How to Rectify UK’s STEM Shortages by Creating a STEM Pipeline (Youth + Undergrad-mentors + STEM Professionals)

Executive Summary

- For 16 semesters, I trained over 300 of my Undergrads to serve as mentors who carried out STEM-focused Mentor-Assisted Enrichment Projects (MAEPs) with over 1,000 Youth (grades 4-12) – and connected these Youth with STEM Professionals.
- 16 semesters of R&D revealed essential components (e.g., planning, structure, roles & responsibilities, training, incentives, Competencies to be developed) needed for creating a Complete STEM Pipeline comprised of Youth + Undergrad-mentors + STEM Professionals.
- Participating in this STEM Pipeline enhanced Person-Career Fit by enabling Youth to explore interesting careers, to identify careers that matched their talents and aspirations, to take the right courses, stay in school and graduate.
- Identifying best-fit careers motivates Youth to develop Competencies that involve learning about STEM, learning why it is important, and learning how to employ STEM skills to solve real world problems.
- I trained Undergrad-mentors to employ best practices of experiential/discovery learning and didactic instruction to maximize learning by different kinds of Youth (gifted/talented/creative; ESL – English-second-language; at-risk of dropping out; Native).
- I trained Undergrad-mentors to manage Project Teams, so that members learned how to work together on a Team (planning, carrying out, completing, and presenting their MAEP).
- Initial Collaborative Program Planning by key stakeholders gets everyone’s agreement on all essential Program components and ensures Multiple Benefits result for everyone involved.
- Each MAEP was presented to an audience (parents, teachers, other students, the public) to illustrate what was done and learned; this recruited new participants.
- Because Undergrad-mentors earned course credit, this reduced costs and provided unmatched Quality Control over what mentors did with Youth during a semester-long MAEP.

Bio for Dr. William A. Gray
Before retiring, Dr. Gray wants to collaborate on a significant project where he can contribute what he has discovered as an Educator (15 years) and Businessman (30 years), such as employing best practices from the Educational Paradigm (different interventions, methods, processes) and from the Business Paradigm (producing intended results). Dr. Gray’s avocation-vocation has focused on collaboratively developing over 150 Formalized Mentoring Programs (most involve skill coaching) for different situations, groups and purposes. Such as: Rectifying STEM shortages by creating a STEM Pipeline (comprised of Youth + Undergrad-mentors + STEM Professionals) – where trained STEM majors carry out Mentor-Assisted Enrichment Projects with interested Youth and connect them with STEM Professionals. Dr. Gray has custom-developed Training Activities & Materials needed to produce Multiple Benefits for everyone involved – especially enabling Youth to identify best-fit careers so they take the right courses needed to become Undergrad STEM majors. See Dr. Gray giving three interviews at: http://www.mentoring-solutions.com/. See his two eBooks (Situational Mentoring and Mentoring Relationships that Work) at: http://www.amazon.com.

A Complete STEM Pipeline is needed to rectify the shortage of persons in each group:
- To motivate more Youth to take the right courses to become STEM majors.
- So, there are more Undergrads graduating in STEM disciplines.
- So, there are more STEM Professionals to solve real world problems (like the 14 Grand Engineering Challenges).
Written evidence submitted by Mentoring Solutions (GAP0083)

Typically, however, only two of these three groups are involved in a STEM Initiative, such as when Undergrads mentor Youth or when Youth job shadow or interview busy Professionals (who can provide occasional mentoring).

My approach creates a Talent/Workforce Development Pipeline that produces STEM majors, who become STEM Professionals to meet industry needs (including the Trades). Below are keys to “connecting all the dots” to produce success.

1. Utilize trained Undergrad-mentors, for these reasons:

- Undergrad-mentors can be readily trained to do things that other types of mentors (e.g., parents, seniors, STEM professionals, teachers) may not be so easily trained to do, or will actually do after training. Such as:
  - Employ best practices of experiential/discovery learning and didactic instruction to maximize learning by different kinds of Youth (gifted/talented/creative; ESL – English-second-language; at-risk of dropping out; Native).
  - Employ Mentoring Style Flexibility so mentors provide appropriate assistance, which their proteges will accept and utilize.
  - Equip proteges with what mentors know and empower what proteges want to learn, do and become.
  - Use a 6-Step Mentoring Process to help proteges deal with difficult challenges – without telling them what to do or expecting them to figure this out for themselves.
  - Create and carry out a Mentoring Action Plan so everyone is prepared for meetings, goals are attained, and completed Plans provide evidence of what was done and learned.
  - Serve as a trained Project Manager of a Team so that everyone contributes, leads, and supports others.
  - Prepare proteges to give a Multi-media Presentation to an audience (parents, teachers, other students, the public) to illustrate what was done and learned; this recruited new participants. For additional publicity and recruitment, these Presentations can be uploaded on the Internet – and be used for instructional by teachers and college/university Faculty.
  - **NOTE:** Only proper Training can ensure such mentoring occurs. Orientations and Pep Talks will not.

- Undergrad-mentors are readily available on campuses – and there are new ones enrolling each year.

- Unmatched Quality Control occurs because Undergrad-mentors will fulfill course requirements to earn full course credit (for a course assignment they chose to do).

- Undergrad-mentors will put in the necessary time to provide effective STEM-oriented mentoring when they earn course credit for doing this. (My 300 Undergrad-mentors invested 2-3 times what the mentoring assignment required of them; they would not have done this if they were being paid.)

- Undergrad-mentors willingly participate in both Quantitative and Qualitative Evaluations (answer surveys and participate in a focus group).

- Faculty evaluations go up when they supply Undergrad mentors and give course credit for effective mentoring.

2. Define, Design, Align, Deliver All Essential Program Components using a Collaborative Process

Many STEM Initiatives fail to produce intended results because all essential components are not identified and designed. In contrast, a carefully planned and implemented Program produces significantly better results. We
employ a **Collaborative Program Planning Process** (involving key stakeholders) to define, design, align, and deliver all essential components needed to produce **Multiple Benefits** for everyone involved (listed later).

As an Education Professor for 15 years, who prepared future teachers, I learned the importance of investigating different Interventions/Methods/Processes to find out which is best (the Education Paradigm). As a Businessman for 30 years, I learned how to produce intended Results (the Business Paradigm). I’ve employed best practices from both Paradigms when facilitating the development of over 150 Formalized Mentoring Programs, including the type of Mentoring Program that rectifies STEM shortages.

Only an **Expert in Mentoring Program Development** has the experience to facilitate this Collaborative Process from start to end, according to Stuart and Hubert Dreyfus’ meta-analysis of many studies on how one becomes an Expert in a dedicated field of practice. Below, their findings are applied to describe the 5-Stage development of an Expert who can develop different/appropriate types of Formalized Mentoring Programs.

**Caution:** Many “instant experts” are springing up everywhere. Typically, they have written a book based on a study of informal mentoring (which just happens spontaneously, without initial planning) – this often shapes their attempt to implement “Mentoring Initiatives” or simplistic “Announcements” to do-your-own-thing.

<table>
<thead>
<tr>
<th>Level</th>
<th>5-Stage Development of an Expert in Developing Formalized Mentoring Programs</th>
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<tbody>
<tr>
<td><strong>Expert</strong></td>
<td>Has at least 10 dedicated years focusing on developing distinctive/appropriate Formalized Mentoring Programs. Because experience in field is broad and deep, this Expert is aware of important variables in any new situation, and thus can quickly focus on these (and avoid irrelevant variables). Able to combine different paradigms, such as Educational emphasis on interventions and Business emphasis on getting results. Appropriately defines, designs, aligns all essential Program Components, and then delivers them to produce intended outcomes that satisfy the business case for starting the Program. Reflective practitioner who self-assesses what works/doesn’t. Discovers the Guiding Principles that others employ.</td>
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<tr>
<td><strong>Proficient</strong></td>
<td>Has at least 5 years in field, with varied experiences. Follows Principles discovered by Experts, but is becoming a reflective practitioner who discovers Principles. Can plan and implement several different types of <strong>Formalized Mentoring Programs</strong>, such as: Programs for new Hires, for Career Development, for Leader Development. Cannot plan and implement complex Programs, such as “connecting all the dots” to create a Complete STEM Pipeline (Youth + Undergrad-mentors + STEM Professionals).</td>
</tr>
<tr>
<td><strong>Competent</strong></td>
<td>Has repeated experience doing the same thing to create one type of <strong>Formalized Mentoring Program</strong>, such as orienting new hires. Follows Guiding Principles discovered by Experts; cannot readily plan and implement variations, such as mentoring recent hires for career development.</td>
</tr>
<tr>
<td><strong>Advanced Beginner</strong></td>
<td>Knows about mentoring for a specific situation. Likely to implement simplistic <strong>Mentoring Initiatives</strong> rather than a more formal approach with structured components. Applies Guiding Principles discovered by Experts, but doesn’t know how to produce all intended outcomes.</td>
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<tr>
<td><strong>Novice</strong></td>
<td>Little or no direct experience. May have read books or articles, but has no practical understanding based on actual experience. Likely to make <strong>Announcements</strong> that encourage informal mentoring to happen (“do-your-own-thing”), for whoever wants to do this. Unaware of Guiding Principles for planning and implementing anything more complex.</td>
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3. Connect all the Dots to create a Complete STEM Pipeline

- Youth need to connect knowing “about” STEM, knowing “why” STEM is important, and knowing “how” STEM Professionals solve real world problems (like the 14 Grand Engineering Challenges). Youth become motivated to develop **Competencies** (comprised of knowledge/understanding + right attitude + behavioral skills) once they identify best-fit Careers that match their talents and aspirations.

Here is one example of how an Undergrad-mentor helped Youth connect “learning about & why” with “learning how”: Several proteges were interested in architecture as a potential career. They wanted to learn about the relationship between architectural design and construction of buildings. Their mentor took them to view and take photos of all the major buildings in Vancouver, Canada that Arthur Erikson had designed – and then helped the proteges formulate good questions to ask him.

Such as: “What design and construction problems had to be solved when you decided to let large trees grow through the roof of the underground library at the University of British Columbia?” “What challenges had to be resolved when you designed Simon Fraser University as a single construction to sit on top of Burnaby Mountain?” Erikson was so impressed with the protege’s questions, preparation and enthusiasm that he spent additional time with them – helping them decide to pursue an architectural career.

Bottom line: This involvement of Youth + Undergrad-mentor + Professional exposes young proteges to the possibilities and realities of STEM careers. Young proteges easily identify and talk with Undergrads (because there is not a large “age gap”) and they learn about “best-fit” careers from busy Professionals, so they can pursue the right career for them.

- Undergrad-mentors are trained to **avoid either-or thinking** by employing best practices of **Didactic Instruction** (to teach fundamental concepts and demonstrate needed skills and procedures) and **Open Inquiry** (to engage students in discovery learning). Providing both methods maximizes learning by all students. [See: J. S. Coleman et al. (1973) The Hopkins Game Program: Conclusions from seven years of research, *Educational Researcher*, Vol. 2, No. 8, pages 3-7. Also see: Louis Alfieri, Patricia Brooks, Naomi Aldrich & Harriet Tenebaum, Does Discovery-based Instruction Enhance Learning? *Journal of Educational Psychology*, Vol. 103, No. 1, 2011, pp 1-18]

- Youth need to **complete what they start** in order to gain a **sense of accomplishment** (parents also want this for their children). In a 1982 study, Dr. Gray found that 29 of 31 proteges in grades 5/6 said that they must **complete** their Mentor-Assisted Enrichment Project for them to view it as worthwhile. This is highly significant statistically (p< .0000). This occurred because mentors and proteges created and completed an agreed-upon **Mentoring Action Plan** for each MAEP so proteges knew from the outset what was expected. A key to success is training Undergrad-mentors to solicit input from proteges so they perceive the Project as “theirs” even though it is based on each mentor’s expertise.

- Perhaps you’ve been wondering whether young proteges can create, carry out, complete and present a MAEP on their own after having done this with a mentor’s assistance. Dr. Gray wondered the same thing, and conducted research to find out. See Table 1 below.

Table 1. “Mentor-Assisted” vs. “Self-Directed” Enrichment Projects
Below are some of the findings from a study of “Mentor-Assisted” and “Self-Directed” Enrichment Projects that involved 31 proteges in grades 5-6. (Reference: William A. Gray, Mentor-Assisted Enrichment Projects for the Gifted and Talented, Educational Leadership, Nov. 1982, pages 16-21.)

### Binominal t-tests comparing the frequency with which 31 students in grades 5-6 indicated a preference between a “Mentor-Assisted” or a “Self-Directed” Enrichment Project. (This tests the probability of students choosing either type of project. “Missing data” occurred when no preference was given.)

<table>
<thead>
<tr>
<th>Questions</th>
<th>MAEP Frequency</th>
<th>SDEP Frequency</th>
<th>2-Tail Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which enrichment project did you most want to do before beginning the project?</td>
<td>19</td>
<td>12</td>
<td>0.28</td>
</tr>
<tr>
<td>2. Which enrichment project did you become more interested in doing as you worked on the project?</td>
<td>25</td>
<td>6</td>
<td>0.00</td>
</tr>
<tr>
<td>3. Which project did you most want to complete?</td>
<td>22</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>4. Into which project did you put your best effort?</td>
<td>22</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>5. Which project did you most want to present to your classmates?</td>
<td>22</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>6. Which project did you do a better job of presenting to your classmates?</td>
<td>24</td>
<td>7</td>
<td>0.00</td>
</tr>
<tr>
<td>7. Which project did you spend more time doing outside of school time?</td>
<td>18</td>
<td>13</td>
<td>0.47</td>
</tr>
<tr>
<td>8. Which project helped you learn how to take more responsibility for doing an enrichment project?</td>
<td>21</td>
<td>4</td>
<td>0.04</td>
</tr>
<tr>
<td>9. Which project was better planned so that you finished the whole project according to your plan?</td>
<td>24</td>
<td>6</td>
<td>0.00</td>
</tr>
<tr>
<td>10. Which project was better planned each week so that you knew what to work on?</td>
<td>24</td>
<td>6</td>
<td>0.00</td>
</tr>
<tr>
<td>11. Which project was better completed to your satisfaction?</td>
<td>22</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>12. Which project required you to use higher level thinking skills?</td>
<td>20</td>
<td>11</td>
<td>0.15</td>
</tr>
<tr>
<td>13. Which project most helped you develop a more positive self-concept?</td>
<td>22</td>
<td>9</td>
<td>0.03</td>
</tr>
<tr>
<td>14. Which project helped you learn how to ask questions you would later answer?</td>
<td>22</td>
<td>7</td>
<td>0.01</td>
</tr>
<tr>
<td>15. Which project most required you to use the community as a resource?</td>
<td>25</td>
<td>6</td>
<td>0.00</td>
</tr>
<tr>
<td>16. Which project most required you to use other people as a resource?</td>
<td>25</td>
<td>5</td>
<td>0.00</td>
</tr>
<tr>
<td>17. If you were to recommend one type of enrichment project to a friend, which one would it be?</td>
<td>27</td>
<td>4</td>
<td>0.00</td>
</tr>
<tr>
<td>18. Which type of enrichment project would you most want to do again?</td>
<td>18</td>
<td>13</td>
<td>0.47</td>
</tr>
<tr>
<td>19. Which project do you think should be done first?</td>
<td>24</td>
<td>7</td>
<td>0.00</td>
</tr>
</tbody>
</table>

After answering this survey, follow-up interviews with the student-proteges revealed the reasons for their responses. These students had no inherent bias for doing either type of enrichment project (see Question-1), and many said they wanted to do a “Self-Directed” project after learning how to do an enrichment project with a mentor (see Q-18). Student-protege responses on 15 other Questions clearly indicate 15 ways that “Mentor-Assistance” has a significantly beneficial impact. Except for Q-7 (it takes time to do an enrichment project) and for Q-12 (these students were already learning to use higher level thinking skills in class).

4. Some Multiple Benefits– produced by properly implemented Mentor-Assisted Enrichment Projects:

**Student-proteges** in grades 4-12 benefit in multiple ways, such as:

- Learn how to **plan and carry out** a project – and create and give a **presentation** of what was done and learned.
- Learn to **connect** “knowing about” STEM concepts and “knowing why” they are important with “knowing how” they are applied in real world situations.
- Utilize **higher-level thinking skills** in each project (based on Bloom’s Cognitive Taxonomy).
- Learn how to be **team members** (take turns leading and following) within the project group.
Learn how to interview and job shadow STEM professionals to learn about interesting STEM occupations.

Identify best-fit careers that match talents and aspirations.

Take the right courses to enter a STEM major, stay in school, graduate.

**Undergraduate-mentors** benefit in multiple ways, such as:

- Learn project management by planning, carrying out, completing and presenting a MAEP with a group of proteges.
- Learn how to get proteges to see the Project as “theirs” so they will carry it out and complete it.
- Learn how to make MAEP activities so engaging that proteges will complete and present “their” MAEP.
- Learn how to utilize STEM professionals (too busy to be mentors) to motivate interest in STEM occupations.
- Learn how to get proteges ready to give a Presentation of their completed MAEP.

**Faculty** benefit in multiple ways, such as:

- Learn how to structure a course assignment so all requirements will be met.
- Get significantly higher course evaluations from Undergrad-mentors vs. other students.
- Can use the Presentations of completed MAEPs to enhance their own instruction.

**Teachers** benefit in multiple ways, such as:

- Learn how to work more cooperatively with Faculty and Undergrad-mentors.
- Can use the Presentations of completed MAEPs to enhance their own instruction.
- **Parents** appreciate teachers more because their children benefit in multiple ways from completing a MAEP.

**Schools and universities/colleges** benefit in multiple ways, such as:

- Learn how to work together more cooperatively – on projects and associated research.
- Because many MAEP activities occur on university/college campuses, this recruits proteges to attend there.

**Employers** benefit in multiple ways, such as:

- Hire individuals whose talents and competencies match the work to be done.
- Enhanced worker performance and job satisfaction.
- Reduced turnover of dissatisfied employees.

6. Some References

• Gray, W. A. & Albert, W. F. (2013). Create a STEM Pipeline for students who become engineering majors who become engineers. *Leadership and Management in Engineering.* 13 (1), 42-46. (Published by American Society of Civil Engineers)

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