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Introduction: The 2017 ATMAE Accreditation Handbook Standard 5 states that each baccalaureate program/ option should meet minimum-maximum semester hour requirements in the foundational areas of general education, mathematics, physical (or life) sciences, management, technical, and electives. The specific credit hours required for each category has a specified range. This study attempted to answer the question of what courses typical ATMAE accredited university programs most frequently require. ATMAE accredits four-year manufacturing, industrial, construction, and information technology programs. To what extent are these accredited programs similar in content? Is there a representative convention of content for university courses?

The objectives of the research were to (a) determine the variety of ATMAE university programs and their constituent courses and (b) identify a composite curriculum for ATMAE university programs. Research was conducted using recent ATMAE accredited self-study reports of four-year programs. Specifically, the study sought to answer the following questions:
• What specific courses are self-reported by ATMAE accredited four-year programs?
• What courses are reported by ATMAE accredited four-year programs to maintain the reasonable balance between practical and conceptual application as stated in the Accreditation Handbook?
• Is there an identifiable composite curriculum for ATMAE accredited four-year programs?

Review of Literature: As outcomes-based accreditation and certification (e.g., SME, ASQ, APICS, PMI, etc.) have gained momentum, reviews of curriculum have become more frequent and useful. Meier, Williams, and Humphreys (1997) and Meier and Brown (2008) suggested an essential curriculum for the success of new employees in engineering and technology. Researchers Rifkin, Fineman, and Ruhnke (1999) developed an ordered model for a technical manager's skills, knowledge, activities, and personal behaviors. Other published literature on curriculum included manufacturing (Payne, 2009; Waldrop & Jack, 2012), industrial engineering (Ferguson, 1991), safety (Blair, 1997), and project management (Golob, 2002).

Litowits (2014) proposed a composite curriculum for undergraduate technology and engineering teacher education programs, identifying three core areas: general education, professional (teacher) preparation, and technical study. This research found a composite in the technical coursework of two courses in energy and power, including electricity/electronics and transportation, and one course each in manufacturing, construction, design, material processing, and drafting/computer aided design.

The Society of Manufacturing Engineers developed the Four Pillars of Manufacturing Engineering using ABET accreditation criteria for manufacturing. The curricular areas identified were (1) materials and manufacturing processes, (2) product, tooling, and assembly engineering, (3) manufacturing systems and operations, and (4) manufacturing competitiveness (Mott, Jack, Raju, & Stratton, 2011). A variety of survey studies followed on student, faculty, and professional perceptions of the Four Pillars (Nutter & Jack, 2013; Nutter, Mott, Williams, Stratton, 2013; Doggett & Jahan, 2014).

Thus, the basis for this study is congruent with the literature where the curriculum is tied closely to desired competencies and there is sufficient data available on current course offerings. In addition, the validation of curricular models or a curriculum composite is frequently accomplished using survey research.

Methodology: ATMAE provided the researcher with aggregate data on the number of required credit hours for each foundational area as self reported by 53 universities having 163 accredited programs. Actual self-study report responses to Standard 5 were obtained from sixteen universities having 31 ATMAE accredited programs. The 31 programs were construction management (7), industrial technology (5), electronic technology (5), manufacturing (4), graphics/drafting technology (3), agricultural systems (2), aviation (2), computer technology (1), mechanical design (1), and automotive technology (1). The courses as reported by each program were loaded into an Excel spreadsheet and sorted under their foundational category. For example, if a particular program listed a course under the technical requirements of the Accreditation Handbook Table C-1 of the self-study, it was placed in the technical column of the spreadsheet. Courses listed in the management area were added to the management column and so forth. The findings of the study were strictly limited to the information reported on each self-study. The identities of the specific universities and programs were asked by ATMAE to remain confidential.

Under each foundational area, the courses were then sorted by subject name. Courses having similar titles were grouped using deductive reasoning. If a single course was listed multiple times across programs, it was counted once for each program. For menu-driven curriculum, where students would select a set of courses from a list, each course was placed in a group. After sorting and grouping courses by their titles, the findings were reviewed for content validity.

Program Findings: The range and average of the total number of hours by area required by ATMAE accredited university programs is shown on Table 1. The reported ranges that exceed the maximum or do not meet the minimum were not investigated as only the Standard 5 tables were provided, not the entire self-study. Prior to the outcomes-based standards, programs were not required to submit their self-study reports electronically. In addition, no historical record was required by or kept by ATMAE. The review of the available Standard 5 tables revealed inconsistencies and some duplication or omission of course reporting. These inconsistencies and errors might have been explained in the body of the self-report, but could not be clarified for this study.

Table 1

Average and range of semester hours required by university ATMAE accredited programs

ATMAE Area	ATMAE Min/Max Semester Hour Requirements	Reported Hours Range	Average Hours
General Education	18-36	18-75	33.8
Mathematics	6-18	3-18	8.5
Physical Sciences	6-18	3-22	9.2
Management	12-24	12-39	21.3
Technical Electives	24-36	12-69	37.3
	0-18	0-42	11.5
Total	120 minimum	96-156	122.1

The courses for each self-reported foundational areas listed in ATMAE Accreditation Handbook Table C-1 were compiled for the available 31 ATMAE accredited programs and courses with similar titles counted. Some assumptions were made regarding equivalency. For example, a course with the title *Elementary Statistics Concepts* was determined to be of similar type as a course with the title *Basic Statistics*, although the exact content might differ. Related topic courses were also grouped by type such as statics, strength of materials, and architectural structures courses. In this case, a course type was created called statics/strengths/structures. Pareto charts of the courses sorted by reported frequency for the 31 programs for each ATMAE foundational area follow beginning with mathematics (Figure 1). The most frequently appearing courses using the 80/20 Pareto Principle were algebra/trigonometry, statistics/SQC, calculus, and general math. The course types falling within the 80% rule are shown in the lighter shade. The average number of math courses per program was 2.7. The actual frequency for all reported courses is found in the Appendix.

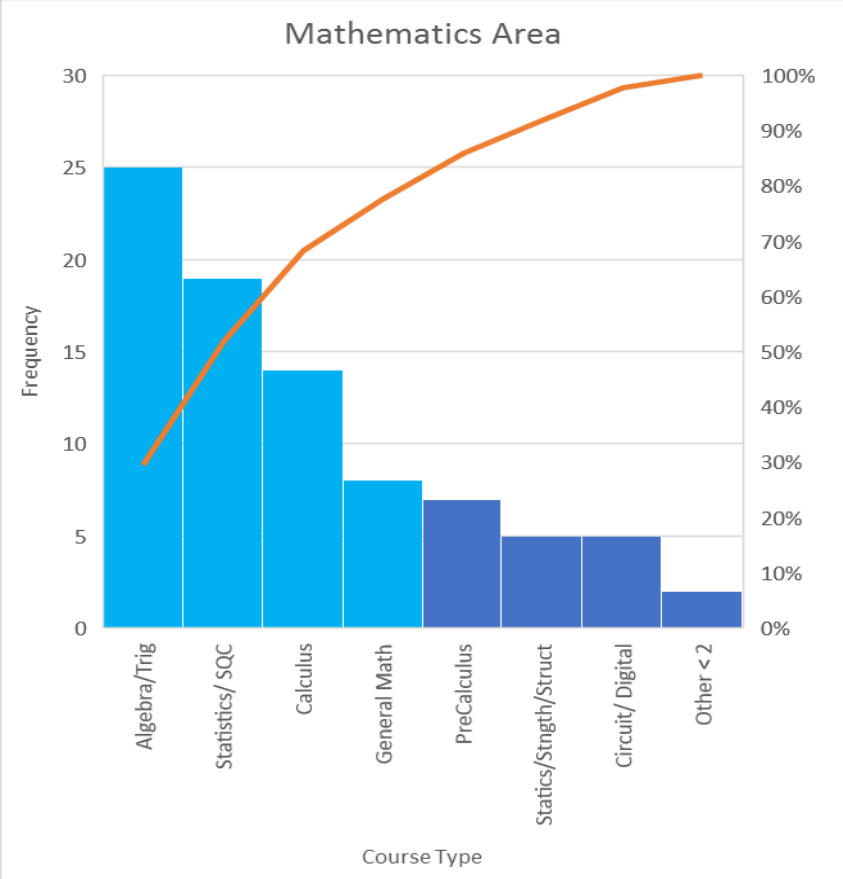

Figure 1. Pareto chart for the mathematics area

The most frequently appearing courses for physical (life) sciences were physics, chemistry, and biology/ecology. The Pareto chart is shown in Figure 2. The average number of physical science courses per program with the addition of labs was 3.1. Not all programs listed labs as an additional requirement so it is uncertain if they were included. The frequency of reported courses and reported courses with labs is found in the Appendix.

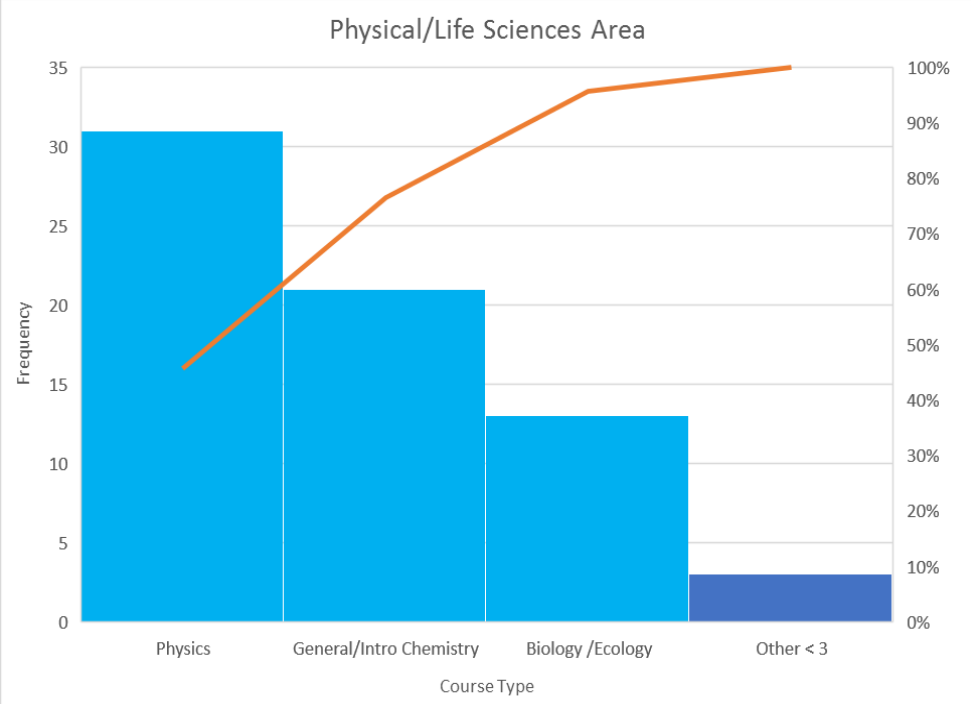

Figure 2. Pareto chart for the physical/life sciences area

The most frequently appearing courses for the management area were internships or work experience, followed by management/supervision, accounting, human resources and organizational behavior. A number of other course types were also reported frequently within the 80% rule. They were planning and operations, safety/ergonomics, senior capstone, project management, law or legal issues, and marketing/sales. The average number of management courses per program was 7.4. See Figure 3.

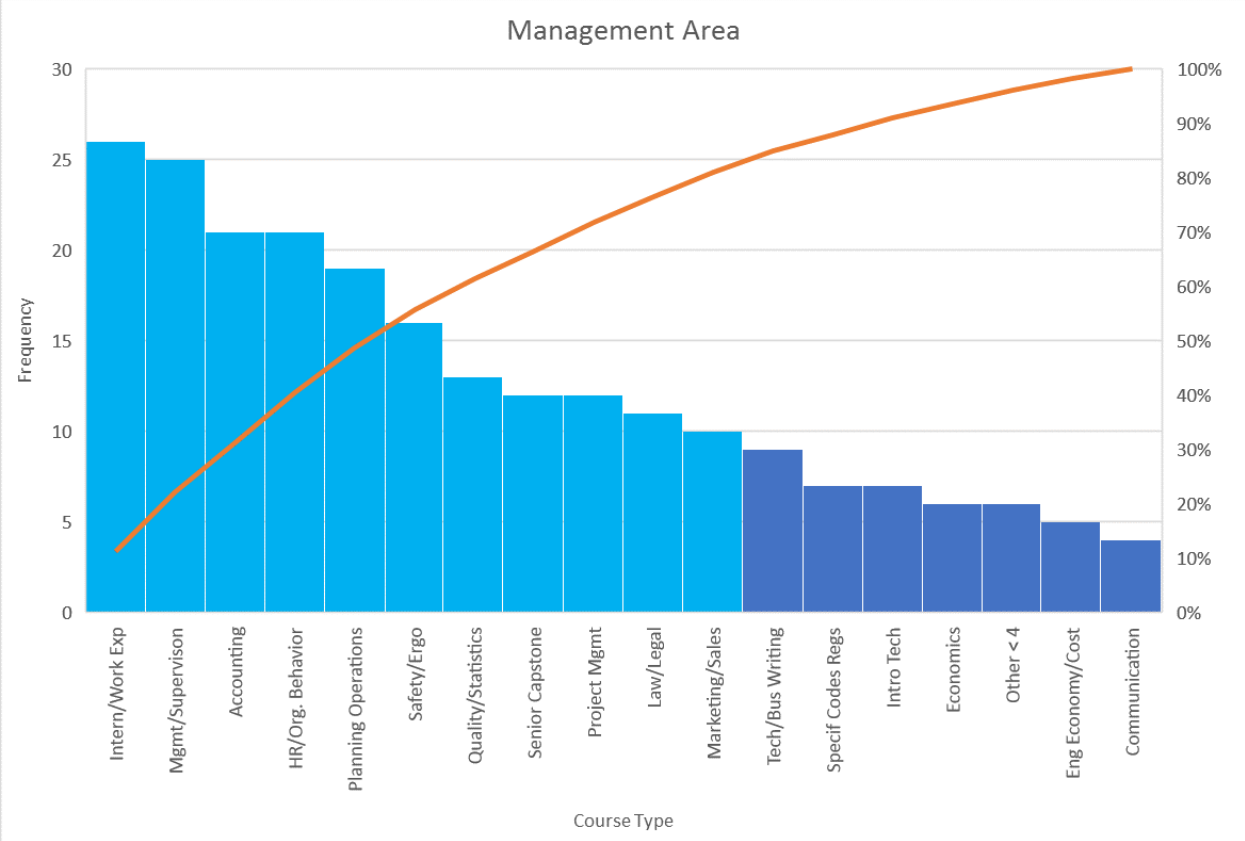

Figure 3. Pareto chart for the management area

The most frequently appearing courses for the technical area were electronics/electrical or digital courses followed by methods/processes/materials type courses, drafting/graphics/CAD, and programming/computing or networking. The other courses frequently reported meeting the 80/20 criteria were industrial/product design, power and energy courses, senior capstone, introduction to technology, business/technical systems, and materials/statics or strengths-type courses. The average number of technical courses per program was 15.7. See Figure 4.

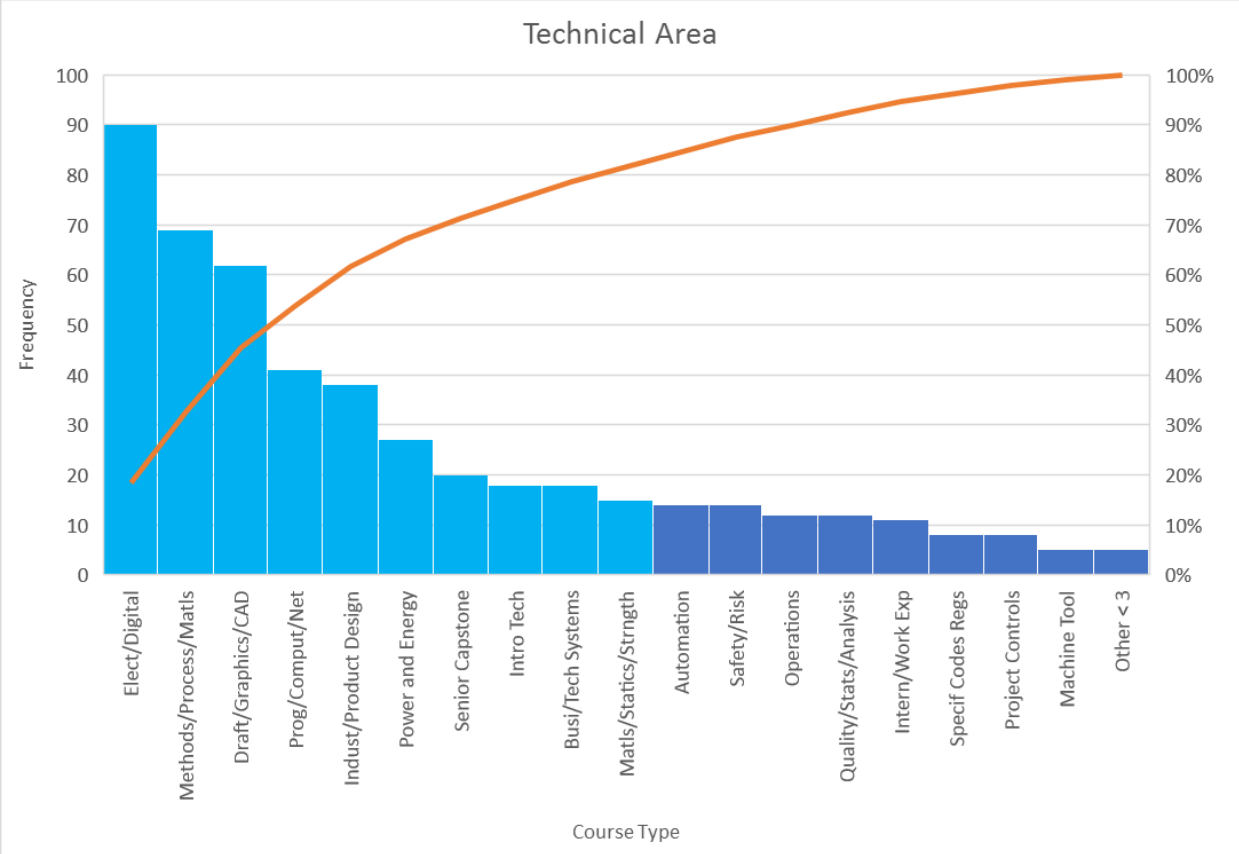

Figure 4. Pareto chart for the technical area

The most frequently appearing courses for the electives area were drafting/graphics/ computer-aided-design (CAD). This was followed by courses specific to mechanical or manufacturing technologies, architectural/civil or construction management, and health or safety. Some of the self-reported data did not call out specific courses. Rather, students were asked to select courses based on university or department/program approved lists. Other criteria for electives were by identified by a block concentration area such as management electives, technical electives, or non-technical. Other course types reported within the 80% criteria were industrial/product design and humanities electives. As the number of electives per program varied widely, an average number of elective courses per program was not calculated. See Figure 5.

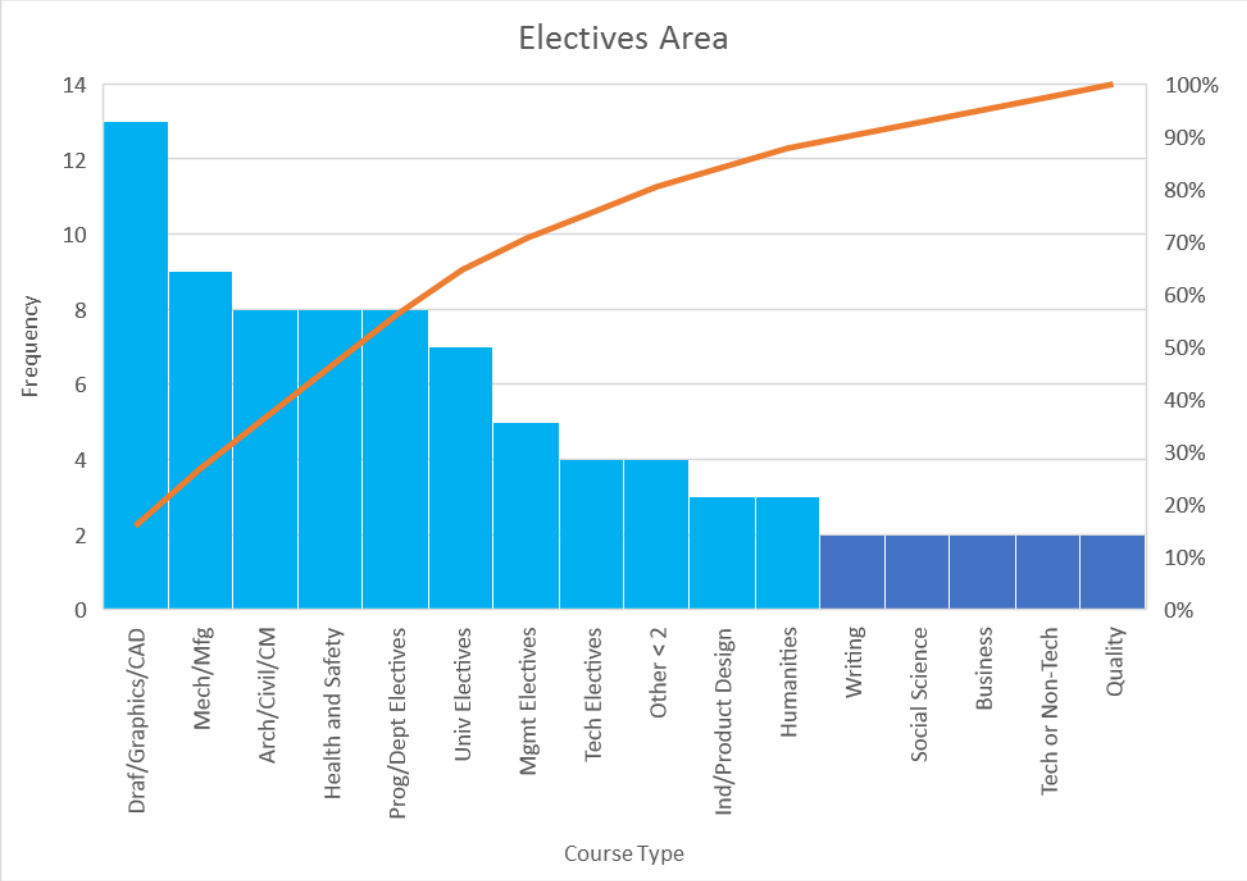

Figure 5. Pareto chart for the electives area

Conclusion: Using a combination of the average number courses per areas, the average hours reported, and the Pareto charts, the most likely courses appearing in ATMAE accredited university programs is shown in Table 2. The three mathematics courses most likely to appear in a university program are algebra/trigonometry, statistics, and calculus. The calculus-based programs required either pre-calculus or combinations of algebra/trigonometry as prerequisites while the non-calculus-based programs required general math and algebra/ trigonometry combinations. The three physical/life sciences courses most likely to appear are physics, chemistry, and biology.

For the management area, 11 courses fell within the 80% rule, but programs typically required between seven and eight courses. However, the frequency of four other courses above 70% was very close. Thus, Table 2 includes the top nine reported courses for management. While law/legal courses and sales/marketing courses were also within the 80% rule, they are not listed. It should be noted that quality/statistics courses were self-reported in both the management and technical areas, but more frequently in the management area. Capstone courses were also reported in both the management and technical areas, but more frequently in the technical.

Programs reported courses in higher frequency for the technical area. While the ATMAE maximum is 36 semester hours, the average hours were over 37 and the range maximum was almost double. In this case, it made more sense to use the 80/20 rule for the composite, which was 10 courses. Materials-type courses in the technical area were reported one of two ways. The first type was materials, methods, and processes, which was generally specific to a program discipline such as manufacturing, construction or graphics. The second type was related to materials science, statics or strength of materials, with the latter associated more with properties of materials. Drafting, graphics, and CAD courses were frequently reported, but also heavily reported as electives. As mentioned previously, capstones courses were reported in the technical area, but also in management. Introduction to technology courses were reported in both technical and management, but more frequently in technical. These introduction courses were also program specific with titles such as *Introduction to* [*Computing, Construction, Manufacturing*] etc.

For the electives, the average number of reported hours was between 11and 12, but the reported range maximum was over twice the ATMAE maximum of 18 hours. However, eleven courses met the 80% rule. For this area, the ATMAE maximum of six courses (18 hours) was used as the cutoff. The most frequent type of elective was drafting, graphics, or CAD courses. This was followed by a variety of program discipline, department, or university-specific electives. Health and safety courses also appeared frequently.

Table 2
Courses most likely to appear in university ATMAE accredited programs

ATMAE Area	Avg. Number of Courses per Area	Average Hours Reported	Courses Most Likely Appearing
General Education		33.8	
Mathematics	2.7	8.5	Calculus, PreCalculus, Stats Or General Math, Algebra/Trig, Stats
Physical Sciences	3.2	9.2	Physics, Chemistry, Biology
Management	7.4	21.3	Internship Management/Supervision Accounting HR/Organizational Behavior Planning/ Operations Safety/Ergonomics Quality/ Statistics Capstone Project Management
Technical	15.7	37.3	Electronics/Electrical/Digital Methods/ Process/Materials Drafting/Graphics/CAD Programming/Computing/Networks Industrial/Product Design Power/Energy Capstone Introduction to Technology Business/ Technical Systems Materials/Statics/ Strengths
Electives		11.5	Drafting/Graphics/CAD Mechanical/ Manufacturing Arch/Civil/ Construction Health and Safety Program/Department Electives University Electives

Based upon the self-reported information, there does appear to be a generally accepted core of knowledge for mathematics and the physical sciences at the university level. The management and technical competencies required by accredited programs are less well-defined, but can be identified. Depending on the program, courses such as quality, statistics, introductory technology, and capstone may be reported as technical or management courses. The composite curriculum is shown in Table 3.

Table 3.
ATMAE accredited university composite curriculum

ATMAE Area	ATMAE Min/Max Semester Hour Requirements	Hours (courses)	Composite Curriculum
General Education	18-36	33 (11)	
Mathematics	6-18	9 (3)	Statistics (Calculus, PreCalculus) or (Algebra/Trig, General Math)
Physical Sciences	6-18	9 (3)	Physics, Chemistry, Biology
Management	12-24	21 (7)	Internship Management/Supervision Accounting HR/Organizational Behavior Planning/Operations Safety/ Ergonomics Quality
Technical	24-36	36 (12)	Electronics/Electrical/Digital Methods/Process/Materials Drafting/Graphics/CAD Program/ Computing/Networks Industrial/ Product Design Power/Energy Capstone Introduction to Technology Business/Technical Systems Materials/Statics/Strengths Automation (Other)
Electives	0-18	12 (4)	Program Specific Electives Department Electives University Electives Mgmt./ Technical Electives
Total	120 minimum	120 (40)	

This composite used the average reported hours and the courses most likely to appear as a starting point while considering the ATMAE semester hour requirements. If any course type was duplicated across areas, the next unduplicated course type of higher frequency within the area was added. The effect of removing duplication resulted in two more course types being added to the technical area. Automation was the first unduplicated course type, but the next five courses were also duplicated in the management area. Thus, the last course in the technical area is undesignated.

In conclusion, the specific courses as self-reported by ATMAE accredited four-year programs can be sorted into course types that are congruent with the ATMAE Standard 5 areas. However, some universities may choose to place certain types of courses in the technical area while other universities choose to place them in the management area. Is there an identifiable composite curriculum for ATMAE accredited four-year programs? Yes. This study, using deductive reasoning and Pareto analysis, was able to identify a set of course types for each foundational area. Conversely, discovering if programs had a reasonable balance between practical and conceptual application as stated in the Accreditation Handbook were determined to be beyond the scope of this study. Each course would have to be evaluated for content; a task better suited for an on-site accreditation evaluator. However, self-reported information infers that ATMAE four-year programs are more practical simply given the number of hours in the technical competencies.

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Appendix: Course Type Tables

Table A1
Courses self-reported in the mathematics foundational area

Course type	Number of times reported	Cumulative %
Algebra/Trigonometry	25	28%
Statistics/SQC*	19	49%
Calculus	14	64%
General Math	8	73%
Pre-calculus	7	81%
Statistical Quality* Statics/	5	87%
Strength/Structures* Circuit/	5	92%
Digital Analysis* Financial	5	98%
Accounting* Computer Literacy	1	99%
	1	100%
Average Number of Math Courses per Program	2.7	

*indicates course-type duplication across areas

Table A2
Courses self-reported in the physical sciences foundational area

Course type	Number of times reported	Cumulative %	Reported with lab
Physics	31	46%	17
General/Intro Chemistry	21	76%	12
Biology/Ecology	13	96%	
Geology	2	99%	2
Engineering Material Science*	1	100%	1
Average Number of Physical Science Courses per Program	2.2		3.2

*indicates course-type duplication across areas

Table A3
Courses self-reported in the management foundational area

Course type	Number of times reported	Cumulative %
Internship/Work Experience*	26	11%
Management/ Supervision	25	22%
Human Resources/ Org. Behavior	21	31%
Accounting*	21	40%
Planning and Operations*	19	49%
Safety/ Ergonomics*	16	56%
Quality/ Statistics*	13	61%
Senior Capstone *	12	67%
Project Management	12	72%
Law/ Legal Issues	11	77%
Marketing/ Sales	10	81%
Technical/Business Writing*	9	85%
Specifications, Codes, Regulations*	7	88%
Intro Technology*	7	91%
Economics	6	93%
Engineering Economy/ Costing	5	96%
Communication	4	97%
Business Information Systems	3	99%
Programming*	2	100%
Applied Creativity	1	100%
Average Number of Management Courses per Program	7.4	

*indicates course-type duplication across areas

Table A4
Courses self-reported in the technical foundational area

Course type	Number of times reported	Cumulative %
Electronics/ Electrical/ Digital*	90	18%
Methods/Processes/ Materials	69	33%
Drafting/ Graphics/ CAD*	62	45%
Programming/ Computing/ Networks*	41	54%
Industrial/ Product Design*	38	62%
Power and Energy	27	67%
Senior Capstone*	20	71%
Intro Technology*	18	75%
Business/ Technological Systems	18	79%
Materials/ Statics/ Strengths*	15	82%
Automation	14	85%
Safety/Risk*	14	87%
Operations*	12	90%
Quality/ Statistics/ Analysis*	12	92%
Internship/Work Experience*	11	95%
Specifications, Codes, Regulations*	8	96%
Project Controls	8	98%
Machine Tool	5	99%
Law/Legal	2	99%
Management/Supervision*	2	100%
Written Communication*	1	100%
Average Number of Technical Courses per Program	15.7	

*indicates course-type duplication across areas

Table A5

Courses self-reported in the electives area

Course type	Number of times reported	Cumulative %
Drafting/ Graphics/ CAD*	13	16%
Mechanical/ Manufacturing	9	27%
Architectural/ Civil/ CM	8	37%
Health and Safety*	8	46%
Program/ Dept. Electives	8	56%
University Electives	7	65%
Management	5	71%
Technical Electives	4	76%
Industrial/ Product Design*	3	79%
Humanities	3	83%
Writing*	2	85%
Social Science	2	88%
Business*	2	90%
Technical or non-technical	2	93%
Quality*	2	95%
GIS	1	96%
Programming*	1	98%
Intro to Higher Ed	1	99%
History of Technology	1	100%

*indicates course-type duplication across areas