function of excitation power and concentration of GFP, the intensity of the excitation illumination per unit area on the sample should be held at constant. In our setup, the UV light source was fixed at the top of the imaging cabinet, and the plant was placed on a computer control lift which can be lowered to maintain a constant distance between the light source and the plant despite its growth over time. This allows the possibility of maintaining the constant excitation power level.

In figure 4A, the infected areas reached their maximums at different dpi. As it is expected that the process should be accelerated when the virus was introduced with agroinfection, the temporal difference of the two curves serves as a control which promises that the increase in fluorescence is from increase of viral expression and not the fluctuation of the imaging setup. Furthermore, as shown in figure 4B, several infected areas on different plants all demonstrated the same temporal behavior: the averaged intensity in all detected areas shows that the amount of detected GPF-TMV reaches its maximum 4-dpi. This is consistent with Lindbo's finding.

Conclusion

Fluorescence intensity acquired from leaves infected with GFP-TMV can be used to monitor protein production repeatedly and non-invasively. The result of the fluorescence macro imaging suggests that using the designed TMV plasmid and agroinfection method would give the highest yield per infected area, when plant tissue is harvested at 4-dpi.

Future work

The pJL TRBO vector is expected to have greatly reduced long range mobility (Donson et al., 1991). Quantification of GFP expression in infected plants may be used to compare the mobility of viruses with altered gene sequences.

Reference

Kohl, T., Hitzeroth, I. I., Stewart, D., Varsani, A., Govan, V. A., Christensen, N. D., Williamson, A.-L., and Rybicki, E. P. (2006) Plant-Produced Cottontail Rabbit Papillomavirus L1 Protein Protects against Tumor Challenge: a Proof-of-Concept Study. *Clinical and Vaccine Immunology*, *13*:845-853.

Grill, L. K., Palmer, K. E. & Pogue, G. P. (2005). Use of plant viruses for production of plant-derived vaccines. *Critical Reviews in Plant Sciences, 24*(4), 309-323.

Halfhill**,** M. D., Millwood, R. J., Rufty, T. W., Weissinger, A. K., and Stewart, C. N., Jr. (2003). Spatial and temporal patterns of green fluorescent protein (GFP) fluorescence during leaf canopy development in transgenic oilseed rape, Brassica napus L. Plant Cell Reports, 22:338-343.

Lindbo, J. A. (2007) TRBO: A high-efficiency tobacco mosaic virus RNA-based overexpression vector. *Plant Physiology, 145*, 1232-1240.

Donson J, Kearney CM, Hilf ME, Dawson WO (1991) Systemic expression of a bacterial gene by a tobacco mosaic virus-based vector. *Proc Natl Acad Sci USA 88*: 7204–7208

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Is "Dewey's Experience" Synonymous with the Current Usage of the Term?

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Abstract

One of the most amazing aspects of higher education, in nearly all cultures, is that while it is generally viewed as valid or important in at least some context, it generally derives its credibility from the external milieus. Thus if intellect is popular, so is higher education – and visa versa. Importantly, this extends well beyond popularity. It includes aspects of acquiring and valuing knowledge that sometimes have the curious effect of putting higher education in the strange position of placating ideas and beliefs that are known (via research and scholarship) to be wrong. While in some ways this is just a political problem that any organization might encounter – it becomes a problem if the results are curricula that lack integrity and ultimately utility. For many fields the key to this problem is the idea of experience. Additionally, there are two aspects to the issue of experience for many curricula. First is the idea that experience is important and necessary as identified externally (beyond higher education) and the second is the idea that some knowledge may not be gained without experience. The following discusses John Dewey and his work, creates a broad description of the concept of experience in higher education for the purpose of further illuminating the aforementioned problem, and provides an initial attempt at a framework for considering the use of experience in curriculum.

Introduction

In order to provide aid to those who wish to consider these issues the following steps are planned. First the American Philosopher John Dewey considered this issue for education generally at the beginning of the twentieth century. He is sometimes thought of as the founder of the American Pragmatic School of Philosophy. The first step in this effort is providing the highlights of Dewey's work in this area with special attention to his book *Experience and Education*[1].

The second step is a discussion of the current usage of experience in higher education. The intention of this discussion is to anecdotally illustrate how views of experience that are external to higher education can create curriculum integrity problems. A metaphor for this might be the idea that it is nice to be fashionable, but the fact that a Lincoln Versailles was once a popular car does not make it a great automobile. This discussion is needed to provide dimension and clarity for the establishment of a framework.

The third step will be to build and present a framework for dealing with this area. The result will be a two by two matrix. Hopefully, many of the issues and tradeoffs for experience can be brought alive is a visual representation of the ideas.

Dewey and experience

Some might classify John Dewey as a social scientist. His first work is on psychology, published three years after earning his PhD at Johns Hopkins University. He is a contemporary of Freud (they never met) and is sometimes discussed with Freud and Skinner as representing one of the three approaches to social thought in the United States. Freud and Skinner would represent the other two[2]. The problem with classifying Dewey as just a social scientist is that it is simply not accurate. Dewey's work can be described as at least 25 books spanning 1887 to 1949; and 41 noted pamphlets essays and other shorter works from the same period. His work can also be descibed as subjects including psychology, philosophy of education, moral philosophy, ethics, education, logic, democracy and even Liebnitz. In fact, by any measure, it is an amazing career. Fairly described, Dewey is a Phiosopher. In his works Dewey discusses experience on may occasions, and his philosophy on experience directly relates to our current environmnet.

One of Dewey's lifelong efforts is the improvement of education. It is likely that Dewey was unimpressed by the educational practices of the late 19th and early 20th centuries. In fact, he makes the following observation in 1902;

The source of whatever is dead, mechanical, and formal in schools is found precisely in the subordination of the life and experience of the child to the curriculum.[3]

This is a good introduction to what Dewey's concern with experience is about. In effect, he observes that we learn by experiencing. His observation for education is that the system in existence at the time of his work is based on an important fallacy. This is that the experiences designed by adults – and particularly to be credible to adults – to teach children were failing. Further, they were failing because these experiences assumed that the child's experience would be the same as the adult's experience.

As one might assume, this is a liberating idea for professional educators. Of course like many liberating ideas, the liberation soon began to resemble anarchy. To get an idea of how this might have looked in the 1920's, one can view the play or movie Auntie Mame. The title character is left to raise her nephew and chooses several avante garde schools for him, until this is curtailed by the executor of her brother's estate.

Dewey was not a proponent of this approach. In fact, he indicates that these efforts were also based on fallacy. That is "experiences" alone – without any vision will not produce an educated person. He spends a significant portion of *Experience and Education*[1] addressing this problem.

So, what is experience? The idea is, in effect, the interaction of a learner and its environment[4]. While this is good news to those who like to advocate a hands-on approach to teaching and learning, it is more complicated in practice.

Current experience issues

One issue that Dewey did not discuss is the impact of the growth of knowledge. In effect, thanks to the "information explosion" there are two additional problems. First, what set of knowledge is appropriate for a "college educated" person in our times. Secondly, education, particularly higher education, is bigger. This is partly due to the information explosion – but raises questions about issues such as a single approach to all of the subjects in higher education. Finally, there are more expectations on higher education – and credibility (the problem first encountered by Dewey) is more important than ever.

The problem for much of higher education is restated as the credibility of graduates. In effect, a program is considered good if it is credible with external validation. Of course a well known approach to this problem is to require more background of the students when they are admitted. Many MBA programs require five years of business experience before one can be admitted to the program. This certainly makes the graduates credible, but the nagging question that remains is what did they learn in the program that they did not already know?

There is also a problem for knowledge that "must" come from interacting with the artifact. While this would definitely be knowledge gained from experience, and something Dewey would likely endorse, what happens if the experience is not credible? This is often witnessed in computer programming. What is the best approach to teaching programming? There have been groups that advocate that you use a language that is designed to teach programming. Others advocate that you teach a language used by a relevant community to help the students adapt to that community. While this might seem minor – consider the idea that there are computing programs in existence in the United States that taught COBOL and only COBOL for more than twenty-five years. Also consider the idea that there is a body of discussion about how COBOL is the worst language to use for teaching programming. Who was right is not a matter for this paper, however, the question "Would COBOL have been an introduction to programming language in any program if it were not for the availability of external validation?" is an important question.

Framework

From both the work of Dewey, and the experiences of our own times two aspects of experience appear as very important. The first is the hope of experience that will increase knowledge. The second is the idea of the experience being credible with some external validation. This seems like an ideal application for a 2x2 matrix[5], along one axis increasing knowledge and along the other increasing credibility.

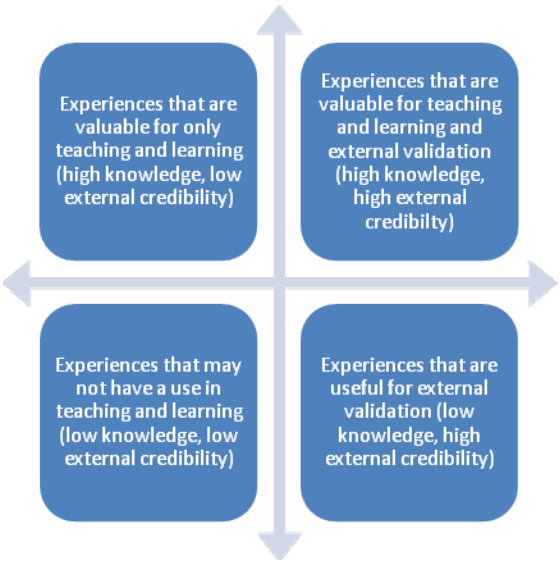


Figure 1 - A 2x2 Matrix of Knowledge and Credibility

The quadrant that has experiences that are likely to require the most attention is the upper right. These are experiences that both increase knowledge and increase credibility. An interesting example of such an experience in programming might be competing in (and perhaps winning) an interschool programming competition.

The most difficult quadrant for teaching and learning is the lower right. In that quadrant the experience has high external credibility and has a low potential for increasing knowledge. A programming example (for the sake of programming and not other purposes) might be building WEB sites for an external organization. This is very likely to have high external credibility (and could even earn some publicity), however, the likely increase in programming knowledge is low.

Another difficult quadrant for teaching and learning is the upper left. In that quadrant the experience has a high potential to increase knowledge, and a low potential for external credibility. An example from programming might be the use of the Scheme programming language. This choice is likely to provide several advantages for teaching and learning, however, it is unlikely to have an external interest. This is particularly the case if there is no external user of the language near where the language is taught.

The last quadrant on the lower left appears easy. These experiences do not have much potential to increase knowledge, and do not have much credibility. A programming example might be teaching an application – for example Power Point. This is unlikely to increase knowledge about programming, and is unlikely to have external credibility for programming. Interestingly, this can happen.

The most likely use for this framework is to provide a means of classifying experiences. However, this can also be used to balance experiences – particularly making sure that most of the experiences increase knowledge. Additionally, the increase must make sense in terms of the development of the student.

Conclusion

The intended outcome is a guide for this issue. Thus, those that are on occasion confronted with these issues have a quick reference resource to at least help in formulating questions for a refined discussion and perhaps an improved situation in their domain.

This work is mainly intended to aid curriculum discussions. However, given both the growth of knowledge and the observations made by E. O. Wilson in *Consilience: The Unity of Knowledge*[6] this is particularly important in those instances where disciplines must combine and cooperate for the purpose of building new knowledge! Thus, academic and nearly all knowledge workers could find a utility in this discussion.

Bibliography

1. **Dewey, John.** *Experience and Education.* London and New York : Macmillan, 1938.
2. *Dewey and Freud.* **Seckinger, Donald and Johanna Nel.** Jackson, WY : ERIC ED379181, 1993. Annual Meeting of the Northern Rocky Mountain Educational Research Association. p. 7.
3. **Dewey, John.** *The Child and the Curriculum.* Chicago : University of Chicago Press, 1902. p.14
4. **Strathern, Paul.** *Dewey in 90 Minutes.* Chicago : Ivan R. Dee, 2002. p.40
5. **Lowy, Alex and Phil Hood.** *The Power of the 2 x 2 Matrix: Using 2x2 Thinking to Solve Business Problems and Make Better Decisions.* San Francisco : Jossey-Bass, 2004.
6. **Wilson, E. O.** *Consilience: The Unity of Knowledge.* New York : Knopf, 1998.

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CIBRED: Engineering Education on Cyberinfrastructure with a Multidisciplinary Approach for Non-Engineering Students

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ABSTRACT

Although the role of cyberinfrastructure in engineering education and research is advancing, the use of the concept and infrastructure are quite limited in the courses for the allied health professionals. CIBRED* (CI-TEAM Implemenrtation for Biological Researchers, Educators, and Developers), an NSF funded project, provides a unique opportunity for these authors to introduce the concept of cyberinfrastructure to non-engineering educators and students by designing, developing, and deploying course materials with a interdisciplinary approach. At present, two courses are being developed for deployment and assessment during Fall of 2009. These interdisciplinary courses are being developed in a modular format integrating scientific and technology information from a variety of disciplines. These modules can be incorporated into existing or newly developed courses. One module is for allied health professionals to learn about cyberinfrastructure for healthcare management. The other module focuses on human migration, which introduces engineering education to the undergraduate students from humanities and social sciences. Project-based learning concepts have been implemented in developing these courses to teach various relevant disciplines. The focus is to teach students from diverse disciplines some essential concepts on computer technology in the context of applying cyberinfrastructure. These courses developed for K13 & K14 levels will be offered in an innovative classroom setting for hands-on experimental learning with a focus on solving scientific problems as a team. These courses will also be deployed for online learning in a virtual classroom. The effectiveness of such an approach, introducing concepts from engineering education to the non-engineering students, will be assessed through formative and summative methods for further development and dissemination.

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INTRODUCTION

Advances in various technologies in biology, medicine and computation have enabled researchers to generate more experimental data for understanding medical science at the molecular level. This

trend is now common in most of the scientific fields that can be exploited for data utilization, data analysis and more useful data mining and visualization of data. Moreover, the advances in computational technology are changing the way research is conducted in all aspects of science and have led to the generation of seemingly limitless possibilities of national and international collaboration and sharing of data for research, education and training. The Office of Cyberinfrastructure (OCI) was created at the National Science Foundation in June 2005[1] following the recommendation of a Blue Ribbon Committee chaired by Daniel Atkins of the University of Michigan to formulate the scientific policies leading to more useful collaboration using computer technology and coordinating these activities building the infrastructure[2,3] The vision of the OCI is making it possible to bridge the gap between the research data infrastructure and the scientific community through federated database systems, collaboratories, and a powerful portal with high performance computing capability for tracking, analyzing, visualizing and interpreting the experimental data and results[4]. Through competitive, merit-reviewed awards for leading-edge, IT-based infrastructure, which is increasingly essential to science and engineering leadership in the 21st century, OCI is developing an infrastructure, termed Cyberinfrastructure (CI) to facilitate rapid progress in education and research.

Cyberinfrastructure and teragrid

"Cyberinfrastructure" describes integrated information and communication technologies for distributed information processing and coordinated knowledge discovery, which promises to revolutionize the way that science and engineering are done in the 21st century and beyond[3]. It is the coordinated aggregate of software, hardware and other technologies, as well as human expertise, required to support current and future discoveries in science and engineering. Thus, CI includes supercomputers, data management systems, high capacity networks, digitally-enabled observatories and scientific instruments, and an interoperable suite of software and middleware services and tools for computation, visualization, and collaboration[1]. The challenge is to integrate relevant and often disparate resources to provide a useful, usable, and enabling framework for research and discovery characterized by broad access and "end-to-end" coordination. NSF has sponsored projects to develop principles for the "design and evaluation of IT-enabled scientific "collaboratories," or "centers without walls" in which researchers can perform their research without regard to physical location, interacting with colleagues, accessing instrumentation, sharing data and computational resources, and accessing information and data in digital libraries and

repositories" (details at www.nsf.gov). One such project, TeraGrid, is a national-scale high performance computing facility to provide large scale resources and services in support of advancing scientific research and education[5.6]. Presently, TeraGrid (TG) includes 11 Resource Providers (RPs) and is a leader and major component of the emerging national and international e-Science (details at www.teragrid.org). TeraGrid is an open scientific discovery infrastructure combining leadership class resources at partner sites to create an integrated, persistent computational resource. Using high-performance network connections, the TeraGrid integrates high-performance computers, data resources and tools, and high-end experimental facilities around the country. Currently, TeraGrid resources include more than a petaflop of computing capability and more than 30 petabytes of online and archival data storage, with rapid access and retrieval over high-performance networks. Researchers can also access more than 100 discipline-specific databases in TeraGrid. With this combination of resources, TeraGrid is the world's largest, most comprehensive distributed cyberinfrastructure for open scientific research. Thus, CI supported by Teragrid is becoming the foundation of 21st Century's discovery through innovative scientific research.

Over the years, the role of CI has evolved. Initially, CI was defined by its role – a research environment to support advanced data acquisition, data storage, data management, data integration, data mining, data visualization and other computing and information processing services over the Internet. Soon the definition incorporated the advances enabled by CI and CI became the technological solution to the problem of efficiently connecting data, computers, and people with the goal of enabling derivation of novel scientific theories and knowledge. In its current stage, CI is taking its place in the advancement of education as a platform for delivery of learning content and continues to advance into a platform to expedite the transition from research data to pedagogical practice[7]. The latest role of CI advances in the face of the realization that a new workforce needs to be trained in the CI environments in which it will function.

Earlier, an awareness program on CI was launched under NSF funded 'inFormation Year 06-07' by the HASTAC organization (www.hastac.org). Among the events organized by nine participating institutions, 'InCommunity' was organized by the NU Community Research Institute (NUCRI) of the National University to promote the concept of CI to the community (archives can be viewed at http://nucri.nu.edu/incommunity). Nevertheless, integration of the engineering

concept of CI is very limited, especially to the non-engineering students due to the lack of appropriate course curriculum for schools and colleges.

Skilled workforce needed to sustain CI/Teragrid Program

Central to this CI environment is the most important element, the skilled workforce that is required to maintain and sustain this program (Figure 1). Two components toward the development of the new workforce are needed: educators with an understanding of the demands of CI and materials for training the students. In answer to some of these needs, OCI has now established a rich source of educational and research materials through TeraGrid to meet the 21st Century's demand for scientific talent (Materials are freely available through CI/TeraGrid – www.teragrid.org). Additionally, OCI put forth the CI-TEAM (Cyberinfrastructure, Training, Education, Advancement, and Mentoring for Our 21st Century Workforce) program to aid education initiatives directed toward this new workforce. Training of a 21st Century workforce demands students have a firm grounding in interdisciplinarity, especially in the sciences.

Today's young generation born in the technological landscape of the digital age is already familiar with participatory media[8] and the practice of integrating knowledge with the aid of digital tools, such as, iPhone or Google phone, and even interacting with unseen peers in the digital metaverse space, such as, in Second Life (http://secondlife.com/). The goal now is to harness and develop these skills. However, the problem is to find instructors who can meet the challenge of training these students and serve as a bridge between these techno-savvy students and the scientific discoveries happening in the CI supported techno-sphere. Many educators today are not familiar with the requirements of the 21st Century digital age where information literacy[9,10] and multimedia savvy are required skills.

The role of CI in education and training and CIBRED

The National Research Council and the US Department of Education conducted a study[11] to evaluate teaching and learning and the use of technology. This study recognized that the proper use of computer technology helps the learning process. Computational technologies have proven to have profound impacts on the practice of science and engineering[3]. TeraGrid has developed many resources of research and educational materials exploiting the computational technologies (TeraGid07 & TeraGrid08). CI's and its role in adhering systems, tools, and services emerging

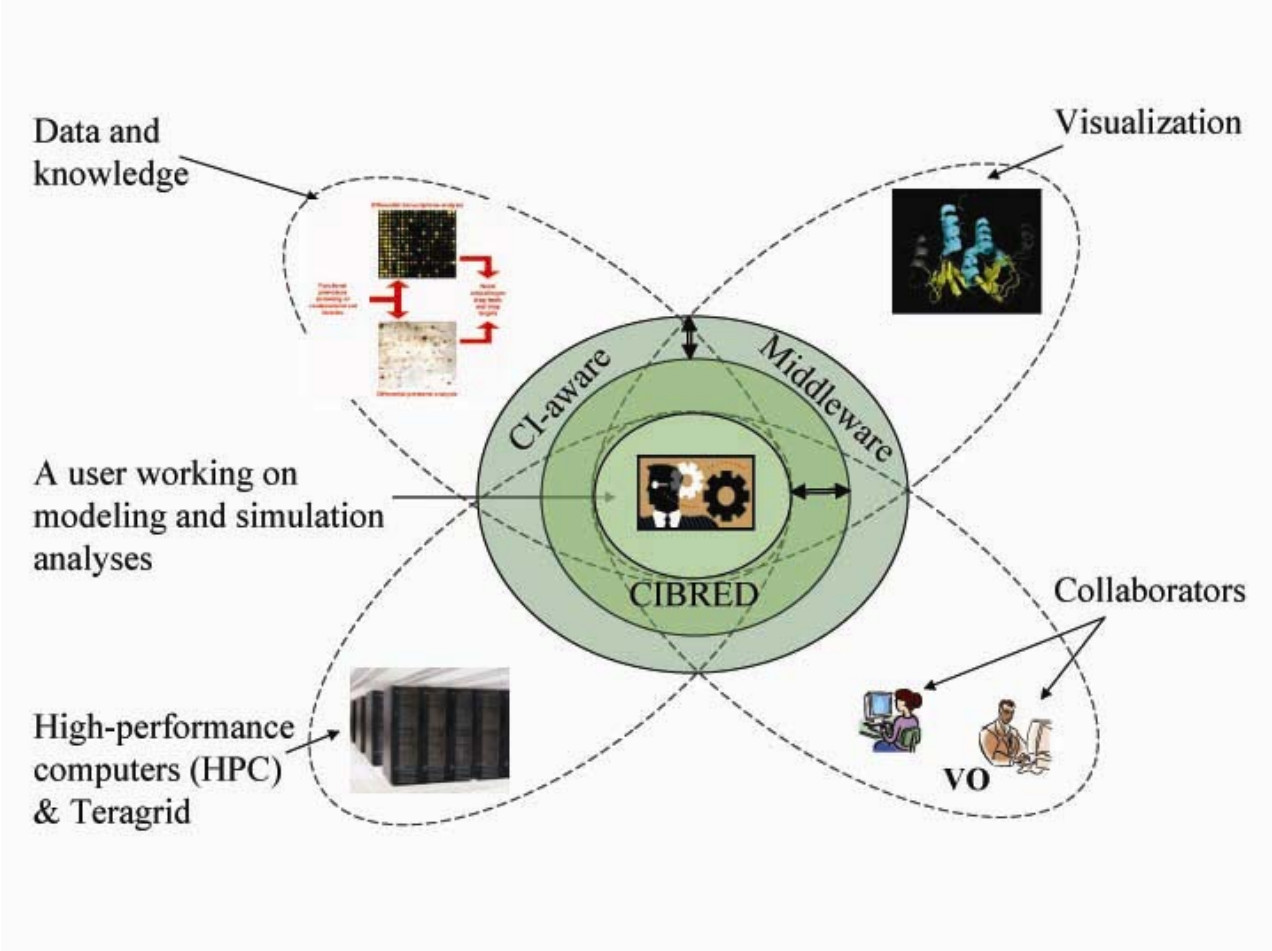


Figure 1. Relationships between the knowledge worker at the center of the CI with high-performance computers and Teragrid, middleware, VO (virtual organizations), data management and knowledge discovery, and visualization services. The objective of CIBRED is to educate and bring awareness of CI (*Courtesy of S. Wang*[12]; *courtesy of S. Watowich*[13]).

from computational technologies, enables individuals, groups, and organizations to advance research and education in ways that revolutionizes the practice of participation. Once again, a new workforce empowered with the knowledge and skills to design, deploy, adapt and apply CI, are needed to sustain this revolution across all areas of science and engineering. The OCI CI-TEAM program supports educational training projects that position the national science and engineering community to engage in integrated research and education activities promoting, leveraging and utilizing cyberinfrastructure systems, tools and services (more info at, http://www.nsf.gov/crssprgm/ci-team/).

One such program, CIBRED (CI-TEAM Implementation for Biological Researchers, Educators, and Developers), brings together faculty, researchers, educators, and academic

administrators from multiple institutions to design, develop and deploy course materials in a collaborative way with the objective of preparing future scientists, engineers, and educators to adopt and deploy, cyber-based tools and environments for research and learning, both formal and informal (for more detail, see: cibred.vbi.vt.edu). The activities involve a diverse group of people and organizations, with particular emphasis on the inclusion of traditionally underrepresented individuals, institutions, and communities as both creators and users of cyberinfrastructure. Like all CI-TEAM funded projects, CIBRED seeks to broaden and diversify the population of individuals and institutions leveraging existing or current development efforts in cyberinfrastructure technologies, open software standards and open educational resources. The vision of this program is to realize the potential of cyberinfrastructure and high performance computing to empower a larger and more diverse set of individuals and institutions to participate in science and engineering education, research and innovation. The mission is to develop and evaluate an extensible, scalable, and comprehensive learning program for the students at academic institutions to effectively utilize CI and TeraGrid resources and services, to advance scientific discovery in all fields.

Six fundamental tenets underlie the CIBRED project:

1. New scientific discovery will increasingly require transdisciplinary research within a cyberinfrastructure (CI) environment.
2. Scientists require increased knowledge and proficiency in team science to conduct transdisciplinary research within a CI environment.
3. There is a decrease in the number of students entering the STEM disciplines.
4. Curricula for existing students require new courses that are built on the principles of team science and methodology for conducting transdisciplinary research within a CI environment.
5. Learning environments must increasingly engage students in STEM disciplines, build awareness of team science and transdisciplinary research within a CI environment, and inspire students to further investigate or pursue a career in these areas.
6. To prepare future scientists, existing researchers and developers must be linked to educators and learners to create data-rich learning environments.

CIBRED, will help bridge this gap by training the trainers through workshops. Although TeraGrid and SC Community (http://sc08.supercomputing.org/) periodically conduct courses through workshops to train people for CI/TeraGrid, CIBRED workshops will specifically serve the school teachers and college instructors to enable teaching CI embedded courses in the classroom.

CIBRED for interdisciplinary courses

This project was not proposed to design courses for a specific scientific discipline, but rather to utilize the information from multiple disciplines while developing some courses for CIBRED. Participating institutes are: Virginia Tech University (VT), National University, Howard University, Hampton University, Denbigh High School, Pheobus High School, Blacksburg High School, Auburn High School, and Galileo Magnet High School. The project established the objectives and goals for team collaborations via a kick-off meeting on April 10, 2008 (The agenda and the copy of all presentations of this meeting can be found at: http://staff.vbi.vt.edu/bsharp/CIBRED_Workshop/Minutes.htm). A variety of CIBRED-course materials for both high school (K8 -K10) and college levels (K13 – K14) are under development by the participating institutions. These course materials are being developed in a modular way, the concept of CI as the common module, for disseminating institutions to choose from according to their standards of learning. The courses are developed by integrating scientific and technology information from a variety of interdisciplinary fields ranging from basic concept of CI, Molecular Biology, Bioinformatics, Genomics and Proteomics to Health Informatics into modules. These modules can be incorporated into existing or newly developed courses. To accommodate specific needs of various institutions and to facilitate adaptation by additional institutions in the future, we have standardized the framework in the following areas[14]:

a. Introduction to CI
b. Inclusion of current research (context, data, and tools)
c. Role-based involvement of the students for transdisciplinary learning; and
d. Forward-looking conclusion of the project with review of the CI systems.

Project based learning concepts[15-18] have been implemented in developing these courses to teach various relevant disciplines. The focus is to teach students from diverse disciplines essential concepts on computer technology in the context of applying CI. The type and number of role-based modules to be incorporated into a CI course will be solely at the discretion of the deploying

institution. Each course will finish with a CI reflection component that reiterates the basic CI components learned, relates them to the role-based modules, and addresses the potential applications of both the specific scientific domains utilized and CI.

CI for allied health professionals

Concerns for the seemingly exponential rate of increase in US healthcare costs have had an impact on the national economy. This concern was reflected in President Obama's first State of the Union Address on February 24, 2009. A component of these rising costs has been identified as the lack of coordination of patient medical records due to the continued and widespread use of paper records. The use of paper records inhibits the ability to coordinate care, measure quality, and reduce medical errors. Processing paper claims also costs twice as much as processing electronic claims. The Obama administration has adeptly targeted a strategy to increase the use of healthcare informatics as a means to update the healthcare system and simultaneously reduce costs associated with uncoordinated patient information. A thorough analysis of the present state of healthcare has revealed that the lack of standards for sharing health related information contributes to increased health care costs through a redundancy of services[19]. Developing the state of health informatics has the potential to eliminate many of these concerns and increase the efficiency of the system. The present US administration's plan is to invest approximately $50 billion over the next five years to move towards the adoption of standards-based electronic health information systems, including electronic health records in the nation's health system. In February 2009, President Obama provided $19.2 billion for health IT in the American Recovery and Reinvestment Act. This legislature is expected to create a demand for skilled healthcare professionals with knowledge of CI. With this in mind, a CIBRED course, 'Cyberinfrastructure in Healthcare Management' has been created for the students at undergraduate level (K13-14).

Medical informatics is a transdisciplinary science that requires domain knowledge of various disciplines, such as, medical science (anatomy, physiology, etc.), molecular biology and bioinformatics, computer technology, among other fields. In the field of modern molecular medicine, advanced computational technologies will certainly play an important role in managing and analyzing massive quantities of medical data once knowledgeable workers are available to serve this growing field. In the treatment of cancer, for example, it is already accepted that it is more beneficial if a patient is treated on the basis of his/her personal health profile by using

information obtained from various data including data from microarray analysis, toxicogenomic analysis, pharmacogenomic analysis[20,21]. Such analysis supported by CI will enable a medical specialist to treat a cancer patient in future by prescribing right medicine at the right dose(s) based on the individual's profile. Over time, it has been realized that individuals respond differently to drugs and sometimes the effects are unpredictable. Safer treatment will utilize the knowledge synthesized from the intersection of genomics and medicine supported by CI, which has the potential to yield a new set of molecular diagnostic tools that can be used to individualize and optimize drug therapy[22].

As discussed during BIO2008, it is becoming clear that a new understanding of the dynamic interplay between genes and environment, made possible by technologies arising from the Human Genome Project, helps support the individualization of medicine[23,24]. Currently, available software tools and focus on data analysis do not provide a platform for the management of patient information[25]. A shift in technology fueled by computational thinking[26] is needed to speed the coupling cyberinfrastructure and medical informatics rapidly and economically[25,27]. Computational modeling and simulation based on cyberinfrastructure-enhanced medical informatics allows researchers to tackle large and complex medical problems[28].

Although the author (AKD) has gained knowledge in both the molecular biology and computer science by educational training and working several years in medical institutes, it is virtually impossible for any one educator/domain expert to develop a course focusing on transdisciplinary concepts and problem solving needed to train the health-informaticians and others needed to serve the 21st Century workforce. A collaborative framework has been designed involving domain experts from the Virginia Bioinformatics Institute at Virginia Tech and the National University in an attempt to develop such a course. Modules will be used so that subjects can be flexible enough for adapting the course. The current modules focus on helping students to develop and understanding of the importance of cyberinfrastructure framework to address critical issues at the societal level, thus introducing the transdisciplinary nature of the project. The course has four main modules: 1) Introduction to CI, 2) Molecular Biology and Bioinformatics, 3) Health Informatics, 4) Vaccine Development and Drug Discovery. The second module is being developed with the help of domain experts available from the Virginia Bioinformatics Institute at Virginia Tech. One author (AKD) is developing the third module 'health informatics'. The Health

Informatics module stems from a course developed and taught for undergraduate allied health professional students at the School of Health and Human Services at the National University. The feedback obtained from the students has become useful in developing this current module. The other two modules are being developed by these authors with the feedback from TeraGrid Resource Providers, feedback from the Campus Champion Program[6,29,30], University of California-San Diego, and The Scripps Research Institute.

One case study used in the project is dengue management. Nevertheless, for the project, an instructor can consider any other disease management using this case study as a model. Dengue, transmitted to humans by the domestic, daytime-biting mosquito, *Aedes aegypti* (Figure 2), is caused by four closely related virus serotypes of the genus Flavivirus, a member of the family Flaviviridae. Each serotype is sufficiently different that there is no cross-protection and epidemics caused by multiple serotypes (hyperendemicity) can occur. According to WHO, 50 million cases



Figure 2. This infected female mosquito, *Aedes aegypti* (and rarely *Aedes albopictus*) transmits dengue virus to humans through the bites. Mosquitoes generally acquire the virus while feeding on the blood of an infected person. After an incubation period of eight to 10 days, an infected mosquito is capable, of transmitting the virus during probing and feeding for the rest of its life[31]. Public awareness to control this daytime-biting domestic mosquito needs to improve through education and community outreach.

are reported annually across the globe (Figure 3). Often the victims suffer from more serious symptom, Dengue Hemorrhagic Fever (DHF/DSS), which may turn fatal. In 2002 alone, 91 deaths occurred in Brazil. This disease previously unknown in US is becoming a concern of the Center for Disease Control (CDC). National Institute of Allergy and Infectious Diseases (NIAID) experts now see dengue as potential threat to U.S. health[32]. Unfortunately, there is no drug or vaccine, at present, to cure dengue. Public health education to control the mosquito or the disease is not good enough even in the countries where it is prevalent. Outbreak of this disease is also common. Moreover, global warming apparently is changing the pattern of infection: more people residing at higher altitude in countries like Costa Rica are becoming infected, causing a grave concern. There are various elements to learn by studying this disease, and thus, may be used as a case study for CI – supported disease management.



Figure 3. Global distribution of dengue infection. The vector mosquitoes are prevalent in tropical and sub-tropical areas. However, these are now causing concern not only in Central and South Americas but also in North Americas. Apparently climate change has a profound effect on these vectors. People residing in higher altitude in Costa Rica, as for example, are becoming infected.

Method of teaching/learning - Project-centric hands-on experimental learning

Learning is a complex phenomenon that depends on various factors including the student's state of mind[11]. The same topic delivered by the instructor in the classroom is 'learnt' differently by different students. There are various techniques to improve the teaching techniques for facilitating learning[33]. Among the teaching techniques we tested, we realized that agile techniques supports learning techniques better[34]. In general, many strategies can be employed, including problem-based learning[15-18], technology-based learning[35], game-based learning[36,37], work-based learning[38,39], inquiry-based learning[40,41], project-based learning[42,43], team-based learning[44], web-based learning[45,46] and participatory learning[8]. Our approach for teaching this course centered on project-centric learning[14] with support of agile teaching technique[34]. The course has been designed with background information (cyberinfrastructure) introduced at the beginning and summarized at the end. However, how to balance the load (in terms of both time and knowledge) among students from multiple disciplines remains a challenge.

A disease management includes a variety of disciplines including Clinical study, Public health education and training, Epidemiology, Environmental issues, local and national resources supported by Geospatial Information Systems (GIS) in case of an outbreak/epidemic, Electronic

Health Record and other Health Informatics –tools and Services, Disease outbreak predictive tools, Decision Support Systems, Drug Discovery Research, Vaccine development - to name a few. Moreover, a student needs to know various public policies including HIPAA compliance (see: http://www.hhs.gov/ocr/privacy/index.html) and FERPA (see: http://www.ed.gov/policy/gen/guid/fpco/ferpa/index.html) for school-aged children. Patient's data sharing even among the healthcare service providers are restricted by these compliances. The law also dictates how the permission should be obtained from parents while sharing the health related data on minors.

In a typical classroom setting, an instructor will initially provide all the relevant information on this disease management supported by this course through lecture and demonstration. In this phase, the CIBRED course instructors will provide background information necessary for the students to understand the scenario for the project and to develop strategies for investigations including identification of the virus, accessing the TeraGrid and National network of bioinformatics resources, and suggesting control of preventive measures in case of an outbreak and the role of Geospatial Information Systems (GIS) in coordinating the resources. In the second phase, following the agile problem driven teaching techniques[34], an instructor will survey the students' aptitude & interest and will facilitate forming a group/team working on a given project, such as, dengue case management. The students will then work through the scenarios assuming different roles in the team. Each team may utilize different tools and address the problem from a different perspective. Some students can assume a role as clinicians, as for example, to 'diagnose' the disease by conducting a series of pathological tests including blood tests and checking the physical symptoms. In doing so, the students need to learn what the symptoms are for dengue and what sort of laboratory tests are required to diagnose such a case. This dengue management project will specifically require students to use various computational and web based tools to discover the identity of the virus, given some preliminary biological data under the supervision of the instructor and in consultation with the researchers and sequences to test a hypothesis regarding the origin of the sample sequence (Figure 4). Students will practice what they would learn by becoming familiar with large, CIBRED team. They should also need to learn about the DNA sequencing that generates a code for a portion of a pathogenic genome derived from a biological or environmental sample. The project will require learning about how gene sequences are stored and how to access

these comprehensive repositories such as the NCBI database Gen-Bank, and focused bioinformatics resources, such as, Patho-Systems Resource Integration Center (PATRIC),

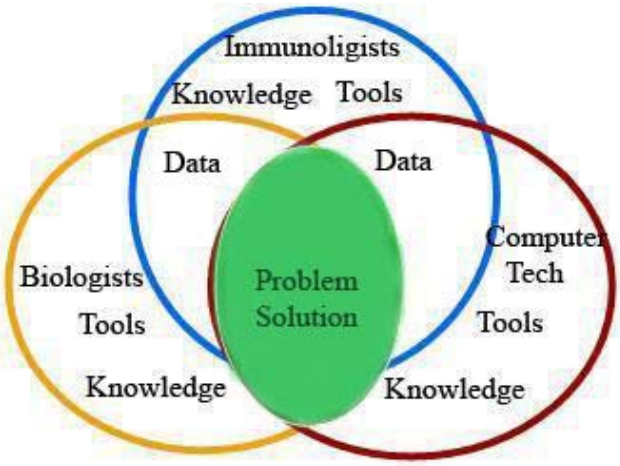


Figure 4. The key to solve a scientific problem is to gather vital information from a variety of disciplines, synthesize those to acquire knowledge. These information are gathered through experiments, literature search, enquiry and communication.

Pathogen Information (PathInfo), and Molecular Interactions Network (MINet) documents that are maintained at Virginia Bioinformatics Institute (VBI), TeraGrid, Biological Workbench http://workbench.sdsc.edu/) or elsewhere on the Internet. Techniques for comparing and manipulating sequences will be addressed to insure students could use similarity to a known genetic sequence to predict possible function for a sequence of interest. In the process, putative genes needed to have their sequences translated to protein sequences for functional features to be identified. Predictions of structural featutures of the protein, such as secondary structure, signal sequence and transmembrane segments, will provide them the first clues as to what types of proteins are present. They will learn the basic information on proteins, how a protein is synthesized in a living cell and folded into a 3D-structure, what factors primarily are responsible for folding into that structure, how a protein can be selected as a drug target. Protease is regarded as a potential drug target for dengue[48,49], and the references therein). Some students can use molecular modeling techniques for this protein[50], during the investigation. Target selection can, however, be made after several proteins are investigated using multiple data resources, including expression

data where available. Experimental laboratory analysis could provide students with new information about the target that may be analyzed to generate possible leads in the search for drug candidates. In the process, students will also learn about small molecule drug discovery supported by World Community Grid (http://www.worldcommunitygrid.org/) of IBM and how that is being used by a scientist, Stanley Watowitch, at The University of Texas Medical Branch (Galveston) for small molecule potential drug candidates against dengue virus[51] (also, see the story at http://www.tacc.utexas.edu/research/users/features/worldgrid.php). Searching his publications in PubMed followed by reviewing the information, and may even interacting with his team at UTMB, the students will learn how computational screening is done for identifying small molecules as potential drug candidates and later conducting cell biology experiments to verify their computational screening results. They will also learn how a small molecule candidate drug can be 'discovered' through structure-based drug design technique when a 3D- structure of the protein molecule is known following the experiments using X-ray crystallography or NMR technique. Some students can assume a role as researchers for vaccine development. They will learn what is vaccine, what is immunity, what is antibody and how do they take part in conferring immunity against a disease, such as, dengue. They will also learn how the environment plays an important role in host-pathogen interaction (Figure 5). In the process, they will need to know the genus (Flavivirus) and family (Flaviviridae) of a dengue virus. They will also learn how a single family can be responsible for causing multiple

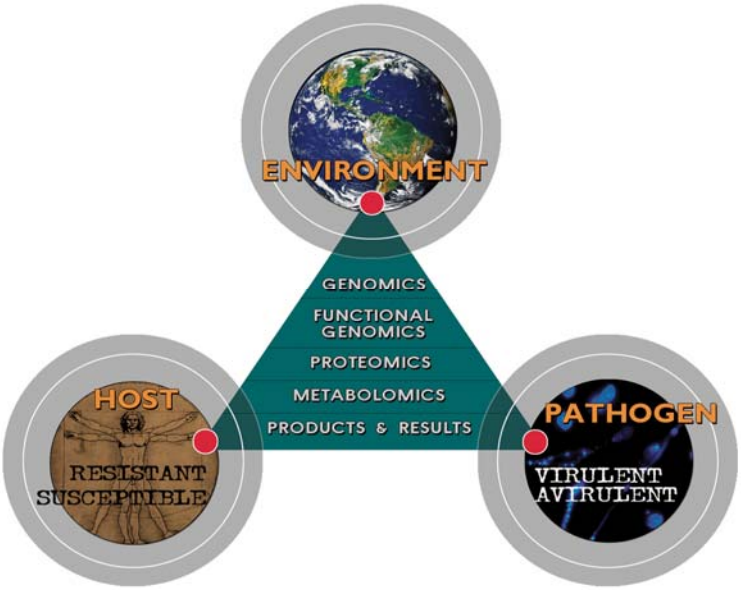


Figure 5. Environmental factors play important roles in the host-pathogen interaction[47].

major diseases including hepatitis C, dengue, Yellow fever, and West Nile fever. They will learn that these viruses are positive strand RNA viruses and their mode of pathogenecity is similar (see: http://www.bioinformatics.org/dengueDTDB/Pages/main.htm). It will be necessary to characterize

the family and use the sequences to generate a multiple sequence alignment to profile the family for subsequent investigation. They will also learn how a 'protein motif' can be selected using computational technique and bioinformatics tools before selecting the right monoclonal antibody(ies) for clinical trial. Such a study is being done in the laboratory of Eva Harris at UC-Berkeley[52,53]. Her collaboration with researchers in Managua (Nicaragua) has established informatics system to identify and monitor dengue infected cases[54]. Most of these information and experimental results are available in PubMed. In addition, this approach will provide the students unique opportunity for hands-on experimental learning with a focus on solving scientific problems as a team. At the end, it is expected that the members of each sub-team will generate a report on their analyses and present those to the other team members. These reports should contain enough information and need to be presented in a clear fashion for other members to understand the information and for the entire group to agree upon a conclusion. Such exercise will also teach them working in a team through social networking & associated tools, because it will be necessary for these students to cooperate with each other to achieve the best results. Finally, the students will assemble the information, synthesized interpretations and conclusions, and may communicate the results to the live and online community. Earlier, during the CIBRED demonstration phase, one of the participating students described her involvement to the local media, and the interview was posted for the government bio-defense agencies such as DoD, NIAID, and the scientific experts in this process.

CI for Humanities and Social Scientists

A module for teaching CI impact on studying 'Human Migration' will be designed and deployed at the college level (K13-14). Advances in technology have had an impact not only on biological and medical sciences, but also on social sciences. Anthropologists have begun to look at the relationships between human migration and cultural diversity with a different lens. Influenced by discoveries in genetics as a result of the Human Genome Project and other scientific milestones, new data has opened the door to meaningful research and provided insights into the connections between human evolution, migration, cultural diversity and diversity[55] (also see, https://genographic.nationalgeographic.com/genographic/index.html for more information). Old concepts have been revisited in light of new information such as the role of natural selection and mutations in genetic variations and the more recent emphasis on the concept of genetic drift. Projects are underway to create an International databank for DNA samples in an effort to obtain

larger and more comprehensive data sources. Needless to say, an interdisciplinary and transdisciplinary academic approach that includes cyberinfrastructure, science and the social science is a relevant and timely prospect for helping students become scientifically literate.

Students will be introduced to the extensive information on the evolution of mankind. Research by key theorists and practitioners, especially the most recent works of Luigi Luca, Sforza-Cavalli and Stephen Wells[56-58] will be explored with the idea of tracing ancestry and cultural groups and tracking scientific methodologies to the present. They will also have an opportunity to review the work of Allan Wilson and Rebecca Cann's research on mitochondrial diversity and mtDNA sequencing[59], which supported the notion of a "single ancestry" prompting the sentiment "Eve is the connecting link for humankind." Information from the National Institutes of Health's National Human Genome Research Institute offers examples of human migration and genetics (see: http://www.genome.gov/25019968). Other scientific search data sources will be included that will focus on understanding cells, genes, DNA, chromosomes (mtDNA and Y - chromosome) and the impact of the environment on diseases. Assignments will be directed toward investigating and gathering data from the major sources identified earlier especially the NCBI Gnome database (the Genome sequence, gMap and Map Viewer and Salmonella SNP), the analytical tools in BLAST, the modeling of the Virtual Cell by CMC-Nature Gateway (Figure 6).

Based on the scientific inquiry model, groups of students will actively engage in experiential projects that are designed to trace patterns of migration by learning about DNA sequencing, DNA hybridization and the Hardy-Weinberg gene frequency and variation theorem. The objective is to connect the sources to disease patterns within cultural groups. They will discuss and review diseases such as sickle cell anemia and Tay Sachs disease, cystic fibrosis as case studies. Students will then engage in problem solving by conducting research based on a case study on diseases impacting more diverse populations such as multiple sclerosis and cancer. Teams of students with diverse skill levels and experiences will engage in investigative data search and analysis.

One of the most important aspects of the course is that expert resources will be available to confer with students on their projects. Finally, students are encouraged to question and explore.

They are introduced to such engaging resources as *Case It*, a National Science Foundation-sponsored case-based learning project involving molecular biology, computer simulations and

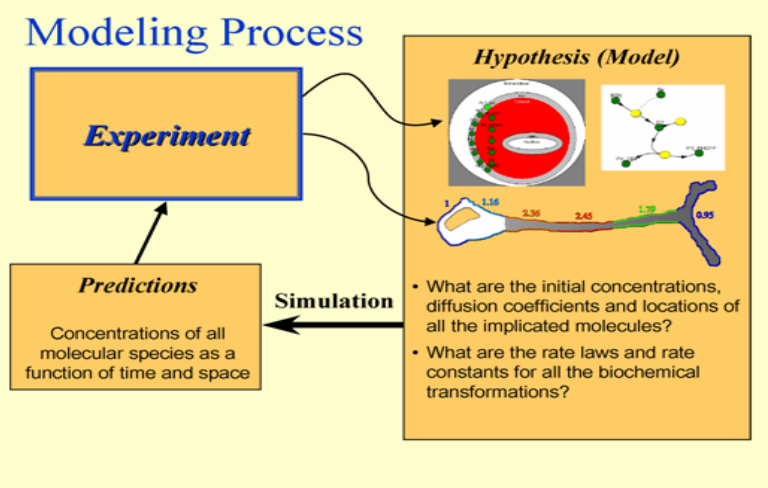


Figure 6. The Virtual Cell was designed specifically as a tool for a wide range of scientists. It was developed at the National Resource for Cell Analysis and Modeling at the University of Connecticut Health Center (http://www.nrcam.uchc.edu) as a unique computational tool that provides a software environment for analyzing, modeling, and simulating cellular function that can range from metabolic pathways to signaling networks to membrane transport and electrophysiology. These models can be based on both experimental data (biochemistry, molecular biology, imaging, etc.) and purely theoretical assumptions by using a very general conceptual structure of a model as a collection of arbitrary processes.

Internet conferencing[60]. The students also are exposed to the Environmental Genome Project sponsored by the National Institute of Environmental Health Sciences, which consider how specific human genetic variations contribute to environmentally-induced disease susceptibility[61,62].

NSF supported CI/Teragrid usage is free for such academic exercise. Teragrid has two important features. It provides the computation power (supported by training) necessary for conducting drug discovery and vaccine developmental research. It also provides a vast amount of scientific information through portals developed for specific type of scientific projects. One can obtain all these information by visiting www.teragrid.org. For computational biology experiments (for the definition, see: http://www.bisti.nih.gov/docs/CompuBioDef.pdf), a student can get access to the computing power of TeraGrid through the instructor serving as PI/Principal Investigator. NSF has facilitated this process through Campus Champion Program of TeraGrid (http://www.teragrid.org/eot/campuschamps.html). The Campus Champions program supports campus representatives as the local source of knowledge about high-performance computing

opportunities and resources. This knowledge and assistance will empower campus researchers, educators, and students to advance scientific discovery[30,63]. An instructor for teaching CIBRED developed courses will be encouraged to apply for the teragrid computing resources through Campus Champion Program. Being a Campus Champion Program of the National University, AKD will be helping the students for such computing analysis.

Availability of publications in most of the peer-reviewed journals was not free at the individual level, until recently. The student or the instructor needed to visit public or University/institute library to get the access to any printed peer-reviewed publications. Online access was also limited and subscription based. However, recently US Federal Government law passed in December 2008 has empowered the National Institute of Health (NIH) to execute the requirement by all of its grantees who publish articles springing from their govt. funded research to file a copy in PubMed Central (http://www.pubmedcentral.nih.gov), a free open access website run by the National Library of Medicine, within one year of its initial publication date. This has made very easy to obtain most of the publications free of charge.

Assessment of the Outcome of CIBRED

The CIBRED assessment for these and other courses will address four research questions derived from a comprehensive list of possible questions. The criteria for selection of those questions included a determination of which are most important to meeting project goals, relevant to the project deliverables and are within the scope of available time and resources. Additional criteria were derived from NSF 02-057 (*The 2002 User-Friendly Handbook for Project Evaluation*). Following those criteria, a document has been generated that identifies the questions and links them to generalized project goals.

An assessment of course readiness will be conducted based on:

1. Accessibility of the network to the collaborators, other institutions and participating student populations
2. Outreach efforts
    a. What other institutions have expressed an interest
    b. What type of reaction have other institutions had

c. CIBRED Web site usage statistics: To disseminate the CIBRED course model, CI courses, and related materials to other participating high schools and colleges via a web-based CIBRED network.

3. The comparative results between the two groups of students completing the courses
   a. Perceptions and experiences of the course developers, course instructors/educators and participating students
   b. Comparison of students interests in and perceptions of STEM disciples before and after completing the courses
   c. Comparison of students knowledge of team science, transdisciplinary research and CI before and after taking the course
   d. Comparison of student's ability to participate in team science, transdisciplinary research and CI activities before and after the course taken.

Importance or relevance to other institutions:

The CIBRED courses will be offered to two groups of students at each institution. The first group will complete the courses in the Spring, 2009, and the second group in the Fall, 2009. A comparison of results will be conducted to determine course readiness for deployment beyond the participating institutions. Those results will be obtained by surveying the participants before and after taking the course, interviews and feedback from all other stakeholders. The CIBRED Course Model may prove to be an effective and sustainable means for developing CIBRED courses through such collaborative efforts. Later, these courses will be made available for use in other academic institutions evaluating the method of deployment on a case-by-case basis.

Acknowledgement

The authors acknowledge contribution through stimulating discussions by various participants of CIBRED, particularly Bruce Sharp of the Virginia Bioinformatics Institute, Tom Klagholz of Klagholz and Associates, Thomas Maccalla of the National University Community Research Institute, Pradip Dey of the School of Engineering and Technology, and Michael Maxwell of the College of Letters and Science, National University. This study is conducted with NSF funding to O. Crasta (OCI-0753375).

References

[1]. National Science Foundation (2006). About Office of Cyberinfrastructure (OCI). Retrieved February 26, 2009 from www.nsf.gov/od/oci/about.jsp

[2]. National Science Foundation (2006). NSF Names Daniel Atkins to Head New Office of Cyberinfrastructure. February 8, 2006, from http://www.nsf.gov/news/news_summ.jsp?cntn_id=105820

[3]. Atkins DE, et al. (2003). Revolutionizing Science and Engineering through Cyberinfrastructure: Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyber - infrastructure. (http://www.nsf.gov/od/oci/reports/atkins.pdf)

[4]. National Science Foundation (2006). NSF'S Cyberinfrastructure vision for 21st century discovery. January, 2006, from http://www.nsf.gov/od/oci/ci_v5.pdf

[5]. McLean, S.A. (2007). Gateway to the TeraGrid for Bioscientists. TeraGrid '07, the second annual TeraGrid conference, June 4 - 8, Madison, Wisconsin. Retrieved Feb 24, 2009 from http://www.teragrid.org/events/teragrid07/agenda.html

[6]. Lathrop, S. (2007). *Education, Outreach and Training (EOT)*. TeraGrid '07, the second annual TeraGrid conference, June 4 - 8, Madison, Wisconsin. Retrieved Feb 24, 2009 from http://www.teragrid.org/events/teragrid07/agenda.html; Advancing Scientific Discovery through TeraGrid. TeraGrid '08, the 3rd annual TeraGrid Conference, TeraGrid '08 www.teragridforum.org/mediawiki/images/8/8f/TeraGrid_Overview.ppt

[7]. Madhavan KPC, Goasguen S. (2007). *Integrating Cutting-edge research into learning through Web 2.0 and virtual environments*. Retrieved online February 25, 2009 from http://library.rit.edu/oajournals/index.php/gce/article/viewFile/94/55.

[8]. Barab, S. A., Hay, K. E., Barnett, M., Squire, K. (2001). Constructing virtual worlds: Tracing the historical development of learner practices. *Cognition and Instruction*, *19*(1), 47–94; also see: http://en.wikipedia.org/wiki/Participatory_Media for definition

[9]. Shapiro, J.J., and SK Hughes, S.K. (1996). Information literacy as a liberal art. Educom Review, 31(2): 31; Association of College and Research Libraries (1989). *Presidential Committee on Information Literacy: Final Report.* American Library Association, January 10, 1989, in Washington, D.C. Retrieved February 24, 2009 from http://www.ala.org/ala/mgrps/divs/acrl/publications/whitepapers/presidential.cfm

[10]. Breivik. P. S. & Senn, J. A. (1998). *Information literacy: Educating children for the 21st century*. (2nd ed.). Washington, DC: National Education Association.

[11]. Bransford, J. D., Brown, A. L., Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

[12]. Wang, S., and Zhu, X-G. (2008). Coupling Cyberinfrastructure and Geographic Information Systems to Empower Ecological and Environmental Research. *BioScience*, 58 (2): 94-95.

[13]. Watowitch, S. (2009). Personal communication; also a part of the Figure 1 was retrieved Feb 24, 2009 from http://www.bmb.utmb.edu/faculty/watowich/

[14]. Rainey, D., Faulkner, S., Craddock, L., Crammer, L., Tretola, B. (2007). *A project-centric approach to cyberinfrastructure education*. TeraGrid '07, the second annual TeraGrid conference, June 4 - 8, Madison, Wisconsin. Retrieved Feb 24, 2009 from http://www.teragrid.org/events/teragrid07/agenda.html

[15]. Barell, J. (2007). Problem-based learning: An inquiry approach (2nd Edition). Thousand Oaks: Corwin Press.

[16]. Duch, B. (2008). *Problem-based learning*. Retrieved, February 10, 2008 from http://www.udel.edu/pbl/

[17]. Kaminski, J. A., Sloutsky, V.M., Heckler, A. F. (2008). Learning theory: The advantage of abstract examples in learning math. *Science*, 320: 454 – 455.

[18]. Savin-Baden, M. (2003). *Facilitating problem-based learning: Illuminating perspectives*. Buckingham: SRHE/Open University Press.

[19]. Devine, K., O'Clock, P. and Lyonsc, D. (2000). Health-Care Financial Management in a Changing Environment. Journal of Business Research, 48 (3): 183-191.

[20]. Furic L, Livingstone M, Dowling RJ, Sonenberg N.(2009) Targeting mtor-dependent tumours with specific inhibitors: a model for personalized medicine based on molecular diagnoses. *Curr Oncol.*16(1):59-61

[21]. Whitfield, K.E., McClearn, G. (2005). Genes, Environment, and Race: Quantitative Genetic Approaches. *By Whitfield, Keith E.; McClearn, Gerald American Psychologist.*, Vol 60(1):, Jan 2005, 104-114.

[22]. Evans, W.E, Relling, M.V. (2004). Moving towards individualized medicine with pharmacogenomics. *Nature*, 429 (6990): 464-8.

[23]. Grimaldi D, Claessens YE, Mira JP, Chiche JD. (2009) Beyond clinical phenotype: the biologic integratome. *Crit Care Med*. 37(1 Suppl):S38-49.

[24]. Individualized Medicine Emerging From Gene-Environment Studies. *ScienceDaily*. Retrieved February 22, 2009, from http://www.sciencedaily.com- /releases/2005/01/050123213425.htm

[25]. Cao Y, Wang N, Ying X, Li A, Wang H, Zhang X, Li W. (2009) BioSunMS: a plug-in-based software for the management of patients information and the analysis of peptide profiles from mass spectrometry. *BMC Med Inform Decis Mak*. 9(1):13.

[26]. Wing, J.M. (2006). Computational thinking. *Communications of the ACM* 49: 33–35.

[27]. Sharpe RE Jr, Sharpe M, Siegel E, Siddiqui K. (2009) Utilization of a Radiology-Centric Search Engine. J Digit Imaging. 2009 Feb 12 [Epub ahead of publication PubMed: 19214633]

[28]. Hoffman MA. (2007) The genome-enabled electronic medical record. *J Biomed Inform*. 40(1):44-6.

[29]. Hunt, K., and Lathrop, S. (2008). *Campus Champions – bringing HPC to your campus* (BoF Topic), Nov 19, in SC08: International Conference on high performance computing, networking, storage and analysis. Austin, TX. Nov 15-21, 2008. Retrieved, November 19, 2008 from http://teragridforum.org/mediawiki/index.php?title=SC08_BoF&printable=yes

[30]. Hunt, H., Lathrop, S., Kucera, B., Barr von Oehsen, J., Moye, R., Datta, A. (2009). *Campus Champions – Bringing High Performance Computing to your Campus*. EDUCAUSE 2009 Annual Conference (Panel discussion), Denver, Colorado, November 3–6, 2009.

[31]. Schneider BS, Higgs S. (2008) The enhancement of arbovirus transmission and disease by mosquito saliva is associated with modulation of the host immune response. *Trans R Soc Trop Med Hyg*. 102(5):400-8; also see: [WHO] World Health Organization. *Dengue*. Retrieved Feb 24, 2009, from http://www.who.int/topics/dengue/en/

[32]. Morens, D.M., Fauci, A.S. (2008). Dengue and Hemorrhagic Fever: A Potential Threat to Public Health in the United States. *JAMA*, 299: 214 - 216.

[33]. Dey, P., Uhlig, R., Amin, M., Datta, A., Romney, G., Gatton, T., Wyne, M., Cruz, A. (2009a) Teaching Mathematical Reasoning in Science, Engineering, and Technology. *Journal of Research in Innovative Teaching* , Volume 2, *in press*.

[34]. Dey, P., Gatton, T., Amin, M., Wyne, M., Romney, G., Farahani, A., Datta, A., Badkoobehi, H., Belcher, R., Tigli, O., and Cruz.A. (2009b). Agile Problem Driven Teaching in Engineering, Science and Technology. ASEE/PSW to be held in San Diego, March 19-20, *accepted*.

[35] Trondsen, E. (1998). *Technology-based learning*. Retrieved February 10, 2008 from http://www.sric-bi.com/LoD/summaries/LoDRpt01.shtml

[36]. Prensky, M. (2004). *Digital game-based learning*. New York: McGraw-Hill.

[37]. Van, R. E. (2008). *Game-based learning*. EDUCAUSE Review, 41(2), 16–30.

[38]. Bailey, T. R. (2003). Working knowledge: Work-based learning and education reform. New York: RoutledgeFalmer.

[39]. Cunningham, I., Dawes, G., & Bennett, B. (2004). *The handbook of work-based learning*. Adershot: Gower Publishing.

[40]. Eick, C. J., & Reed, C. J. (2002). What makes an inquiry oriented science teacher? The influence of learning histories on student teacher role identity and practice. *Science Teacher Education*, 86: 401–416.

[41]. Educational Broadcasting Corporation (2008). *Inquiry-based learning*. Retrieved, February 10, 2008 from https://www/thirteen.org/edonline/concept2class/inquiry/inded.html

[42]. Helic, D., Maurer, H., & Scerbakov, N. (2004). Knowledge transfer processes in a modern WBT system. *Journal of Network and Computer Applications*, 27(3):163–190.

[43]. George Lucas Educational Foundation (2008). *The Project based learning*. Retrieved, February 10, 2008 from http://www/edutopia.org/projectbasedlearning

[44]. Michaelsen, L. K., Knight, A. B., & Fink, D. L. (2008). *Team-based learning: A transformative use of small groups in college teaching*. Sterling, VA: Stylus Publishing.

[45]. Lee, M. & Baylor, A. L. (2006). Designing Metacognitive Maps for Web-Based Learning. *Educational Technology & Society*, 9 (1), 344-348.

[46] O'Neil, H. F., Perez, R. S. (2006). *Web-based Learning: Theory, research, and practice*. Hillsdale, NJ: Erlbaum.

[47]. Sadikot, R.T., Blackwell, T.S., Christman, J.W., and Prince, A.S. (2005). Pathogen–Host Interactions in Pseudomonas aeruginosa Pneumonia. American Journal of Respiratory and Critical Care Medicine, 171: 1209-1223.

[48]. Chambers, T. J., Hahn, C.S., Galler, R., Rice, C. (1990). Flavivirus genome organization, expression, and replication. *Annu Rev Microbiol*, 44: 649–688

[49]. Rosaura, P., Valle, C., and Falgout, B. (1998). Mutagenesis of the NS3 Protease of Dengue Virus Type 2. *J Virol.*, 72(1): 624–632.

[50]. Lee, Y.K., Tan, S.K., Wahab, H.A., Yusof, R., Rahman, N.A. (2007). Nonsubstrate Based Inhibitors of Dengue Virus Serine Protease: A Molecular Docking Approach to Study Binding Interactions between Protease and Inhibitors. *Asia Pacific Journal of Molecular Biology & Biotechnology*, 15 (2): 53-59.

[51]. Wang, E., Ni, H., Xu, R., Barrett, A.D., Watowich, S.J., Gubler, D.L., and Weaver, S.C. (2000). Phylogenetic Analysis of Endemic/Epidemic Dengue Emergence from Sylvatic Progenitors, J. Virology 74, 3227-3234; also see, http://www.bmb.utmb.edu/faculty/watowich/)

[52]. Kyle, J.L., Harris, E. (2008). Global spread and persistence of dengue. *Annu Rev Microbiol*., 62:71-92. Review

[53]. Kyle, J.L., Balsitis, S.J., Zhang, L., Beatty, P.R., Harris, E. (2008). Antibodies play a greater role than immune cells in heterologous protection against secondary dengue virus infection in a mouse model. *Virology*, 380(2): 296-303

[54]. Avilés, W., Ortega, O., Kuan, G., Coloma, J., Harris, E. (2007). Integration of information technologies in clinical studies in Nicaragua. *PLoS Med*. 4(10):1578-83.

[55]. Behar, D.M., Rosset, S., Blue-Smith, J., Balanovsky, O., Tzur, S., et al. (2007) The Genographic Project public participation mitochondrial DNA database. PLoS Genet 3(6):1083- 1095

[56]. Stone, L., Lurquin, P. F., and Cavalli-SforzaGenes, L.L. (2007). Culture, and Human Evolution: A Synthesis. Blackwell Publishing: MA.

[57]. Sforza-Cavalli, L.L. (2001). *Genes, Peoples, and Languages*. University of California Press: Berkeley.

[58]. Well, S. (2002). *The Journey of Man: A Genetic Odyssey*. Random House: New York 2002

[59]. Cann, R.L, Stoneking, M., Wilson, A.C. (1987). Mitochondrial DNA and Human Evolution, Nature, 325: 31-6.

[60]. Bergland, M., Klyczek, K., Mogen, K., and Johnson, D., Lundeberg, M., Nelson, M.A. (2001). Case It! - a collaborative BioQUEST project to enhance case-based learning in university and high school biology education worldwide via molecular biology computer simulations and Internet conferencing. CAL-laborate Volume 6 June 2001 (Published by: UniServe Science, URL: http://science.uniserve.edu.au/pubs/callab/vol6/index.html).

[61]. Levin, S.A., Grenfell, B., Hastings, A., Perelson, A.S. (1997). Mathematical and computational challenges in population biology and ecosystems science. *Science*, 275: 334–343 (also see: http://www.niehs.nih.gov/research/supported/programs/egp/)

[62]. Molnar, S. (2006). *Human Variation* (Sixth Edition). Pearson Prentice Hall.

[63]. Datta, A., Crasta, O., Rainey, D., and Maccalla, T. (2009). *CIBRED- educating Cyberinfrastructure concept and teragrid resources to the 21st Century's biological researchers*. EDUCAUSE 2009 Annual Conference (Panel discussion), Denver, Colorado, November 3–6, 2009.

BIOGRAPHICAL INFORMATION



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CIBRED via CIERRA for Educating the Next Generation of Engineers

Thomas MacCalla, Ed.D., NUCRI, Jacqueline Caesar, Ph.D., and Michael Maxwell, Ph. D., NUCRI and National University College of Letters and Science, VBI Project Teachers Shay Vanderlaan, Sandra Valencia, Terena Henry, and Matt Leader

Abstract

The National Science Foundation CI-TEAM (*Cyber-Infrastructure Training, Education, Advancement, and Mentoring for Our 21st Century Workforce*) awarded the Virginia Bioinformatics Institute at Virginia Tech University a two-year Implementation grant for a CIBRED* (Cyber-Infrastructure for Biological Researchers, Educators and Development) project. The collaborative undertaking involves partnerships with scientists, researchers, secondary school teachers, and college faculty from several institutions nationwide. It is designed to build an enriching and engaging curriculum development and deployment program that would prepare undergraduate, middle and high school students for research environments where cyberinfrastructure systems, tools and services are used effectively to fuel a knowledge-based economy.

The deployment phase is a CIERRA for STEM field careers and 21st century education and workforce component. This two-pronged approach could be considered as K-12 educational, outreach, and training (EOT) stimulus and renewal strategy. CIERRA stands for Cyber-Infrastructure Education Recruitment, Retention, Advancement), while STEM stands for Science, Technology, Engineering, Mathematics. EOT is the roadmap for preparing the next generation of engineers and future scientists in the global knowledge economy. This paper highlights the E in STEM referencing a Team Science approach to preparing the next generation of engineers, technicians, researchers, and future scientists. CIBRED and CIERRA are used here as a way to show how this collaborative, project-centric bioinformatics initiative can contribute to the development of an educational pipeline to prepare in/out-of-school youth with 21st century workforce skills and foster innovation and interdisciplinary practice. The product and the processes are applicable to K-12 engineering education

*CIBRED is funded by NSF award OCI)-0753375 to O.Crasta

Introduction

Russell A. Hulse noted in his Nobel Laureate Paper, "Preparing K-12 Students for the New Interdisciplinary World of Science" that attitudes and habits are life skills formed during the early growing-up years and that all students need to acquire basic factual and procedural knowledge. He also argued that all students should have an understanding of science and that we should develop a capacity for interdisciplinary work while fostering the excitement of scientific research.

> *For K-12, we are talking about first steps toward this goal, which certainly involves enhanced exposure to a broad range of fundamental scientific content as well as conveying the excitement of scientific research. Beyond this, however, is the need to lay a foundation in such overarching subjects as the varied to good scientific process, systematic analysis, and problem-solving, complemented by development of good communication skills and the ability to work well in collaborative groups.* (1)

Hulse's insightful observations reinforce today's clarion call for Science, Technology, Engineering, and Mathematics (STEM) educators to facilitate and encourage collaboration in engineering education, math, and science. They also underscore the alarm sounded by the National Science Teachers Association (2) in its recent national survey and substantiate the findings of the American Society of Engineering Education in its 2004 report on *Engineering in the K-12 Classroom*, "Current Practice Analysis and Guidelines for the Future" (3) What we are suggesting here is that the project-centric approach introduced in the NSF-sponsored Virginia Bioinformatics Institute's CIBRED Project, coupled with the National University Community Research Institute's companion CIERRA (*Cyber-Infrastructure, Recruitment, Retention, Advancement)* initiative and distributed learning efforts, can add to the promise.

The purpose of this paper is to introduce a multi-level, interdisciplinary education, outreach and training approach to integrating CIBRED (*Cyber-Infrastructure into curriculum design, development, and delivery for Biological Researchers, Educators, and Developers*) and contribute to the preparation of future scientist and engineers in our global knowledge economy. CIBRED's mission is to empower current researchers and the future workforce with specific CI tools and an interdisciplinary work environment that will enable them to generate new knowledge with a focus on the problem that transcends the boundaries of different disciplines and technologies needed to achieve their scientific objectives. The basis for the trans-disciplinary enterprise is the National Science Foundation's CI-TEAM program, which is designed to promote the acquisition of knowledge and the requisite skills needed to create, advance and exploit the potential of cyberinfrastructure.

The long term objective of CIBRED is to make state-of-the-art science and engineering research more accessible to all by providing training, education, and mentoring to meet the needs of current and future scientists. Such an objective could be applicable to the future of engineering education. CIBRED"s target audience is high school and college STEM students STEM and its complementary agenda is the introduction of a CIERRA education, outreach and training strategy for broadening participation and the applicant pool in the

STEM fields. Nonetheless, this dual thrust is tantamount to a K-12 educational stimulus and renewal strategy and could make an important contribution to the education of the next generation of engineers. https://cibred.vbi.vt.edu/drupal/



The Status of STEM

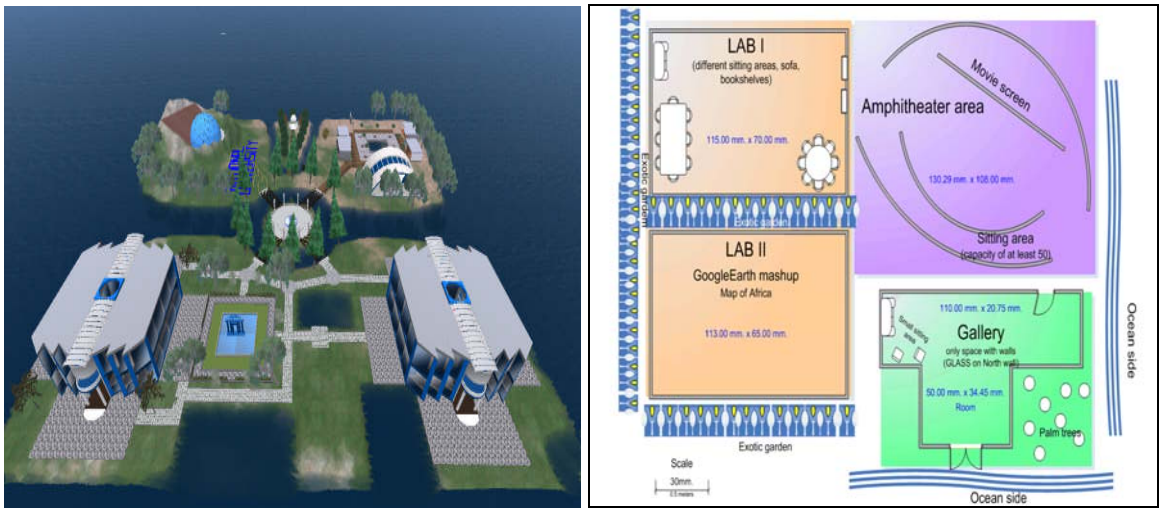
The STEM education issue is well-documented. A 2008 Congressional Research Report stated that a large majority of secondary school students fail to reach proficiency in math and science, and many are taught by teachers lacking adequate subject matter knowledge. It also noted that in an assessment of 15-year old students, the United States ranked 28th in math literacy, 24th in science literacy, and 20th among all nations in the proportion of 24 year olds who earned degrees in natural science or engineering. (3) The good news is that educators, business and industry leaders, professional groups, and policy makers are responding and results from the National Assessment of Educational Progress report steady improvement in math and science and recognize the interdisciplinary approach is critical for taking the nation's STEM performance to the next level http://www.edweek.org/ew/articles/2008/03/27/30intro.h27.html. Moreover, several major U.S. companies are investing large amounts of money into schools and colleges to support and strengthen STEM education initiatives. Likewise, the American Society of Engineering Education has exerted leadership with its one-stop ASEE EngineeringK12 Center that identifies and makes available effective engineering education resources to the K-12 community. A collection of STEM education resources also are provided through web portals, websites, and individual digital resources through the National Science Digital Library (http://nsdl.org/collection/stem-education/) and the California Space Authority's online searchable database called the STEM Inventory and Talent Development program to accelerate development of a highly-skilled 21st century talent pool and support for a continuum of math, science, engineering education, and lifelong learning. http://www.militaryconnection.com/events/pdfs/CSA-STEM-Inventory.pdf

The CIERRA initiative is an educational outreach and training and resource network for Science, Technology, Engineering, and Mathematics (STEM) of the National University Community Research Institute (NUCRI) in San Diego (http://www.nucri.nu.edu) More specifically, CIERRA is designed to identify, engage, and develop middle and high school students and teachers for collaborative learning and related workforce development.. Central

to its EOT strategy is the K-12 professional development of teachers and community practitioners through a blended Professional Development Extension (PDX) Online series of familiarization/enrichment courses, student engagement, and project-based service learning programs. CIERRA participants begin by taking a GLOBE K-12 Science Education onsite/online program and continue with such blended e-Learning digital media skill-building courses as "Digital Storytelling," "Animation in the Science Classroom" and selected "Introduction to STEM" courses.

CIERRA was a response to the need for an education and workforce development pipeline in the STEM fields. It started with serving charter school teachers and underserved middle/high school students in the Los Angeles Basin. The program soon expanded to include teachers and students at the residential Job Corps Center in San Diego and the highly touted High Tech High charter school. These classroom teachers and counselors then were encouraged to participate in related STEM projects associated with NUCRI. They conduct experiential service learning projects take, PDX Online/Onsite courses, and participate in digital media and learning activities, such as VBIsland in CyberEdWorld.

CyberEdWorld is a private 3D immersive, multiplayer learning environment designed to foster interdisciplinary teaching, learning and team research. It resides on the Second Life Grid and enables participants in different environments and locations to interact and collaborate in real time in 3D space. The VBIsland layout provides a digital media learning environment that simulates real world space and stimulates creativity. The private virtual island can accommodate interactive science labs, a gallery, information exchange lounges, library resource kiosks, work rooms for a collaboration, community areas, etc.



A special feature of the CIERRA initiative is not only to broaden participation in the STEM fields, but also encourage teachers to become STEM master teachers in the process by becoming National Board Certified Teachers (NBCT) as CIERRA Champions. The NBCT awards are a symbol of professional teaching excellence and are recognized by the National Board for Professional Teaching Standards and the National Research Council, which attest to the teachers meeting rigorous standards through intensive study, expert evaluation, self-assessment and peer review.

CI-TEAM and CIBRED

Currently, Virginia Bioinformatics Institute at Virginia Tech University (http://www.vbi.vt.edu) is conducting a two-year, NSF-sponsored Cyber-Infrastructure Training, Education, Advancement, and Mentoring for Our 21st Century Workforce (CI-TEAM) Implementation project for Biological Researchers, Educators, and Developers (CIBRED). Two interdependent goals focus on leveraging:

- effective Cyberinfrastructure (CI) collaborations with current researches to use and advance CI
- the research data, context and experience for use by the educators in training the future workforce using a project-centric bio-informatics course to broaden participation.

The collaborative project-centric, team science curriculum/module design, development, and deployment effort involves middle/high school teachers in Virginia, California, and New Jersey and faculty at National University, Howard University, Hampton University, and Stockton State College in New Jersey. Individually and collectively they are putting the pieces together, "stand-alone" or "plug in" enrichment modules for the interdisciplinary biology and life science classroom. The intent is to engage and prepare students and teachers to be in research environments where CI systems, tools, and services are utilized effectively to fuel the knowledgebase economy. The process builds upon the CI-TEAM Demonstration project developed by the Virginia Bioinformatics Institute in collaboration with Galileo Magnet High School and Bluefield State College. The goal of the high school Microbial Genomics class was to study pathogens from a bioinformatics perspective.

CIBRED research data and results from the current Implementation collaborations will be leveraged towards the development, modification, implementation and dissemination of a new, multidisciplinary course in bioinformatics and multi-level STEM instruction with a project-based learning paradigm. The objective is to stimulate interaction and participation and embed the cyberinfrastructure concept through role playing activities and presentation. Roles are developed around professionals that would come into play should an outbreak occur (i.e. Center for Disease Control specialists, researchers involved in vaccine and/or drug development, hospital physicians, microbiologists, and evolutionary biologists)

Illustrated below is a CIBRED Course Model which depicts cyberinfrastructure concepts, related course concepts, and begins at Level Zero. The curriculum focus is on collaborative learning and problem-solving to generate solutions that transcend discipline-specific boundaries. Instruction is provided in flexible teaching modules to promote project-based learning in different delivery formats. The process emphasizes: 1) Teaching bioinformatics through scenarios focused on key pathogens, 2) Cutting edge data and techniques centered on real problems, and 3) the use of a cyberinfrastructure approach to problem solving.

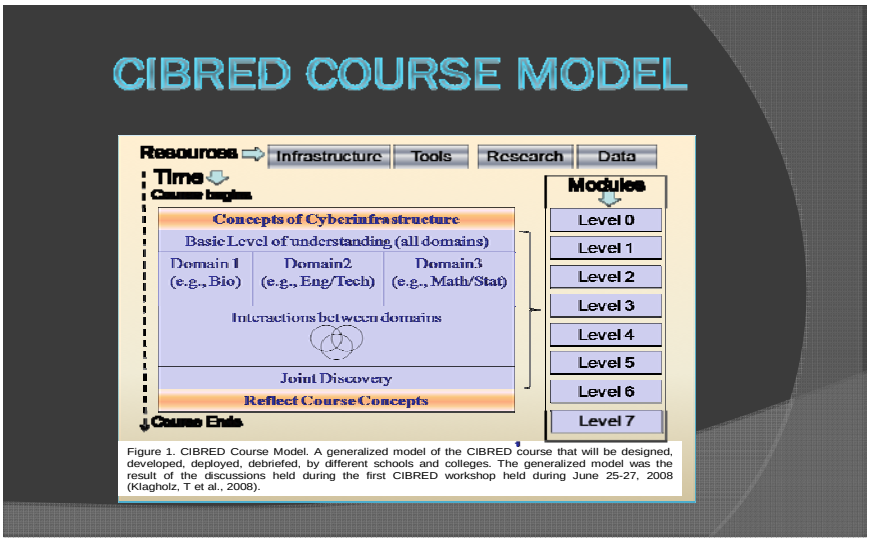


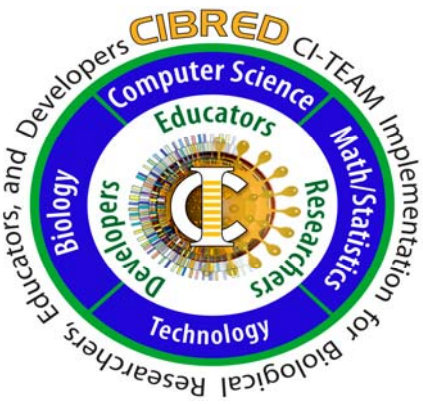
Figure 1. CIBRED Course Model. A generalized model of the CIBRED course that will be designed, developed, deployed, debriefed, by different schools and colleges. The generalized model was the result of the discussions held during the first CIBRED workshop held during June 25-27, 2008 (Klagholz, T et al., 2008).

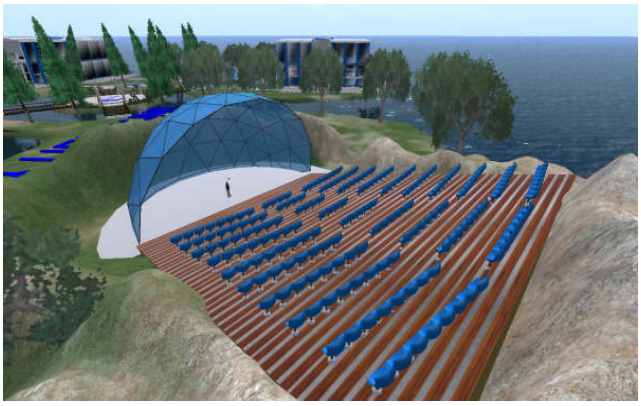
The CIERRA teachers developed a Crime Scene Investigation (CSI) approach to building a stand-alone curriculum module, and created a Viral Scene Investigation (VSI) case study called the "Ebola Virus Module." They presented an investigative scenario to engage three different groups (6-9) of students to identify a viral outbreak, track the spread of the virus, find the cause, and develop a drug to stop/control recurrent infection. The Scenario was presented as follows:

> *World Health Organization (WHO) officials reported 95cases of an outbreak Of disease in the Cuvette-Quest region of the Republic of Congo, resulting in 77 deaths so far. WHO has also identified 149 more people who had been in contact with patients suffering from the highly contagious disease. The first ten patients were admitted to a local hospital. One patient was admitted complaining of flu-like symptoms and continued to rapidly digress. Five more patients were admitted with headaches, intense muscle pain, and diarrhea resulting in internal bleeding and death.*
>
> *Two adolescent patients were admitted after severe rashes developed. Two other patients were re-admitted after continued complaints of dehydration and headaches. Fluid samples were taken from all ten patients and given to the microbiologists for examination. The same family of RNA viruses called Filoviridae were detected in each patient. WHO and the Center for Disease Control (CDC) were called. Upon hearing of the "outbreak," representatives from a major pharmaceutical company called to offer assistance. They are working with biologists at the area university on a new medicine that could help the case. The CDC workers arrived on the scene and took patient background information.*

Teachers and students have access to large amounts of pertinent data and have contact with researchers. It is felt that a similar approach to curriculum development could be used for K-12 engineering education.

As mentioned earlier, the CIERRA group of teachers developed a 3D virtual lab and learning environment in Second Life for engaging students and other teachers in related exploration, experimentation and knowledge sharing. They were encouraged by knowing that Virtual Labs also are being used by the Center for Disease Control (CDC) and the National Aeronautics and Space Administration (NASA). The result was to secure and build a virtual teaching and learning environment in CyberEdWorld, now referred to as VBIsland. The middle and high school CIBRED teachers would be the classroom content experts, NUCRI digital media fellows and faculty associates would serve as SL multimedia consultants, along with a very experience virtual space builder.





The Second Life scene accommodates engineering practice as well as education. As Pam Broviak, PE, (aka Pam Renoir in SL) who is the Public Works Director and City Engineer in La Salle, Illinois, said in *Second Life: A Virtual Universe for Real Engineering*, by applying SL building tools, engineers are facilitating a paradigm shift in computer-aided design Broviak used the SL environment in her engineering practice to design plumbing systems and illustrate how the virtual space facilitates engineering design while reconfiguring the piping in a residential building to prevent sewage backup. She also used the venue to demonstrate "Real life engineering with Second Life tools.





Pam Renoir & TEEX Clary on Public Works Island
http://www.theseventhsun.com/0308_publicWorks.htm
Of particular note is the Second Life presence of the Institute of Electrical and Electronics Engineers **(**IEEE) who created a virtual environment to support its organization's needs across two islands. http://www.ieee.org/web/volunteers/tab/secondlife/index.html





Cyberinfrastructure and Interdisciplinary Practice

As we know the term Cyberinfrastructure refers to the integration, coordination, and deployment of information technology and human resources to support modern science and engineering problems. CI includes hardware (computers, data storage, networks, visualization facilities, and scientific instruments) and software to provide the technology "fabric" and infrastructure foundation for modern science. We maximize the use of CI by engaging in team science or working together across disciplines. In the CIBRED project we broaden participation in STEM by beginning at "level zero" and practice interdisciplinarity and extend the reach via transdisciplinary team science, which integrates discipline-specific theories, concepts, and methods into a research environment that transcends academic discipline boundaries. In 2006, Virginia Tech University became the first U.S. higher education institution to offer an integrative STEM Education graduate program to develop 21st century K-16 STEM educators, leaders, scholars, and researchers to promote trans-disciplinarity (http://teched.vt.edu/TE/STEM.html)

Another part of the framework is the digital media and learning environment or Cyberlearning space, which is supported by networked computing. The National Science Foundation's 2008 Task Force Report on *Fostering Learning in the Networked World* (8) envisioned a "Cyberlearning" noted that content is no longer limited to books, filmstrips, and videos associated with classroom instruction and that networked content today provides a rich immersive learning environment that incorporates accessible data using colorful visualizations, animated graphics, and interactive application (8). The creation of *VBIsland* in NUCRI's *CyberEdWorld*, reflects NSF's virtual learning vision and advances the notion of a collaborative work environment for an interdisciplinary education, outreach and training pipeline for the next generation scientists, engineers, and 21st century workforce.

The Institute also is developing a complementary MAGNA (*Multimedia Access Grid Networking, Achievement*) Charter School Resource Network in CyberEdWorld for student engagement, discovery, and knowledge-sharing. It is a networked world that will focus on a motivational paradigm where many can contribute collaboratively to shaping educational reform and promoting student achievement. The overarching goal is to shift away from the more traditional *one-to-many* teaching to a *many-to-many* approach. The MAGNA Charter also includes a 3D immersive learning space with a number of virtual rooms for object-based learning, events-based learning, and theme-based learning. It is designed to be a

gateway to game spaces where geographically-dispersed and diverse students from public charter high schools can connect with inquisitive learners everywhere. They also can extend their reach and enlist others to broadening participation in the STEM fields.

The developmental resource network is aligned with a "Trilogy for Student Success" model (9), which focuses on *Engagement, Capacity, and Continuity*." It addresses the persistent problems of disengagement, diversity, and low academic achievement while fostering educational empowerment for the future of science, quantitative disciplines and the 21st century knowledge economy. "Trilogy" defines "Engagement" as that which draws the learner to study and "Capacity" as the fundamental knowledge needed to advance to more advanced levels of learning. "Continuity" is the pathway that offers the necessary resources for advancement. Access is vital to Continuity, and all three are interdependent.

NxGen Target Audience and Implications for Engineering Education

A key question to be considered is "How can these innovative approaches contribute to educating the next generation of engineers?" We know that much is being done to address STEM education pipeline issues, but we know little about who is getting the message, and how we can determine the effectiveness of our collective effort. One place to start is to identify and link one-stop STEM resource centers already in place and development a community outreach, education, and training informatics systems to distribute their treasury of information. The Institute of Electrical and Electronics Engineers'(IEEE) Pre-University Education website and related educational activities, http://www.ieee.org/web/education/preuniversity/home.html, ASEE's EngineeringK-12 Center, and the hands-on learning DTEACh (*Design Technology and Engineering for America's Children*) Program at the University of Texas at Austin are starting points http://www.engr.utexas.edu/dteach/

The National Science Digital Library http://nsdl.org/ and the Texas-based Infinity Project, http://www.infinity-project.org/contact/contact_idx.html which was created by a world-class team of university faculty, high school teachers, working engineers, and leading researchers, the University of Virginia's Middle School Engineering Education Initiative and the California Space Authority's STEM Inventory, also can serve as pivotal nodes. Moreover, we should not just think in terms of information and knowledge sharing, but also new skill development, as underscored in a 2006 *Educause Quarterly* web article "Connecting the Digital Dots: Literacy of the 21st Century" http://connect.educause.edu/Library/EDUCAUSE+Quarterly/ConnectingtheDigitalDotsL/39969?time=1235597927 and the Metiri Group's "enGauge 21st Century Skills" website. http://www.metiri.com/features.html

Another important question is: "Who and broad is our audience, including youth in-and-out of school, prospective STEM teachers, ethnic minorities, women and those students with special needs. In California approximately twenty-five percent of its 127,292 high school youth were dropouts, with African American and Latino students leaving at a much higher rate than any other ethnic group. These youth represent a potentially untapped pool. http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2008/07/16/BAS311QATI.DTL

Conclusion

In his "The Future of Engineering, Science & Mathematics: Who Will Lead?" Remarks on the occasion of Harvey Mudd College's 50th Anniversary Celebration, National Science Foundation Director Arden Bennett Jr. stated:

> *In this knowledge economy, intellectual and human capital, infrastructure, and R&D investment are more important than the availability of raw materials…. The rapid spread of computer and information tools compels us to join hands across borders and disciplines. Communications and collaboration hasten the transformation of knowledge into products, processes, and services. In their wake, they produce jobs and wealth and improve the quality of life worldwide.*
> *http://www.pkal.org/documents/2007%20Summer%20Institute%20Notebook.pdf*

The challenge is still with us and an answer to Arden Bennett's question is: What can we do together? *and* When can we get started?

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Selected Reference

1. Husle, Russell A. Nobel Laureate Papers, "Preparing K-12 Students for the Interdisciplinary World of Science." University of Texas at Dallas, 2006 (PDF) http://www.ebmonline.org/cgi/content/full/231/7/1192

2. National Science Teachers Association. "National Survey Depicts Status of K-12 Science and Math Education" Arlington, Virginia: NSTA News Digest, 2002 http://www.nsta.org/publications/news/story.aspx?id=46422

3. Congressional Research Reports for the People. Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action. Washington, D.C.: Center for Democracy and technology, March 21, 2008. http://opencrs.com/document/RL33434/

4. The National Science Foundation. *Fostering Learning in the Networked World, The Cyberlearning Opportunity and Challenge,* A 21st Century Agenda for the National Science Foundation. Report of the NSF Task Force on Cyberlearning. Arlington, Virginia. June 24, 2008

6. Jolly, Eric J., Campbell, Patricia B., Perlman, Lesley. *Engagement, Capacity, and Continuity: Trilogy for Student Success.* GE Foundation, September 2004