

DRAFT

Technical Infrastructure for the Development and Support of Academic Partnerships

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A principal focus of the Appalachian Mathematics and Science Partnership (AMSP) has been the creation, support, and evaluation of partnerships whose activities promote the improved student achievement in mathematics and science. Partnerships, by their very nature, involve the cooperation of two or more distinct entities to create a new one with a stated purpose or objective. Each partner initially has its own environment. The creation of a partnership requires a context in which these possibly independent environments exist and within which they can be integrated in some manner to serve the partnership. Of course a completely general common environment would be incredibly complex with cultural, political, organizational, physical, social, financial, and technical components coming into play at different levels of importance and different stages of development of any particular partnership. An inquiry into the nature of such a general setting is far beyond the scope of anything contemplated here. Our point of departure is the observation that, *a priori*, partnerships require communication.

At the outset each partner comes to the partnership formation process with its own communications environment. Our interest here is in the concept of a context in which these can be brought together to form an associated and essential communications partnership.

In section 1 we explore an abstract model for partnership development which strips away most of the complexity by hiding it in abstraction. There are abstract entities called “activities” which have “members” who “access” the activity “resources” and produce “data” which may be new activities or resources. Activities are organized into “communities” and the totality of the members of the community activities are the “individuals” of the community. The activities of which a particular individual is a member, together with the resources to which that individual has access are the individual’s “neighborhood”. All of these are functions of a parameter called “time”¹.

¹ Although the terms are (intentionally) suggestive it is important to emphasize the abstract nature of these concepts. There is nothing to keep the number 12,345 from being declared an activity with the digits {1,2,3,4,5} as members and resources being decimal positions with occupancy being access. Thus member

There are notions of sub activities and sub communities and of morphisms for relating and identifying activities and communities. There is a notion of order among the activities and resources of a community which provides a representation of the community as a (time dependent) directed graph. For each individual in the community the associated neighborhood is a subgraph which provides a representation of the individual's "place" in the community. Finally, there is, within these abstract communities a formal definition of a "partnership" among a set of activities. It follows then that there is a corresponding notion of partnership within any human enterprise that fits this abstract community model. That is, one possessing entities that can be interpreted as "individuals", "activities", "resources", "roles", etc.

In section 2 we define a communications resource as one defined by a URL. We then have the obvious notions of communications activities and communities and that of the communications sub-community of any community. Within a communications sub community the neighborhood of an individual formalizes the individual's communications environment. This completely describes the individual's capacity (within the community) to establish connections and participate in activities and makes it apparent that fundamental requirements for effective community communications are that: (a) each individual be able to locate and efficiently traverse the sub-graph defining his/her neighborhood, and (b) there be efficient mechanisms for joining (subsets of) individual sub-graphs (so that individuals wishing to collaborate can communicate). The notion of partnership then gives us a formal construction of a communications partnership among a group of activities within a community.

In section 3 we describe the Kentucky Partnership System (KPS)², a technical communications environment for the establishment and support of (academic) partnerships. KPS is a "universal" communications community in the sense that given any human enterprise which constitutes a community, C , there is a mapping of the communications sub-community of C into KPS. Thus a finite set of communities can have, prior to any consideration of the actual complexities of a partnership, a functioning partnership of their communications sub-communities.

In Section 3 we describe some specific applications of KPS for the establishment and support of academic partnerships.

4 has access to the "tens" position but 3 does not. All entities can be viewed as constant functions of time. That is they do not change with time.

² KPS has been developed with support from the National Science Foundation (through the Appalachian Math Science Partnership), The U.S Department of Education (through the Morgan County Technology Challenge Grant), The Kentucky Department of Education (through an Online Formative Assessment Prototype Development contract), The office of the University of Kentucky Vice President for Information Systems, and the Kentucky Council on Postsecondary Education (through the KEMTP project).

Section 1: An Abstract Model of Partnership Formation

For the purpose of this discussion the variable t represents **time**, beginning at $t = t_0$. A **community**, C consists a pair of time-dependent collections of **individuals**, I , and **activities**, A . At times $t > t_0$ any of these collections may, as a result of the community activities change with t .

An individual activity W is a set $\{M_W, R_W\}$ where M_W is a subset of the community individuals with a distinguished element called the **owner**, and R_W a set of **activity resources**. R_W contains at least one element D_W , which depends on W and is itself a set and is called the **activity data**. M_W , R_W , and D_W are themselves functions of t . The community C is considered to be an activity whose member set (at time t) is $I(t)$, whose resources (at time t) is the totality of the all individual activity resources, and whose data (at time t) is the union of all of the individual activity data sets. The intersection of all activity resources is the set of **community resources**. All members of the community enjoy the only available status which affords full access to the community resources. There are no roles for community members. The owner therefore has no function and can be any individual.

For simplicity of notation, when discussing a single activity W we will, in context, drop the subscripts and use the notation $W = \{M, R\}$ with it understood that there is a distinguished D in P .

The resources, R , of an activity, W , are of two types: **public** and **restricted**. Public resources are accessible by member of the public while restricted resources are accessible only to members of the activity³. This access is afforded according to the member's **status** and **roles** which are assigned by the **Owner** of the activity. Within an activity there is a notion of precedence in access to a resource in the sense that access to one resource a be required for access to resource b .

The activity data is the result of activity members accessing the activity resources and performing the functions defined by their status and roles. Activities can be (or become) resources for other activities and activities can produce activities as part of their data.

Relationships Among Activities and Resources in a Community

Within a community, C , two activities or resources A and B are related (denoted $A \ll B$) if:

- a. A and B are activities and B is a resource of A , or
- b. A and B are resources of the same activity and access to A is required for access to B
- c. B is a resource of a resource of A

³ Public resources are not necessarily community resources. They need not be among the resources of all activities although they are available to become resources of activities. Public resources can be viewed as a dissemination vehicle.

Since activities can also be resources it is possible for the same pair of objects to be related in both senses, in neither sense, or in one and not the other.

Sub Activities

If A and B are activities then A is a sub-activity of B if:

- a. The members of A are members of B
- b. The owner of A is the owner of B
- c. Each resource of A is a resource of B
- d. The data of A is contained in the data of B
- e. Members' roles and status in A are among their roles and status in B. In particular if a member has access to a resource in A then that member has access to a resource in B

Sub-communities

If S and T are communities then S is a sub-community of T if every activity of S is a sub-activity of an activity in T

Principal Activities and Neighborhoods

If A is an activity and m is a member of A then A_m , the principal sub-activity of A determined by m is the activity defined by:

- a. The members of A_m are the members of A
- b. The owner of A_m is the owner of A
- c. The roles and status of members of A_m are the same as those of the members of A
- d. The resources of A_m are precisely those resources of A to which m has access

If C is a community and m is an individual in C then the neighborhood of m (in C) is the collection of all principal sub-activities of C that are determined by m.

Morphisms of Activities and Communities

If $S_1 = \{M_1, R_1\}$ and $S_2 = \{M_2, R_2\}$ are activities with data D_1 and D_2 respectively then an activity morphism $f : S_1 \rightarrow S_2$ is a pair of functions (f_1, f_2) such that

- a. $f_1 : M_1 \rightarrow M_2$, $f_2 : R_1 \rightarrow R_2$ with $f_2(D_1)$ contained in D_2
- b. f preserves ownership and access

The activity morphism f is an isomorphism if there is an activity morphism $g : S_2 \rightarrow S_1$ such that $g(f)$ is the identity mapping on C_1 and $f(g)$ is the identity on C_2

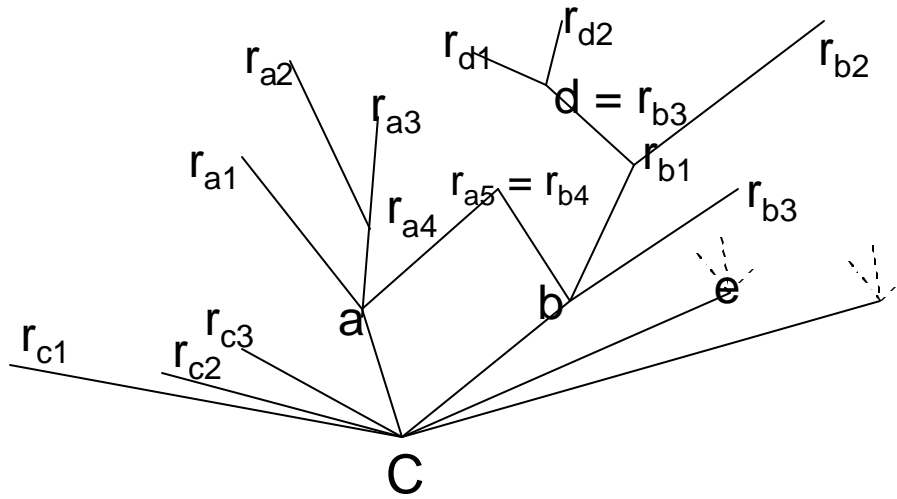
If C_1 and C_2 are communities then a community morphism $h: C_1 \rightarrow C_2$ is a family of activity morphisms h_S , one for each activity S in C_1 such that $h_S(S)$ is an activity in C_2 and $U \ll V$ in C_1 implies $h_U(U) \ll h_V(V)$ in C_2 .

The community morphism h is an isomorphism if each of the component maps h_S is an isomorphism. It is an embedding if it is an isomorphism onto its image in C_2 .

Graphical Visualization of a Community.

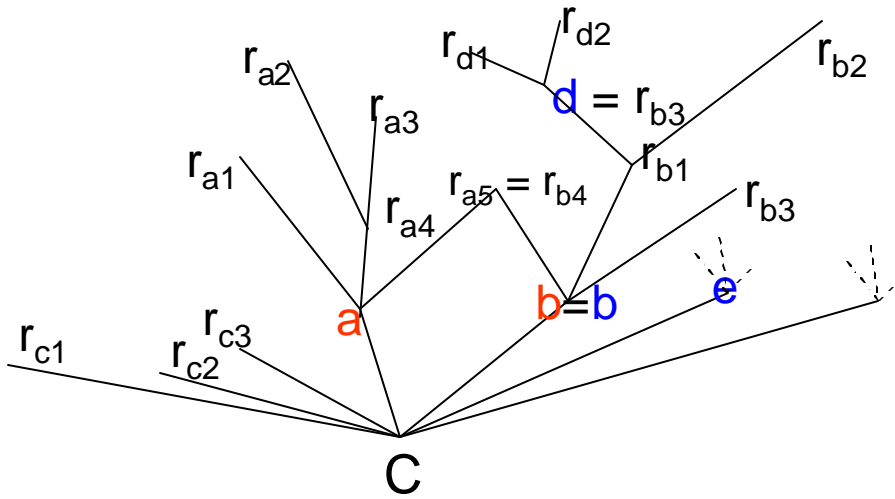
A community can be visualized as a directed graph with its activities and resources as nodes. For pair of activities or resources (A, B) there is a directed edge A to B if $A \ll B$. In particular, there is an edge from each activity node to each of its resources and within an activity there is a directed edge from resource r to resource s if access to r is required for access to s ⁴. Since each activity is a resource of the community activity, C , the graph is connected with root C . In addition to the activities a_1, a_2, \dots, a_m the root may have resources r_1, r_2, \dots, r_n . If activities a_1 and a_2 have resources r_{a_1}, \dots, r_{a_1} and r_{a_2}, \dots, r_{a_2} . One can visualize the arrangement with the following type of diagram where individual letters represent activities and subscripted symbols are resources (which may be activities). In this diagram we think of an edge as being directed from A to B if B sits at a higher level than A . Since " \ll " is not a partial order (in principle it is possible for $A \ll B$ and $B \ll A$ without $A=B$) the general diagram could contain loops.

⁴ The "within an activity" qualification is important. There is nothing to say that, for a common member, and the same resources, r may be required for access to s in one activity but not in the other.

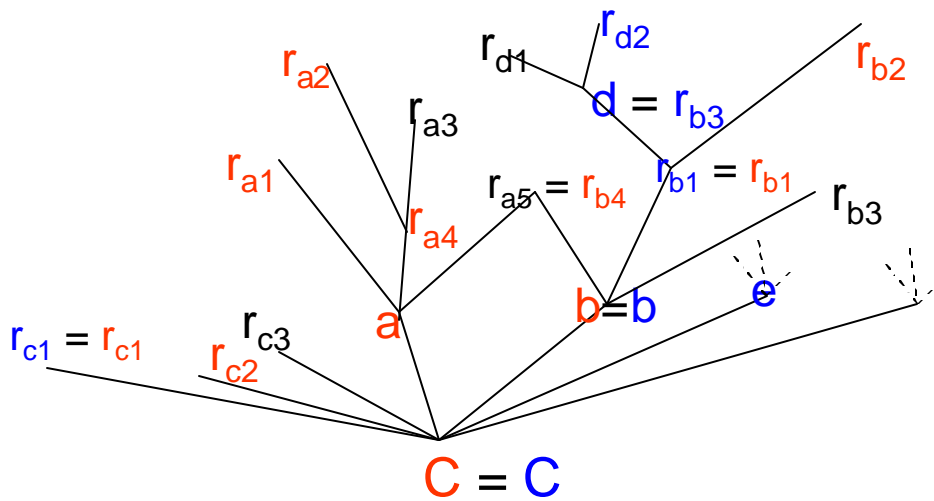


The sub-graph associated to an individual

Now consider two individuals: Red and Blue. Assume that the neighborhood of Red contains activities **a** and **b** and that of Blue contains activities **b**, **d**, and **e**. We can begin to represent this by coloring the nodes to indicate membership.



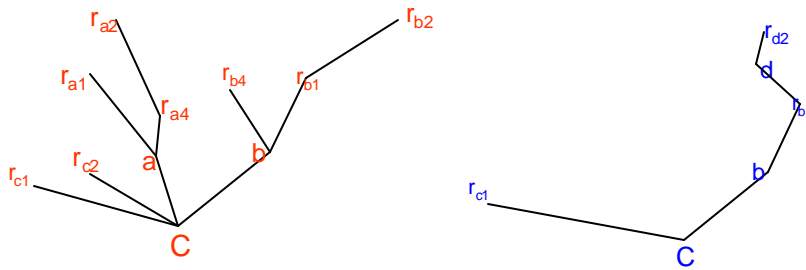
This gives a general picture of which activities Red and Blue are members but does not yet include information about their access to resources. If we further color the resource nodes to which each has access we produce a picture such as the following which displays the neighborhoods of each.



In this diagram we have included the fact that Red and Blue are both members of the community. Resource c_1 of C is in the neighborhood of each whole c_3 is in neither neighborhood. The resource c_2 is in Red's neighborhood, but not Blue's. Activity a is in only Red's neighborhood while b is in both neighborhoods. a_5 is not in the principal activity a_{red} but it is (denoted b_4) in b_{red} .

From the perspective of Red and Blue and their ability to function, to play their roles, within their activities in this community is completely determined by their neighborhood.

We can display these neighborhoods:



Each node of the graph of \mathcal{B} be reached by traversing one or more (directed) paths from C . This number of edges in such a path is its **length**. The length of the shortest path from C to a node is the **level** of the node. The same activity or resource can occur multiple times in the graph, at the same or different levels. A node with at least one departing edge is called a **branch** node while one with no departing edges is a **leaf** node. The display of A 's neighborhood can be represented by listing all of the nodes with tabulation reflecting level and different symbols representing branch and leaf nodes. Thus Red's neighborhood can be represented by:

```
*C
  -r1
  -r2
  * a
    -r1
    *r4
    -r2
  *b
    -r4
    *r1
    -r2
```

Blue's can be represented by

```
*C
```

-r1
*b
-r1
*d
-r2

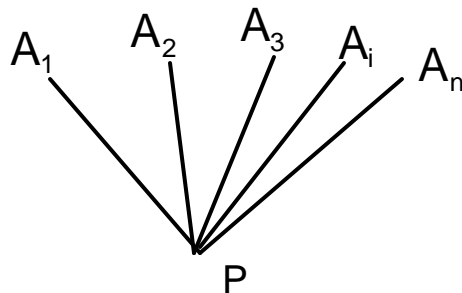
There is no suggestion that a view of the entire graph may not be useful or interesting to Red and Blue for some purposes. A person leaving for work may have a serious intellectual interest in the roadmap of the entire city. However, for efficiently accomplishing the task of getting to work, the best available routes from home to workplace is likely of more immediate interest. Likewise, an instructor heading for class may, at different times, be interested in the location of many campus classrooms. However once class has begun the interest, for the most part, is in but a few rooms and the most efficient way to move among them.

Partnerships Within a Community

A **partnership** among a set of activities $\{A_1, A_2, \dots, A_n\}$ within a community C is an activity P such that:

- i. The members of P are contained in the members of the activities A_i
- ii. Each A_i is a resource of P .

Visually, this just means that the graph of the community contains the following sub-graph



We hasten to emphasize that a construct as general as this is not intended to capture the complexity of partnerships among human beings and their organizations. On the contrary, it is intended to lose almost all of that complexity in an effort to gain some insight into communications environments that will facilitate their development and promote their success.

Many collaborative activities can, at least formally, be viewed as partnership activities in this model. An example of a community may be constructed from a school. The teachers, students, and staff are the community individuals, the classes the activities and the student grades the data. The owner of a class is the teacher who has that role and assigns the role of “student” to other class members.

Another example of a partnership within a school community might be a language festival put on by the foreign language department in which each class fields a team. The members of the partnership activity might be those of the individual teams and their sponsoring classes the activity resources. The activity owner might be the festival chair and the activity data may be the results of the competition.

In a university setting a large, multi-section course can be viewed as a partnership among all of the individual sections with the course coordinator as owner and partnerships such as the NSF or USDoE MSP's can be viewed in this setting.

An example in a multi-university setting is a co-operative degree program. The individual partner activities are the separate graduate programs, the partnership is the degree program.

Technical Infrastructure for Communities: KPS

A **communications resource** is one that is accessed by a Universal Resource Locator (URL). We restrict ourselves now to those communities all of whose resources are communication resources.

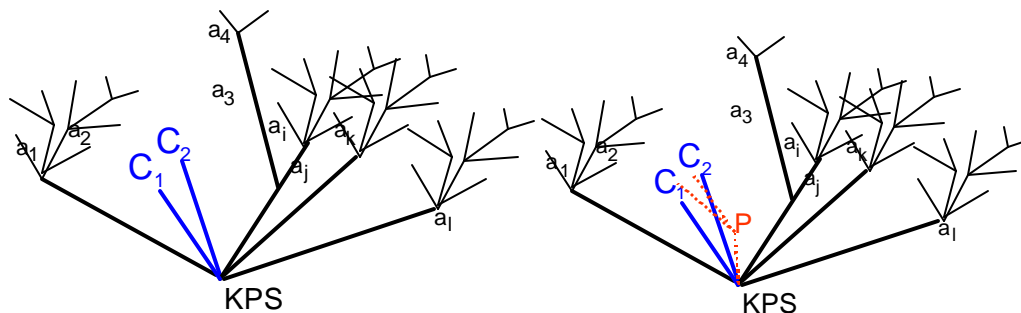
The Kentucky Partnership System (KPS) securely maps a community and its communications resources into a large, secure web site which has supporting infrastructure that provides members with efficient access to their resources, enhances the development, management, and operation of partnerships, and provides a common locus for data collection and management.

KPS is itself organized as a community and the site accounts are the community members. The site manager is the owner and certain sub-sites are designated activities

and the remaining site URLs are resources. The system database is the community data.

A community is mapped into the site by assigning members unique, password-protected KPS accounts⁵ through which they interact with the system. Each community activity is assigned to a corresponding site activity to which only activity members have access and within which the activity resources are organized with their original dependencies. Thus the community graph becomes a sub-graph of the KPS site map. Since the KPS site is extensible, large collections of communities can be mapped into KPS. This efficiently places multiple communities in a larger community within which the concepts of common activities and partnership have meaning.

Thus given communities C_1 and C_2 we have mappings $C_1 \rightarrow \text{KPS}$ and $C_2 \rightarrow \text{KPS}$ which permit us to think of each as an activity in KPS. This can be visualized in the following image where we have embedded C_1 and C_2 as activities in KPS which now gives a context⁶ in which a partnership activity P can be created and systematically maintained.



KPS Resources

⁵ One has to keep in mind that everything varies with time and that a particular member may have previously been assigned a KPS account, perhaps as part of another community. If the member wants to maintain that same identity in the second community then the member is assigned the original account. It is possible for a person to have multiple KPS accounts. When this happens KPS treats them as entirely independent individuals. The individual in the KPS community is the account, not the person who owns it.

⁶ This mirrors one of the great themes of mathematics research which dictates that when looking for a solution to a problem one first searches for (or constructs) a place where a solution can exist.

Among the KPS community resources are account creation/maintenance⁷ and password recovery tools, a global User Directory, system FAQ, system tutorials. Resources of the KSP “root” activity which are not true community resources⁸ include: a site News and blog system, a web homework system called WHS, a course management system called Moodle, and a synchronous conferencing/distance learning system called Centra. Of these, Moodle is an open source application and Centra is a licensed, commercial system.

Within KPS there are activities whose members’ roles include the ability to create new activities. Some of these are specialized. For instance there is within the WHS a membership class called “instructor”. Members with this role can create “class” activities whose owner is the class instructor and whose other members are the students, assistants, tutors, etc. It is also possible to associate with an activity a recruitment resource within which general members can apply to join the activity. Within the “class” activity in WHS this translates as a student requesting admission to a class. In this case the “status” attribute takes the values “applied”, “registered”, and “browsing”. The first indicates application for full participation, the second is the status if the owner approves, and the third is a request for “observer” or (in the case of a class) “audit” status.

The “News” resource in KPS allows members with the appropriate status to create new resources as activity data. The data can be anything that can be referenced by a URL. It can be made public or have access restricted to members of specific activities. Thus it is a simple matter for an activity owner to create private activity data (e.g. an internal web site to which only activity members can view and/or contribute). This is based on an integrated routing system for “News” data through which any user can, within the system, create and securely route web resources to specific activities or a collection of activities. The resulting functionality addresses many questions revolving around the protection of student identity when employing web-based resources to facilitate student class participation. It also provides for secure electronic data collection with digital signatures and account participation controlled by a “Completed IRB” status attribute. The web site has an integrated routing system through which any user can create and route web resources

Navigation in KPS

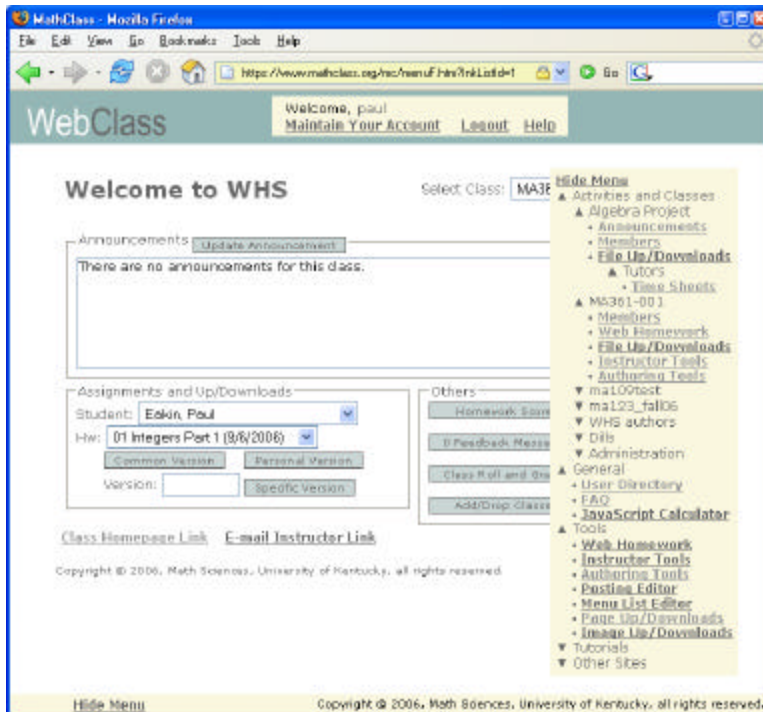
As noted above when a community is mapped into (or originates in) KPS each member account is identified (at any given time) with a sub-graph of the KSP site map (at that time) corresponding to all activities in which the account is a member and the resources to which the account has access. KSP provides the member, upon login, with menu of links which displays, in a tabbed-level format all paths through the account’s part of KSP. This provides for extremely efficient navigation with, typically, no two nodes of the

⁷ KPS is an open system in the sense that anyone can create an account. New accounts are automatically members of the KPS activity and have access to the community resources and public KPS resources.

⁸ These are resources that may be included in the resources of any activity but for which the activity owner may limited or no control of members’ access to features past the resource gateway.

user's graph separated by more than three mouse clicks. The menu is automatically updated when the user's "KSP World" changes, can be dragged to different parts of the screen, and can be hidden and displayed with toggle keys on every page header and footer, and on the menu itself.

The image below shows a KPS menu on a WHS page. Triangles denote branch nodes and bullets denote leaf nodes. The user can "prune" or expand the tree at a branch. The reader will note that some resources (e.g. "File Up/Downloads" and "Web Homework") appear more than once in the menu since they are resources in more than one activity.



Some examples

There are a number of current academic partnerships organized under KPS.

- a. Mathematics instruction at the University of Kentucky

The mathematics program at the University of Kentucky has four large-enrollment, multi-section courses which form academic communities within KPS: MA109 (College Algebra) with approximately 2000 students in Fall 2006, MA 113 (Calculus I) with approximately 600, MA123 (Introduction to Calculus) with about 900, and MA162 (Discrete Math) with about 500 students. For each of these communities the individual classes defined by the UK registrar's enrollment files were mapped into KPS as WHS class activities. Partnership resources

include common homework with common due dates and common syllabi⁹.

b. AMSP Excel

The AMSP Excel program for 2006 is a partnership of 16 AMSP K-12 partner school activities for 137 math students and 48 math teachers. The activity owner is partner high school math teacher in Garrard County, Ky. Partnership resources include a common application/registration interface and common, secure survey data collection through the News resource.

c. Kentucky Center for Mathematics coaches and intervention specialists

The Kentucky Center for Mathematics was established in April 2005 at Northern Kentucky University after a competition required by HB 94 of the 2005 Ky General Assembly. The bill decreed a statewide mathematics resource center, including the recruiting, training, and support of an annual cadre of up to 240 mathematics coaches and 40 early math intervention specialists, with annual operating expenses and program operation budgets of approximately \$5 Million. The coaches and specialists are to be uniformly distributed across the state. The center was ordered by the same bill to establish local demonstration sites at each of the 8 state universities with each site to support the coaches and intervention specialists in their area. The center and three of the regional sites were established as KSP recruiting/training activities, with a new recruiting resource¹⁰ through which coaching candidates and their school or district administrations could construct applications for participation. A separate, Centra communications training activity at the University of Kentucky was established as a resource for each of these in May 2006. By the end of August 2006 the KCM community consisted of the center staff (about 20 people), 80 coaches, 45 intervention specialists, and a small number of professional coaches training staff who are members of the four activities. New activities owned by each of the 8 regional coordinators who run the regional demonstration sites are under construction with the cadre of coaches and intervention specialists as members. Each of these has the Centra system as a resource which is used for weekly meetings among the members. Recorded Centra sessions are part of each

⁹ Significant portions of the instructional programs in mathematics at the University of Tennessee at Chattanooga and Spanish at the University of Kentucky have also been embedded in KPS. The tools for doing this are quite general. They make it possible to concurrently (and securely) embed large segments of the non-laboratory instructional programs (and their supporting academic infrastructures) of a family of academic institutions. This would support such things as joint courses and joint programs of study.

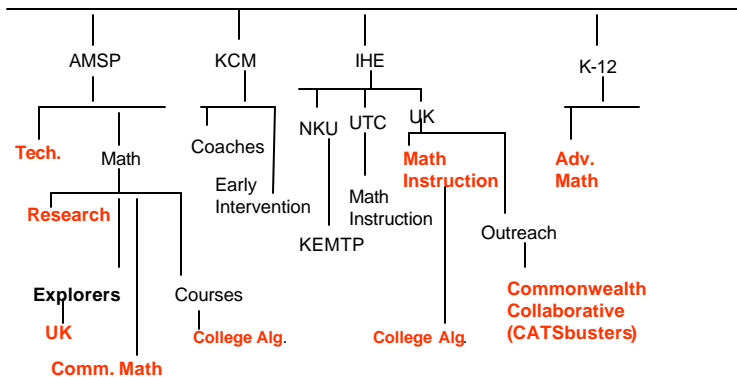
¹⁰ A reflection on the industry of the NKU people and their tools is the fact that the Math coaches program received its funding (and hence its ability to start its work from scratch) on April 1, 2005. A complementary reading coaches program with the same budget (\$2.15 Million) and located at the center for reading which has operated from UK since the 1990's received its funding on January 1, 2006. KCM created its program and recruited 80 coaching participants. The reading program recruited 25.

activity's data, together with reports collected through reporting resources provided for the activities. All 8 of these are part of two separate partnerships, one for coaches and one for intervention specialists, owned respectively by the KCM coaching and intervention specialist coordinators. As local coaches establish their programs they will establish new, school-based activities with the math teachers and administrators they support as members and in partnership with the regional centers that support them.

d. Access to Algebra

The objective of the Access to Algebra program is to demonstrate a capability to employ synchronous distance learning to afford remote high school students access to college-level mathematics courses which provide the same content and experience as that afforded on-campus students – at no cost to the student. The program has critical technical, instructional, research, staffing, logistic, and institutional support requirements that can, collectively be met through available resources developed through other activities. The partner activities in the program are indicated in red in the following image.

The Access to Algebra Partnership



The partners are:

- a. The AMSP technology program which is itself a community of activities in the AMPS Activity System (AMSPAS) which is a KSP predecessor.
- b. The AMSP Research Program – this inclusion is symbolic and represents the data collection and analysis and IRB management tools (including many survey instruments) which are incorporated as resources in this partnership

- c. The UK component of the AMSP Explorers program. This activity has developed a cadre of outstanding pre-service teachers and mathematics majors as collaborative tutorial assistants in the on-campus college algebra. In this project it is extended to provide the same assistance to both on-campus and (through e-tutoring) distant students.
- d. The AMSP College Algebra program is a project to develop a complete college algebra course with integrated web homework and complete text which can be freely used by K-12 math teachers. Free, high quality instructional materials are an absolute requirement if the program is to serve low-income schools and students.
- e. The AMSP Communicating Mathematics program which has focused on the development and implementation of long-term, systematic, professional development programs for secondary school math teachers. This program, in collaboration with the UK Commonwealth Collaborative “CATSbusters” program has developed the cadre of secondary teachers prepared to bring the Access to Algebra program to their students.
- f. The UK Mathematics instructional program which has been mapped into KPS so that on-campus sections of most classes have a parallel electronic representation which provides the web-based homework. This provides the mechanism for parallel on-campus and remote presentation of the same course.
- g. The K-12 Advanced Math Instructional Programs. Each of the participating K-12 teachers is the owner/instructor of a “class” activity in KSP which is formally parallel to an “Advanced Math”, “Pre-calculus”, or even “Algebra II”, class in their school but is otherwise identical to one of the participating UK College Algebra sections. This permits some of the teachers to offer the course, perhaps on a year-long basis, to students who are not necessarily prepared to take it at the college level.
- h. The UK Commonwealth Collaborative “CATSbusters” activity has, in partnership with the USDoE-sponsored Morgan County Technology Challenge Grant and the AMSP Communicating Math program, developed a seminar format academic year model for math teacher professional development of college and school math professionals. The program model has IHE faculty regard secondary faculty colleagues as applied mathematicians who specialize in instruction while the secondary faculty regard IHE as resources for support on the underlying theory. This program produced the pilot in spring 2005 which demonstrated the soundness of the Access to Algebra design. The activity carries the UK presidential designation of “Commonwealth Collaborative” which affords access to additional university resources. This activity brings to the partnership the tuition and fee waivers for the high school participants.

The Access to Algebra program currently (Fall 2006) has (approx) 50 high school students from 15 schools (13 AMSP) taking college algebra

concurrently with (approx) 50 UK college students in two sections. The activity is owned by Ms. Lee Alan Roher who is an AMSP-supported math ed doctoral student. Mr Roher is the teacher of record for all of the students. She is assisted by a team of AMPS Explorers who provide online tutoring and by an in-service teacher and alumnus of the UK Explorer program, Ms Sarah Stinson. Ms Stinson and Ms Roher conduct weekly meetings among the participating teachers and participating UK faculty via the Centra system.